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Neurolinguistics: Learning Languages as an Adult Rewires the Brain

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DEPARTAMENT D'ESTUDIS ANGLESOS I ALEMANYS

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ABSTRACT

This project aims to discover how learning languages can modify the structure and functionality of the human brain. The theoretical section investigates neurolinguistics to uncover the reasons behind these changes. Additionally, it introduces the differences in second language acquisition (SLA) between childhood and adulthood. The first section overviews bilingual language learning and SLA in older children. Next, the challenges and implications associated with learning as an adult. And finally, the neurological processes involved in SLA. To address uncertainties, the practical part involves two interviews with linguistic and medical experts, plus a survey to assess public knowledge on the subject. The interview responses yielded similar insights, providing clarification on the studied concepts. The questionnaire results from 70 participants in the Catalan region of Spain revealed that there is limited knowledge of adult SLA and neurolinguistics. Expanding people's awareness about the cognitive benefits of adult SLA could encourage more individuals to explore this opportunity.

Keywords: Neurolinguistics, Second Language Acquisition, SLA, Adult SLA, Bilingualism, Brain, Neuroplasticity

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I want to thank Laura, who has been my constant companion throughout these last four years. And thank you to Alícia. Our friendship is unlike any other I have ever known, a treasure I hold dear. I am so proud to have you in my life.

Lastly, I thank the person currently holding this thesis in their hands. Knowing you are reading it now brings me a profound sense of accomplishment. May the contents of this thesis bring you joy and inspiration as you delve into its pages.

“The adult brain and nervous system grow and change throughout our lives.

Until the very end, we are neurologically transformed by whatever we practice.

We are not limited by the past.”

— *Jack Kornfield*

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LIST OF ABBREVIATIONS

AD	Alzheimer's Disease
BFLA	Bilingual first language acquisition
CP	Critical Period
CPH	Critical Period Hypothesis
DTI	Diffusion Tensor Imaging
FLA	First Language Acquisition
fMRI	Functional Magnetic Resonance Imaging
GM	Gray matter
L1	First language or native language
L2	Second language
MRI	Magnetic Resonance Imaging
NDDs	Neurodegenerative Diseases
SLA	Second Language Acquisition
sMRI	Structural Magnetic Resonance Imaging
TL	Target Language
WM	White matter

GLOSSARY OF TERMS

Alzheimer's Disease	(1) A degenerative brain disorder and a prevalent form of dementia, characterized by progressive memory loss, impaired thinking, disorientation, and other associated symptoms.
Bilingual First Language Acquisition	The simultaneous acquisition of two languages from birth.
Broca's area	(2) A brain center in the frontal lobe, typically located in the left inferior frontal gyrus, responsible for speech production
Cognitive decline	(3) Progressive deterioration of cognitive abilities, including memory, attention, judgment, and mental sharpness, across the adult lifespan.
Critical Period Hypothesis	A theory in the study of language acquisition that claims there is a specific time to easily learn an L2.
Dementia	(4) A general term for the loss or damage of neurons in the brain, resulting in severe intellectual impairment. It manifests as memory loss and other cognitive deficits that interfere with daily life.
DTI	(5) A neuroimaging method that gives information about white matter microstructures within the central nervous system.

fMRI	(6) A neuroimaging method for measuring and mapping brain activity by detecting changes in blood oxygenation and flow that occur in response to neural activity.
Gray matter	(7) A central nervous system tissue that forms the brain's outer surface and is responsible for processing and releasing information. It primarily consists of neurons, dendrites, and unmyelinated nerve fibers, which give it its gray color.
Linguistic input	The material that the learners are exposed to while engaging in receptive skills during SLA, such as listening or reading.
Linguistic output	The language production that the learners generate during SLA, including speaking or writing.
Multilingualism	The ability of individuals to communicate in more than one language (although the term “bilingualism” is often used interchangeably).
Neural connections (synapses)	(8) Links between billions of brain cells that send electrical signals to communicate with each other. They form circuits that become the foundation of brain architecture, enabling complex information processing and cognitive functions.
Neurodegenerative disease	(9) A type of disorder characterized by the malfunctioning or death of cells within the central nervous system. These disorders typically progress over time and currently lack a cure.

Neurolinguistics	An interdisciplinary field that studies the relationship between language and the brain.
Neuroplasticity	The brain's ability to change and adapt in response to stimuli or experience.
SLA	This abbreviation stands for Second Language Acquisition and refers to the branch of study that explores how people learn a language other than their L1.
sMRI	(10) An imaging technique for examining the anatomy and pathology of the brain.
Target language	In the context of SLA, a TL is a language that a non-native speaker is trying to learn.
Wernicke's area	(11) A language area in the posterior segments of the superior temporal gyrus, usually found in the left hemisphere. This area encompasses the auditory cortex and is responsible for comprehension.
White matter	(12) A tissue in the deep parts of the brain (subcortical) containing nerve fibers surrounded by a protective layer of myelin that gives its white appearance. It improves the speed and efficiency of electrical signal transmission along the extensions of the nerve cells (axons).

Note: The definitions have been created by combining both the researcher's understanding of the topic and the retrieval from the following sources:

(1) https://www.merriam-webster.com/dictionary/Alzheimer%27s%20disease

(2) https://memory.ucsf.edu/symptoms/speech-language

(3) https://dictionary.apa.org/cognitive-decline

(4) https://www.alz.org/alzheimers-dementia/what-is-dementia

(5) https://www.sciencedirect.com/topics/medicine-and-dentistry/diffusion-tensor-imaging#:~:text=Diffusion%20tensor%20imaging%20(DTI)%20is%20a%20novel%20imaging%20technique%20that,water%20molecules%20within%20the%20brain

(6) https://www.open.edu/openlearn/body-mind/health/health-sciences/how-fmri-works

(7) https://my.clevelandclinic.org/health/body/24831-grey-matter

(8) https://developingchild.harvard.edu/science/key-concepts/brain-architecture/

(9) https://www.cancer.gov/publications/dictionaries/cancer-terms/def/neurodegenerative-disorder

(10) https://bit.ly/3Cb8Qn9

(11) https://www.ncbi.nlm.nih.gov/books/NBK533001/

(12) https://medlineplus.gov/ency/article/002344.htm

1. Introduction

Language is essential in our lives, distinguishing humans from other animals. Animals may be able to communicate in diverse ways, but only humans have the capacity to produce or learn complex languages. As Berwick and Chomsky (2016) highlighted about the uniqueness of human communication, “the core properties of human language appear to differ sharply from animal communication systems, and to be largely unique in the organic world” (p. 64).

Learning a second language has become increasingly important in today’s globalized society. Being multilingual allows us to connect with people from diverse cultural backgrounds, opening new educational and career opportunities. Although language acquisition usually starts at an early age, many adults decide to immerse into the realm of languages later in life. Nonetheless, there has always been a debate on the difficulty and effectiveness of adult language learning (Bailey et al., 1974).

There is a widely held belief that acquiring a new language during adulthood is complicated, if not impossible (Hu, 2016; Stefánsson, 2013). Some people question their ability to learn languages, assuming they are either not capable or too old to begin. However, is it true that only the younger ones can become proficient in a language? Or can mature adults learn languages as quickly and effectively as children?

This thesis explores the potential implications of language learning in adulthood by investigating the capacity of the brain to change and adapt, the effects of language learning on cognitive processes, and how language learning may affect other aspects of the brain's structure and function (e.g., preventing neurodegenerative problems).

Furthermore, it seeks to contribute to understanding language acquisition in adults and how it differs from children.

The theoretical section provides an overview of recent research on second language acquisition and its connection to brain activity. The method section uses two interviews with experts and a survey to compare background information with people's knowledge.

1.1 Second Language Acquisition

1.1.1 What is SLA?

Second language acquisition (SLA), according to Saville-Troike (2012), is the study of how people learn a language other than their first or native language (L1), as well as the process of acquiring this new language (L2). It is important to emphasize that the term "second language" can refer to any additional language learned and does not always imply that a person only speaks two languages (Ellis, 2015; Saville-Troike, 2012; Sun, 2019).

Concepts and methods from several disciplinary fields, particularly linguistics, psychology, and sociology, are used in the study of SLA (Sanz, 2005). Moreover, first language acquisition (FLA) should also be considered, since the L1 might affect the acquisition of the L2 (Ellis, 2015). Kellerman (1983) proposed that the more different the L2 is from the L1 (i.e., language distance), the harder it will be to learn the target language (TL) (Ellis, 2015).

Throughout human history, SLA has been a commonly observed phenomenon, often attributed to the necessity of engaging in trade or business with other nations (Grosjean, 2010; Djumabaeva & Kengboyeva, 2021). The rise in the number of

individuals acquiring a second language nowadays, whether early on or later in life, can be attributed to the ongoing interactions with people from diverse linguistic backgrounds (Grosjean, 2010). Several different reasons can lead people to learn a foreign language. Some of these motives include immigration, a desire to get employment or education in a foreign country; wanting to connect with people around the world; or even political reasons may be involved (Crystal, 1997; Grosjean, 2010; Saville-Troike, 2012).

Several critical factors that may have an impact on the individual's language learning experience have been examined. As several researchers on the topic point out (Ellis, 2015; Dörnyei, 2005; Saville-Troike, 2012; Sun, 2019), the most important factors influencing the acquisition of an L2 include age, aptitude, motivation, cognitive style, personality, and learning strategies.

1.1.2 Bilingualism

When someone can communicate in two languages, they are said to be "bilingual," whereas a person who speaks more than two languages is known as "multilingual."[1] Nonetheless, people often use the two terms interchangeably.

The classification of bilingual individuals can be diverse, influenced by factors such as the timing and manner of SLA. According to Saville-Troike (2012) and Bozic (2018), general two main groups of bilinguals can be identified: simultaneous bilinguals, who acquire multiple L1 from birth and are considered balanced bilinguals, and sequential bilinguals, who learn an L2 after their L1. To further categorize these two groups, researchers in the field of SLA (Bialystok, 2001; Cook, 2008; Nacamulli, 2015; Saville-

[1] People often use the two terms interchangeably, but this thesis will generally adopt the term "bilingual," as most of the cases studied are of people who know two languages.

Troike, 2012) have explored Weinreich's (1953) three-fold analysis, which divides bilinguals into groups based on "the relationship of the two languages in the individual mind" (Cook, 2008, p. 9). Thus, Weinreich identifies coordinate, compound, and subordinate bilingualism.

Compound bilinguals acquire the two languages simultaneously, and they fuse or share information at the meaning or conceptual level but do not mix the two languages (Heredia & Cieślicka, 2014). Therefore, code-switching is easy in this case. This type of bilingualism typically occurs in children who grow up learning both languages.

On the other hand, coordinate bilinguals work with two linguistic codes at the same time, the two being independent of one another (Saville-Troike, 2012). This is often the case for children who speak one language in their household and another different language at school (Nacamulli, 2015).

Lastly, subordinate bilinguals filter the newly acquired language through their mother tongue (Nacamulli, 2015). When a person learns a language later in life, usually after moving abroad and needing to acquire the TL, they mentally translate the concepts to make connections between their L1 and the L2.

During a talk on bilingualism with Boroditsky (2021), she discussed the variables that can predict which language will be more active in the bilingual's mind. These predictions are based on the order in which things have been learned and the frequency of language use. Primacy, recency, and frequency are the three separate consequences that emerge from this. Primacy represents the better memory for material that has been learned first, recency is the better recall for material that was learned most recently, and frequency highlights the improved memory for content that is practiced most often. As

noted by Yoo and Kaushanskaya (2016), a common pattern of performance on free-recall tasks resembles a U-shaped serial-position curve, with items at the start and end of the list being more accurately remembered than ones in the middle (primacy and recency effect, respectively).

Figure 1. *U-shaped serial-position curve: Primacy and recency.*

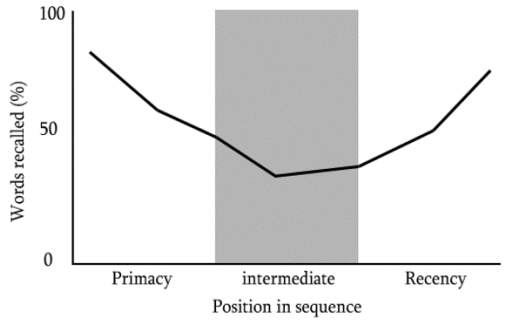


Figure retrieved from the Psychology of the Memory class notes URV Ferré, 2023.

1.1.3 Second language learning in children

The Critical Period Hypothesis (CPH), first proposed by Penfield and Roberts in the late 1950s, postulated that the window of opportunity for relatively effortless language acquisition was limited to a specific period, extending from birth until puberty. Beyond that period, it becomes increasingly challenging to learn a language (Ellis, 2015; White & Genesee, 1996; Yule, 2020).

Children's increased ability to learn a language is rooted in their brain plasticity and flexibility (see section 1.4.3), enabling them to adjust to a new linguistic code. According to Penfield and Roberts (1959), "for the purposes of learning languages, the human brain becomes progressively stiff and rigid after the age of nine […]" (p. 236).

The CPH was popularized thanks to Chomsky (1969) and Lenneberg (1967). Lenneberg (1967) observed that the growth of nerve connections and development reach a peek at puberty, coinciding with the end of the child's period of language acquisition (Muñoz, 2006).

In the realm of SLA, the CPH has been the focus of research and debate for many decades. The idea that language can only be learned in childhood is not universally accepted, as some studies demonstrate cases of adults who have picked up a language later in life (Chacon, 2020) or young adults who were taught to talk after the so-called "critical period" had passed.

Regarding the latter instance, the discussion could revolve around "feral children, children, that is to say, who have grown up in isolation from normal human contact and society" (Singleton & Ryan, 2004, p. 46). Among the most famous examples are the "Wild Boy of Aveyron," who was found in the Caune Woods in 18th century France (Du Plessis, 2021), and Genie, a 13-year-old girl who had been denied social contact her entire life. When Genie was discovered in 1970, she had not been taught how to speak. However, she quickly began reacting to other people's speech in an attempt to communicate (Yule, 2020). Other less well-documented cases, such as Isabelle, Kaspar Hauser, Peter of Hanover, and the Indian wolf-children, are explained by Candland (1995) and Newton (2002) (as cited in Singleton & Ryan, 2004)

Besides the age factor, affective characteristics are also essential aspects of SLA. Children quickly overcome any initial hesitations they may have had when using the L2 since they are less self-conscious and less afraid of making mistakes, (Yule, 2020). And then, an important individual factor was found, which is pronunciation. As stated by Ellis

(2015), “learners who start learning an L2 at a young age achieve a more native-like accent than those who start later” (p. 146), an idea supported by Singleton & Ryan (2004), Águila (2005), Pinter (2011), and Suryantari (2018).

After introducing SLA in children, it is appropriate to form a distinction based on when and how the L2 is introduced (Genesee et al., 2004; Goldstein 2004, as cited in Paradis, 2007), establishing two subsections: bilingualism from birth and older children learning.

1.1.3.1 Bilingualism from birth

In bilingualism, children exposed to two different languages from birth or before the age of three are simultaneous or balanced bilinguals (Grosjean, 2010; Lightbown & Spada, 2013; Paradis, 2007; Pinter, 2011). As a result, such a child grows up learning each of their parents’ L1 at the same time. This process is also referred to as “bilingual first language acquisition” (BFLA) by other authors, as noted by Genesee and Nicoladis (2007). Despite this, one L1 typically prevails over the other, as Grosjean (2010) and Paradis (2007) further explained.

Exposing a child to an L2 at an early age increases cognitive flexibility (Poulin-Dubois et al., 2021). Bilingual toddlers “receive this dual input before they are old enough to explicitly or consciously understand that their input comes from two linguistic sources” (Paradis, 2007, p. 17). Based on Genesee’s (2015) research, early bilinguals who receive consistent exposure to both languages achieve language development milestones at ages similar to monolingual children. However, bilingual development differs from that of monolinguals in terms of the need to learn to select which language to use and whether to merge the two L1s depending on the conversation setting (Paradis, 2007).

A common misconception about bilingualism is that children who grow up listening to two distinct languages will experience confusion due to their tendency to mix words within the same sentence (i.e., code-mixing) (Byers-Heinlein & Lew-Williams, 2013). Authors shed light on the topic of language mixing by highlighting that children tend to code-switch not because they cannot distinguish between the two languages, but rather when they lack the appropriate word for a particular referent in one of the languages (Paradis, 2007; Grosjean, 2010; Byers-Heinlein & Lew-Williams, 2013).

Furthermore, Paradis (2007) categorizes code-switching into inter-utterance code-switching, which involves shifting from one language to another between utterances, and intra-utterance code-switching, characterized by using elements from both languages within a single utterance.

1.1.3.2 Older children learning

When children acquire an L2 at the age of three years or older, they are considered sequential or successive bilingualism, having already mastered their L1 before starting to learn the L2 (Grosjean, 2010; Paradis, 2007). Compared to early bilinguals, older children acquiring an L2 have more advanced cognitive development, potentially leading to accelerated SLA (Paradis, 2007).

In the case of sequential bilinguals, their phonological development can be influenced by interference from the L1 (McCarthy et al., 2014). If their dominant language is the L2, they might show unusual attrition patterns in their L1 (Paradis, 2007). Research by Winitz et al. (1995) and Flege (2004), as cited in Paradis (2007), suggests that “early sequential bilinguals tend to pronounce the L2 more like monolinguals than L2 adults” (p. 25).

Furthermore, according to Patterson and Pearson (2004), older children learning an L2 may benefit from cognates (i.e., words with similar meanings and spelling in both their L1 and L2). This can help to improve their vocabulary acquisition (as cited in Paradis, 2007). Since sequential bilinguals at first only have one language, which is always present as they learn and use the L2, language dominance is significantly greater than it is in simultaneous bilinguals. The constant presence of the L1 can be perceived by the numerous transfers that children make (Grosjean, 2010).

Regarding learning speed, it is predicted that older children learn faster than adults because they have superior memory (Suryantari, 2018). Ellis (2015) argued that older learners begin with an advantage over younger ones, especially when it comes to grammar and vocabulary skills.

1.2 Second language learning as adults

Learning languages during childhood is generally considered easier. However, the question remains: can adult learners achieve native-like competence in an L2 acquired later in life? The topic of adult SLA is still debated. While learning new languages in adulthood demands greater effort and motivation (Saville-Troike, 2012), it is not an insurmountable task (Lightbown & Spada, 2013). Sanz (2005) emphasizes the need for adults to optimize their cognitive resources to overcome both internal and external limitations, such as diminished cognitive resources and decreased input quality and frequency compared to their L1.

Cook (2008) outlines possible reasons for the decline in adults' ability to learn an L2. These include physical factors like decreased neuroplasticity and brain lateralization (see section 1.4), social factors that stem from different circumstances and relationships

from those of childhood, and cognitive explanations like interference caused by the more abstract way of thinking in adults.

In the context of the CPH, Doğan (2009) explores Brown's (1994) analysis of the neurological, psychomotor, and cognitive aspects. Due to the dominance of the left hemisphere in adults, they tend to overanalyze and focus excessively on the intellectual aspects of SLA (Brown, 1994, cited in Doğan, 2009). Regarding the psychomotor component, scientists hypothesize that adult experience decreased flexibility in their speech muscles, preventing them from achieving native-like pronunciation in the TL. Flege (1995) further asserts that adults face difficulties in SLA because of the influence of their L1 phonetic system. Lastly, Doğan (2009) and Yule (2020) note that affective factors like anxiety and motivation are linked to adults, as they are more self-conscious.

Among adult L2 learners, motivation is closely tied to two commonly encountered phenomena: interlanguage and fossilization. As described by Yule (2020), interlanguage represents the intermediate system used by adult L2 learners during the process of SLA, which may appear disconnected from both their L1 and the TL. When the learner's repertoire of expressions in this intermediate system reaches a point where it no longer progresses, it is known to be "fossilized" (Saville-Troike, 2012; VanPatten & Williams, 2015; Xu, 2022 Yule, 2020). Maintaining motivation to persist in learning the TL despite fossilization can be challenging, but it is a powerful strategy for adult learners to overcome errors to achieve accurate SLA (Demirezen & Topal, 2015; Qian & Xiao, 2010).

Chacon (2020) asserts that the difference in SLA between adults and children may not be primarily caused by a shift in brain plasticity, but rather by adults having less

exposure time. She stresses that adults can acquire fluency at a slower rate even if reaching native-level ability may not have major advantages.

1.3 Teaching methodology

The need for L2 instruction has prompted the exploration of teaching strategies[2] in search of the most effective approach to L2 learning (Yule, 2020). As previously mentioned (section 1.1.1), individual differences among students are potential factors contributing to SLA, requiring teachers to adapt their teaching approaches for improved SLA outcomes (Doğan, 2009; Lightbown & Spada, 2013). In the context of SLA, it is crucial to expose L2 learners to *input*, which refers to the linguistic samples that learners are exposed to (i.e., reading or listening), and *output*, which includes what learners produce (i.e., speech/sign or writing) (Haley & Rentz, 2002; Saville-Troike, 2012).

Three teaching methodologies are discussed by Yule (2020), the first one being the traditional Grammar-Translation Method. This approach relies on vocabulary lists, and sets of grammar rules, and encourages memorization and written language. However, a drawback highlighted by Yule (2020) is that students may lack the ability to use the L2 in a conversation.

In contrast, the Audiolingual Method offers an alternative approach that prioritizes the development of oral language skills, progressively moving from simpler to more complex structures in the L2 (Yule, 2020). However, it is argued by Yule (2020) that this practice can be monotonous and does not reflect authentic speech patterns.

[2] N.B. As there are many different teaching strategies, this thesis will only explore some of them.

Lastly, Yule (2020) explores Communicative approaches as a response to the limitations of "pattern-practice" methods and the notion that consciously acquiring grammar rules leads to language proficiency. These approaches prioritize the functional aspects of language over its structural forms, proposing the need for diverse social settings in lessons to enhance usage and communication in the L2 (Yule, 2020). Another common type of communicative activity is Task-Based Learning (Yule, 2020), where learners engage in group interactions to exchange information or solve problems.

When preparing language lessons, it is fundamental to consider the students' ages and academic levels, as what might captivate young L2 learners could potentially bore older ones (Doğan, 2009). Likewise, promoting teacher-student interaction can greatly improve SLA (Haley & Rentz, 2002). For instance, incorporating corrective feedback– where teachers address mistakes made by the L2 learner–can help the learning process (Ćeman & Dubravac, 2019).

1.4 The brain functions with foreign language learning

1.4.1 Neurolinguistics

Once a comparison between adult and child SLA has been made, it becomes crucial to delve into the neural processes that underlie language acquisition. The first step is to define "neurolinguistics," which constitutes a branch of research dedicated to exploring the connections between language and brain function (Ahlsén, 2006; Yule, 2020). Neurolinguistics examines how language is processed and produced within the brain, drawing upon insights from diverse disciplines (Ingram, 2007; Menn, n.d.). Consequently, it serves as an interdisciplinary domain that integrates findings from neuroanatomy, neurology, psychology, speech pathology, and computer science to build

a comprehensive understanding of language and its neural foundations (Ahlsén, 2006; De Zubicaray & Schiller, 2019).

1.4.2 Brain areas in language

Language is an elaborate human ability, intricately woven with cognitive processes, relying on the coordinated action of various brain regions (Pagel, 2017). As Pinker (1994) stated, "some cognitive scientists have described language as a psychological faculty, a mental organ, a neural system, and a computational module" (p. 18). Notably, it was in the late 19th century that some neurologists made a groundbreaking discovery: carefully examining patterns of aphasic[3] symptoms could have far-reaching implications for understanding how the brain is structured for higher mental functions (Binder et al., 1997; Ingram, 2007; Saville-Troike, 2012).

To clearly define the different areas involved in language, the parts of the brain must first be introduced (*see Appendix A*). The cerebral cortex, also known as gray matter (GM), forms the brain's outermost layer of nerve cell tissue and is divided into two halves. Its surface is characterized by numerous folds, with deep grooves (sulci) and ridges (gyri). Each brain hemisphere is divided into four lobes (frontal, parietal, temporal, and occipital), each playing a different function in the higher-level processes of the human brain. (Johns Hopkins Medicine, 2021; Professional, 2022; *see Appendix B & Appendix C*).

Two crucial areas are integral to speech processes (*see Appendix D)*. The first is Broca's area, identified by Paul Broca in 1861 when he discovered a brain region in patients with speech impairments. This area is situated in the left inferior frontal gyrus

[3] *See section 1.4.5* for the definition of aphasia.

and is responsible for speech production (Ingram, 2007; Yule, 2020). The second area is Wernicke's area, discovered by Carl Wernicke in 1874, located in the left superior temporal gyrus. It encompasses the auditory association area surrounding the primary auditory cortex and plays a vital role in speech comprehension (Ingram, 2007; Javed, 2022). These landmark discoveries laid the foundation for the Wernicke-Geschwind model, which explores the understanding and production of speech and significantly influenced aphasiology during the 20th century (Silva-Barragán & Ramos-Galarza, 2020).

According to the Wernicke-Geschwind model (*see Appendix E*), certain brain areas are involved in conversation. Firstly, the sound produced by the speaker registers in the primary auditory cortex, located in the superior temporal gyrus, in the temporal lobe (Purves, 2001; Yule, 2020). Next, the speech is decoded and understood in Wernicke's area. A white matter fiber pathway known as arcuate fasciculus (connecting Broca's and Wernicke's areas) transfers the information into Broca's area for speech production (Zubicaray & Schiller, 2019). Lastly, the information reaches the motor cortex, which controls the physical articulation of speech (Friederici, 2011; Yule, 2020). These language-related areas remain the same in all age groups, though the language is better organized in adults (Rosselli et al., 2014).

A remarkable characteristic of language is its lateralization, predominantly found in most individuals' left hemisphere or cortex (Ingram, 2007; Menn, n.d.; Pinker, 1994; Saville-Troike, 2012; Wattendorf & Festman, 2008; Yule, 2020). Nevertheless, according to Carter et al. (2009), some individuals demonstrate language functions on both brain hemispheres, challenging the notion of hemisphere specialization. Schlegel et al. (2012)

expand on this idea by presenting additional information about a pervasive network of language-processing regions in both hemispheres.

1.4.3 Neuroplasticity

The brain's capability for plasticity, also known as neuroplasticity, enables it to undergo functional and physical changes or remodel in response to diverse stimuli, behavioral experiences, or cognitive demands (Ahlsén, 2006; Aliouche, 2022; Li et al., 2014; Queensland Brain Institute, 2018). Zubicaray & Schiller (2019) highlight that neuroplasticity is more pronounced in the developing brains of young children, as their neural tissue is less specialized and neurons are more flexible. However, evidence suggests that even in adulthood, the brain retains some degree of plasticity, albeit to a lesser extent due to allocating neural resources to various cognitive functions (Zubicaray & Schiller, 2019).

An extraordinary method for augmenting neuroplasticity is SLA, even among older learners (Bubbico et al., 2019). Engaging in SLA involves participating in a learning task that activates widespread neural networks and fosters the development of cognitive abilities, including working memory, inductive reasoning, and semantic memory (Bubbico et al., 2019). This indicates that contrary to the CPH, SLA in adult learners can lead to behavioral and neural changes that approximate those of L1 acquisition (Li et al., 2014).

Anatomical changes in brain structure associated with SLA include increased GM density, enhanced cortical thickness, and improved white matter (WM) integrity (Aliouche, 2022; Bubbico et al., 2019; Kliesch et al., 2017; Li et al., 2014). Said

transformations have been observed in individuals across different age groups, including children, young adults, and older people.

Although younger L2 learners generally possess a brain plasticity advantage (Saville-Troike, 2012), research suggests that older individuals retain the potential for neural plasticity, though with considerable individual differences (Kliesch et al., 2017). Thus, robust evidence supports exceptional structural and functional neuroplasticity in adulthood, influenced by the learning trajectories followed during SLA (Kliesch et al., 2017).

1.4.4 Monolingual vs. bilingual brains

As has been demonstrated, the brain areas associated with language are the same throughout all age groups. But what distinguishes the brains of monolingual individuals from those of bilinguals?

Brain imaging techniques are used to see brain activity and structure, thus distinguishing monolingual and bilingual brains (Grosjean, 2020). The primary methods employed are Functional Magnetic Resonance Imaging (fMRI)[4], which measures brain activity by detecting changes in blood flow changes during task performance, and Structural Magnetic Resonance Imaging (sMRI), which analyzes the anatomical features of the brain (Pernet, 2021; Sui et al., 2013; Wardlaw, 2021, *see Appendix G*).

In a Kovelman et al. (2008) study, Spanish-English bilinguals and English monolinguals were compared through fMRI analyses. The results revealed that both groups exhibited increased activation in classic language areas, indicating similarities in

[4] *See Appendix F* for an fMRI showing brain activation in bilinguals with different ages of activation.

neural patterns. However, a significant difference among bilinguals was that they displayed a significantly greater increase in blood oxygenation when processing English than English monolinguals (Kovelman et al., 2008).

Similarly, differences in GM and WM density between bilingual and monolingual individuals have been discovered (*see Appendix H*). Bilinguals have higher GM density in particular brain regions, with a considerable difference in the left hemisphere and a trend also visible in the right hemisphere (Van Den Noort et al., 2010). Furthermore, studies using sMRI to compare bilingual and monolingual seniors have revealed that lifelong bilingual experience is associated with structural changes in GM and WM (Sala et al., 2022).

Wang et al. (2020) investigated neuroplasticity in fluent Chinese-English bilinguals, finding that bilinguals with higher L2 proficiency used extra neurocognitive resources for cognitive control, and these functional alterations in their brain were consistent with the structural neuroplasticity caused by SLA. Likewise, Marian and Shook (2012) noticed a positive correlation between early SLA, L2 proficiency, and increased GM volume in the left inferior parietal cortex.

Diffusion Tensor Imaging (DTI), an alternative neuroimaging technique that detects the WM fibers connecting different brain parts, has revealed changes in WM structure associated with SLA (Mohades, 2012; Schlegel et al., 2012). When examining monolingual and bilingual individuals, Bubbico et al. (2019) found that SLA has a profound impact on the brain, as demonstrated by higher WM integrity in bilingual older adults, particularly in the corpus callosum connecting the two hemispheres and other WM tracts connecting different brain regions (Luk et al., 2011, as cited in Bubbico et al., 2019).

Therefore, the bilingual experience not only influences the processing of information in neurological structures but also can potentially modify the structures themselves, thereby manifesting the differences in brain activation and structure between monolinguals and bilinguals (Grosjean, 2020; Marian & Shook, 2012; *see Appendix I, Appendix J, Appendix K*).

1.4.5 Brain injury or Aphasia

Examination of patients with brain injuries has contributed insights into the specific brain regions involved in language, supporting the long-standing notion that language primarily lateralizes to the left-hemisphere inferior frontal and superior temporal areas in adults (Dronkers et al., 2004; Ingram, 2007; Yule, 2020).

Aphasia is a language disorder that arises when damage occurs to the brain regions involved in language processing, disrupting communication abilities (ASHA, n.d.; Połczyńska-Fiszer & Mazaux, 2008; Yule, 2020). This condition is commonly caused by injury (often from a stroke), which affects the brain's language centers that control speech comprehension, production, and the use of signed languages, as well as the ability to read and write (ASHA, n.d., *see Appendix L & Appendix M for differences in brain activation*).

There are several types of aphasia[5], each with its characteristics and effects (*see Appendix N & Appendix O)*. Among them is Broca's Aphasia, also known as non-fluent or expressive aphasia, which occurs due to damage to Broca's area. Individuals with this condition have difficulty speaking fluently, but their comprehension skills are relatively preserved (Westin, 2021; National Aphasia Association, 2021; Yule, 2020). Wernicke's

[5] There are around eight different types of aphasia. Therefore, only four of them will be covered in this thesis.

aphasia, also known as receptive or fluent aphasia, results from damage to Wernicke's area. Those affected by this type of aphasia experience comprehension deficits but can produce connected speech (Westin, 2021; National Aphasia Association, 2021). Conduction aphasia, a rare type, is caused by damage to the arcuate fasciculus, which leads to a disconnection between Broca's and Wernicke's areas (Acharya, 2022; Herbet & Duffau, 2020). Individuals with conduction aphasia typically have intact expression and comprehension abilities but struggle specifically with repeating simple phrases (Acharya, 2022; Carter et al., 2009). And lastly, Global aphasia, the most severe form of aphasia, where patients can produce few recognizable words and understand little or no spoken language. They can neither read nor write but preserve intellectual and cognitive capabilities unrelated to language and speech (National Aphasia Association, 2021).

The study of aphasia in bilingual individuals, especially their recovery patterns, has garnered significant interest. Researchers have endeavored to adapt language processing models to suit the bilingual context (Ahlsén, 2006; Marrero et al., 2002). De Letter et al. (2021) explain that the diagnostic procedure for bilingual individuals with aphasia relies on their L1 and L2 proficiency. It has been proposed that bilingualism may confer cognitive benefits, potentially enhancing processing speed during rehabilitation.

Additionally, people with L2 possess a protective factor known as "cognitive reserve[6]" (*see Appendix P)*, the ability to effectively use brain resources to adapt to neuropathological changes and maintain cognitive functioning, which contributes to better recovery following a stroke (De Letter et al., 2021; Guzmán-Vélez & Tranel, 2015).

[6] While everyone possesses a cognitive reserve that develops over time, bilingualism has been shown to enhance cognitive functioning even in the presence of adverse conditions, resulting in improved cognitive abilities among older adults (Guzmán-Vélez & Tranel, 2015; Harvard Health, 2023)

1.4.6. Neurogenerative diseases

As underscored by Carter et al. (2009), bi/multilingual individuals create more neural connections and denser GM, particularly in the left hemisphere's inferior frontal cortex, which plays a crucial role in language and communication skills. The enhanced cognitive reserve they possess acts as a protective factor against age-related decline (*see Appendix* and neurodegenerative diseases (NDDs), such as Alzheimer's disease (AD) (*see Appendix Q & Appendix R)*, the most prevalent form of dementia (Woumans et al., 2015, as cited in De Letter et al., 2021). The positive effects of bilingualism on cognitive reserve may even surpass those of other known factors (Gallo et al., 2022; Moosa et al., 2022).

There is compelling evidence demonstrating a substantial impact of bilingualism on the onset of AD, with individuals developing dementia 4.5 years later than monolinguals and suffering to a lesser extent from associated cognitive deficits (Alladi et al., 2013; Berkes & Bialystok, 2022; Moosa et al., 2022; Sala et al., 2022).

1.5. Research questions

Upon discovering all this information, the researcher wanted to confirm the information gathered with the knowledge of professionals and see what the general public knows about neurolinguistics. To that aim, several questions arose: (1) Is the CPH true, or can adults also achieve fluency in an L2? (2) Should the teaching methodology be different for children and adults? (3) How do adults learning an L2 differ from children growing up bilingual? (4) What are the brain differences between children and adults? (5) How does SLA impact memory and other skills? (6) Where are the language center and the language-related brain areas? (7) Can SLA alter brain function and structure? (8) What is

the relation between brain injuries, NDDs, and bilingualism? and (9) Are people aware of the cognitive benefits of SLA?

2. Method

After studying SLA and the brain functions in language, the knowledge is ready to be put into practice. To this end, a two-part study was created to better understand adult language learning and its repercussions on the brain. The first part of the study consisted of two interviews with experts on the subject. Once the interviews were completed, a survey was created to determine how knowledgeable people were on the topic.

2.1. Participants

2.1.1. Interview Participants

The researcher had the privilege of conducting interviews with two doctors from the University of Alberta in Canada, aiming to use their extensive knowledge in linguistics and science to address any doubts that may have arisen during the research process.

The first interviewee was Dr. Kim, a speech-language pathologist at the Faculty of Rehabilitation Medicine. She has been teaching Adult Language Disorders since 2010 and focuses on people with aphasia. Dr. Kim's research centers on improving outcomes for those facing communication problems caused by brain injuries, utilizing behavioral treatments and non-invasive brain stimulation. The second participant was Dr. Blekher, a professor in the Department of Linguistics specializing in psycholinguistics, language acquisition, and bilingualism. With over two decades of experience, the insights and responses from both doctors were valuable.

2.1.2. Questionnaire Participants

The survey aimed at adults from the Catalan region of Spain, spanning multiple age groups (18-24 years, 25-34 years, 35-44 years, 45+ years). It was assumed that the participants had limited prior knowledge of how the brain and language learning processes work. They were expected to respond based on educated guesses or what they knew about the subject.

A total of 70 people participated in the questionnaire. Among the participants, the majority (45 people, 64%) belonged to the age group of 18-24 years, while only five people (7%) were between the ages of 35 and 44. Concerning gender, 44 participants identified as women, 25 as men, and one person preferred not to specify their gender.

When asked about the number of languages they spoke, 38 participants (55%) indicated they were trilingual. The finding aligns with the linguistic context of Catalonia, where it is common for people to have Spanish and Catalan as their L1 and acquire an L2 during their school years. Regarding adult SLA, 25 participants (36%) reported not having learned an L2 as adults due to difficulty or lack of time, 22 participants (31%) were willing to learn other languages as adults, and only 6 participants (9%) showed no interest in SLA.

2.2. Materials

2.2.1. Interview Materials

The interviews were done through video calls using Microsoft Teams and Zoom. Prior consent was requested from the participants to record their voices, ensuring a natural conversation and enhanced comprehension of the topics discussed. This approach

improved the effectiveness of data collection, eliminating the need for constantly typing responses. When the participants declined to be recorded, the interviewer took detailed notes on paper or in a Word Document, which were later incorporated into the thesis.

2.2.2. Questionnaire Materials

The questionnaire was completed through Microsoft Forms using a multiple-choice format. This type of survey allowed for interaction with a larger audience and kept the data organized, making it easier to report the results later. The participants filled out the informed consent form and the questionnaire on their electronic devices. Microsoft Forms was also used to organize the graphs shown in the results section.

2.3. Procedure

2.3.1 Interview Procedure

After receiving ethics approval[7], the interviews were conducted. The objective of the interviews was to clarify uncertainties encountered during the development of the theoretical background. The researcher posed 13 questions to compare the findings with the responses provided by the experts, who offered thorough explanations of how SLA impacts the brain, including ideas of neuroscience and neuroplasticity.

Before starting the interviews, the researcher introduced the topic of the thesis and the interview's purpose. Then, the participants had to introduce themselves, outlining their backgrounds, educational pursuits, and professional experiences. The meeting proceeded with the prepared questions (*see Table 1, Appendix S & Appendix T*).

[7] To ensure the privacy of participants, approval was obtained from The Ethical Committee concerning Research into People, Society, and the Environment (CEIPSA) under the ethics approval number CEIPSA-2023-TFG-0004.

The first video call was with Dr. Kim via Microsoft Teams, lasting approximately 30 minutes. Permission to record the interview was granted, allowing the participant to share their knowledge while the researcher attentively listened. This interview was captivating and enlightening. Dr. Kim made all the technical material easily understandable by employing accessible language and simplified terms.

The second meeting was with Dr. Blekher, with whom the researcher talked for around 42 minutes. Since Dr. Blekher requested not to have her answers recorded, notes were taken during the conversation. Once again, the meeting facilitated the collection of valuable information. Additionally, Dr. Blekher provided diverse resources to explore neurolinguistics further.

After talking with the experts and studying the theoretical perspectives, a comparative analysis was performed to enrich the understanding of the research topic. Said approach helped to identify similarities and differences, leading to the conclusions. Consequently, a better interpretation of how SLA impacts the adult brain was established.

2.3.2 Questionnaire Procedure

The questionnaire needed a minimum of 30 participants from 18 to more than 45 years. Surpassing expectations, the participation of 70 individuals was received. Before answering the questionnaire, they had to complete an informed consent form (*see Appendix U*). The estimated time to complete the survey was 6 minutes, during which the participants had to answer 16 multiple-choice questions on language learning in adulthood and its effects on the brain (*see Appendix V & Appendix W for the questions, answers, and the translation*).

3. Results

3.1 Interview Results

One of the doctors interviewed specialized in Psychology and speech pathology, and the other in Linguistics. Both were very knowledgeable in neuroplasticity, language-related brain regions, and SLA. A summary table (*see Table 1)* comparing relevant information from the professionals is presented below (*see Appendix S* & *Appendix T* for the full interview transcriptions).

Table 1. *Summary of the relevant questions and answers from the interviews*

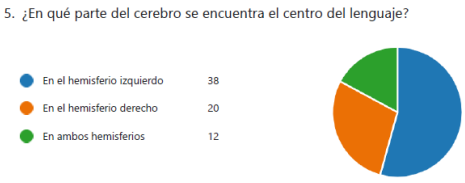
Interview Questions	Answers
1. Adult L2 learners vs children growing up bilingual	Dr. Kim: SLA is harder for adults as they have a fixed language network, while children benefit from neuroplasticity. Dr. Blekher: Age is key in SLA. Children have a natural ability for SLA, often surpassing adults in proficiency.
2. Brain areas that benefit from SLA	Dr. Kim: The auditory cortex, Wernicke's area, Broca's area, the motor cortex, etc. Dr. Blekher: Primarily, Broca's area and Wernicke's area.
3. Adult SLA and NDDs	Dr. Kim: Adult SLA engages the brain and cognitive systems, potentially preventing NDDs. Dr. Blekher: Adult SLA may delay the onset of NDDs.
4. Adult SLA and neural connection loss	Dr. Kim: SLA works on neuroplasticity, increasing neural connections and creating protective factors. Dr. Blekher: SLA can slow down neural connection loss by building a cognitive reserve.
5. SLA and memory improvement	Dr. Kim: SLA activates semantic memory. Dr. Blekher: SLA activates semantic memory and increases memory ability.

6. CP for SLA	Dr. Kim: SLA after the CP is possible but more difficult. Dr. Blekher: Research suggests a CP exists, but it is still being studied.
7. Brain differences in SLA: Children vs adults	Dr. Kim: Children form new brain connections while adults modify existing ones, requiring more cognitive effort. Both age groups activate the same language areas in the brain. Dr. Blekher: Biological, age-related, and affective factors and brain predisposition make SLA easier for children.
8. Adult L2 proficiency	Dr. Kim: Adult L2 proficiency is possible through efficient and consistent practice in varied contexts. Dr. Blekher: Motivation, intensive instruction, and language aptitude enable some adults to achieve L2 proficiency.
9. Monolingual vs bilingual brains	Dr. Kim: Bilinguals have more representation in both hemispheres. Dr. Blekher: Bilinguals have more diffused brain activation.
10. Teaching methodology: Children vs adults	Dr. Kim: The teaching methods should be adapted to the different needs of children and adults. Dr. Blekher: The teaching methods need to be adapted to secure the correct progress of children and adults.

3.2 Questionnaire Results

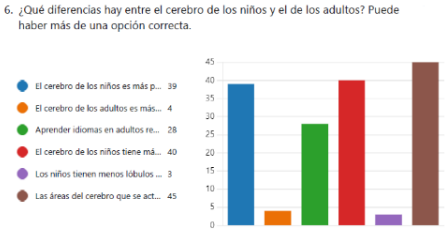
Considering that the questionnaire participants were mainly between 18 and 24 years old, it was unsurprising that they had limited knowledge about how the brain works during language acquisition. The graphical representations (*see Figures 2 to 13*) were collected for data analysis from Microsoft Forms, the same program used for administering the questionnaire.

Figure 2. *Responses about the location of the language center.*



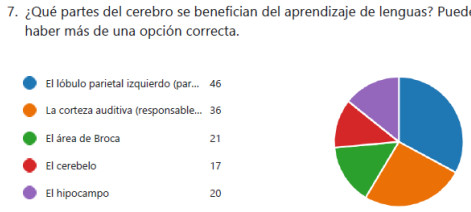
In Figure 5, 54% of participants believed the language center is in the left hemisphere, 29% think it is in the right hemisphere, and 17% think it is distributed across both.

Figure 3. *Responses to the differences between the brains of children and adults.*



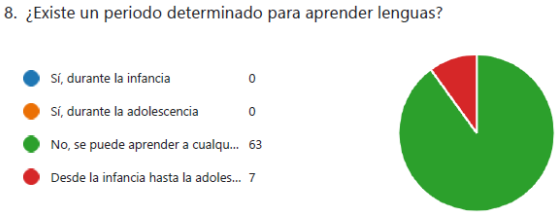
In Figure 6, 40 participants said children have more neural connections; 39 noted children's neuroplasticity, and 28 thought adult SLA reorganized neural connections; but 45 wrongly assumed the activated brain areas during SLA differed between children and adults.

Figure 4. *Responses to the brain parts that benefit from SLA.*



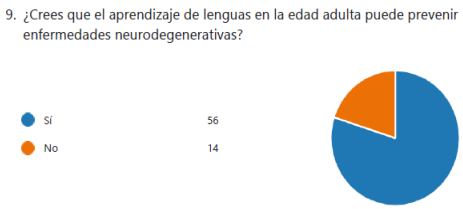
Most participants (46 people) identified the left parietal lobe and auditory cortex (36 people) as the areas that benefit from SLA, but only 21 knew about Broca's area (see Figure 7).

Figure 5. *Responses to whether a CP in SLA exists.*



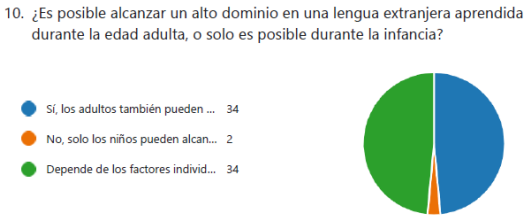
In Figure 8, 90% of participants noted there is no specific period for SLA. Only 10% recognized a CP.

Figure 6. *Responses to whether SLA can prevent NDDs.*



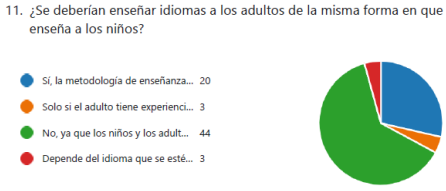
Almost all the participants (80%) believed adult SLA can delay NDDs (see Figure 9).

Figure 7. *Responses to whether high proficiency in adult SLA is possible.*



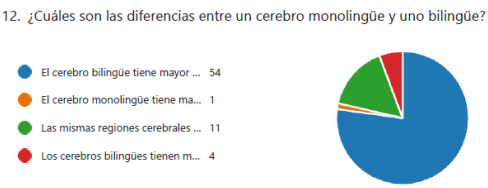
In Figure 10, 34 participants said adult L2 proficiency is possible, while 34 noted it depends on individual factors. A minority of two people said only children achieve L2 proficiency.

Figure 8. *Responses to whether languages should be taught to adults as taught to children.*



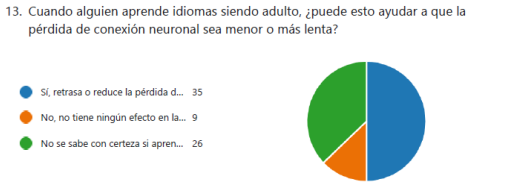
63% of respondents favored adjusting L2 instruction to cover the different needs of children and adults, while 29% believed the teaching methodology should be the same for both groups (see Figure 11).

Figure 9. *Responses regarding the differences between monolingual and bilingual brains.*



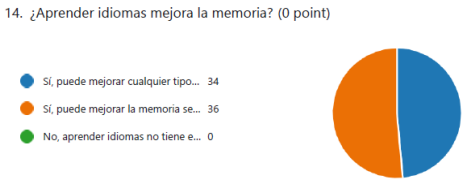
In Figure 12, 78% of people said the difference between monolingual and bilingual brains is the increased activity in specific areas of bilingual brains, though 16% wrongly believed both types of brains activate the same regions.

Figure 10. *Responses to whether adult SLA reduces or slows the loss of neural connection.*



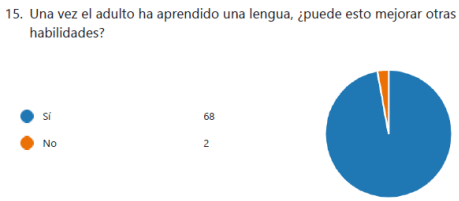
50% of participants answered that adult SLA could reduce neural connection loss, while 37% believed the effects of SLA remain unknown (see Figure 13).

Figure 11. *Responses to whether SLA improves memory.*



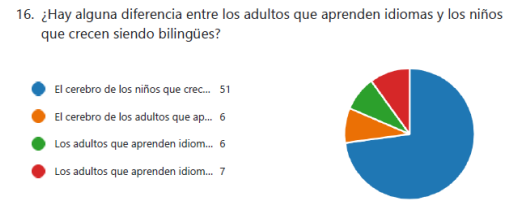
In Figure 14, 51% of participants said SLA enhances semantic memory. However, the remaining 49% believed it improved all memory types.

Figure 12. *Responses to whether adult SLA improves other skills.*



Almost all the participants (97%) agreed that SLA could improve other skills (see Figure 15).

Figure 13. *Responses to whether there is a difference between adult L2 learners and children growing up bilingual.*



73% of participants thought the difference between adult L2 learners and children growing up bilingual is that children's brains develop linguistic abilities simultaneously for both languages (see Figure 16).

4. Discussion

The first research question addresses the existence of the CPH and whether individuals can attain high proficiency in a new language acquired during adulthood. While children are commonly regarded as quick learners, compared to "sponges," the CPH suggests that this advantage in SLA diminishes after puberty. However, the validity of this hypothesis has been debated for many years, as detailed in the theoretical background (*see section 1.1.3*).

During the interviews, the two doctors discussed the existence of a CP but expressed the view that adults can still succeed in SLA. Oppositely, the questionnaire responses (*see Figure 8*) showed that 63 out of 70 participants were not aware of a CP. Still, this does not invalidate their perspective, as anyone can learn at any stage of life. However, several factors make SLA more challenging for adults compared to children.

Despite these challenges, adult SLA is feasible and can lead to high language proficiency. Figure 10 indicated that 34 participants believed in the possibility of achieving high competence in an L2 learned during adulthood, while 34 others assumed it depends on individual factors. The thesis and discussions with the doctors provided evidence supporting the attainability of adult SLA under appropriate conditions. Tailored instruction that meets individual needs is crucial for adult learners (*see Figure 11*), a view shared by 44 participants. Therefore, it would be beneficial for the general public to consider pursuing SLA, even later in life, if they become aware of its feasibility.

One aspect examined when analyzing age differences in SLA was the distinction between adult L2 learners and children who grow up learning multiple languages, as well as the differences in brain functioning between children and adults. Experts coincided

with the researcher's findings, indicating that the younger ones have more brain plasticity and less self-awareness than adults, facilitating their SLA process. In contrast, adults have a well-established language network that they have constructed over their lifetimes, which may hinder adult SLA as they must add new language components into existing neural connections, requiring reorganization.

When surveying the general public, 40 out of 70 of the participants (*see Figure 6*) recognized the increased neural connections in children, and 39 acknowledged the enhanced neuroplasticity in children. However, 45 individuals incorrectly assumed that the brain areas activated during SLA differ between children and adults[8]. In Figure 16, 51 participants correctly answered that children's brains are developing as they acquire an L2. These results suggest that people know the advantages of children over adults in SLA, though not so much about language-related brain activation.

Another question posed to the interviewees revolved around the impact of SLA on memory and pre-existing skills. Both doctors explained that there are different types of memories, which the researcher did not know beforehand, and SLA only affects semantic memory, which stores everything the learner knows about language (e.g., meanings and definitions). As for skills, adult SLA can also improve pre-existing abilities, as the doctors explained. Armed with this newfound knowledge, the researcher directed the question to questionnaire participants (*see Figure 14*). The participants, much like the researcher, were unsure whether SLA improved memory in general (which 49% of the participants marked) or specifically enhanced semantic memory (indicated by 51%). Many respondents were likely unfamiliar with the concept of semantic memory

[8] As elaborated in the subsequent paragraphs, the brain regions involved in SLA remain consistent across all age groups, with variations in activation observed exclusively between monolingual and bilingual brains.

before encountering it on the questionnaire, but upon seeing the option, it seemed plausible to them that this was one possible option. Regarding skills, 97% of participants agreed that SLA might improve skills that the learner already possessed (*see Figure 15*).

In terms of neurolinguistics, the researcher aimed to confirm that the language center predominantly resides in the left hemisphere of the brain and that the brain areas involved in language correspond to those described in the theoretical section. According to explanations from Dr. Kim and Dr. Blekher, the central regions involved in SLA and benefiting from it include the auditory cortex, auditory association areas (like Wernicke's area), frontal areas responsible for speaking (specifically the left inferior frontal gyrus or Broca's area), the motor cortex for muscle coordination, and other parts distributed throughout the brain. These areas are always the same, both in children and adults. However, while most people are indeed left-lateralized for language, bilinguals show more engagement of the right hemisphere.

The questionnaire participants (*see Figure 5 & Figure 7*) were uncertain about these two aspects. Regarding the location of the language center (*see Figure 5*), 54% of the participants indicated it is found in the left hemisphere, while only 17% believed it could involve both hemispheres. Still, it was shocking to see that many people (29%) believe it is exclusively located in the right hemisphere. As for the parts of the brain that benefit from SLA, the answers were mixed (*see Figure 7*) reiterating that people are uncertain about how the brain handles language processing. Only 21 individuals knew about Broca's area, although they may not have been familiar with its connection to SLA.

Continuing with the subject of the brain, the next issue examined was the difference between monolingual and bilingual brains. When asked about the differences

in brain activity between monolinguals and bilinguals (*see Figure 12*), 78% of the participants correctly believed that bilingual brains have more activity in certain areas. Despite this, 11 individuals wrongly claimed that the activated brain areas are the same in both brain types. Dr. Kim and Dr. Blekher highlighted that bilingual brains display more diffuse brain activation compared to monolinguals. Likewise, bilingual brains have higher grey matter volume than those who only speak one language, indicating a clear distinction between the two brain types. This distinction holds relevance for patients with NDDs and brain injuries, as explained in the following paragraph.

Concerning NDDs, professional opinion was instrumental in understanding how SLA interacts with damaged brains. Dr. Kim, a specialist in the field who deals with patients who have suffered brain injuries, confirmed that SLA could benefit individuals with aphasia, Alzheimer's disease, or dementia. Drawing from her experience, Dr. Kim remarked that bilinguals are more likely to have greater representation in both hemispheres of the brain. She discovered that bilinguals' brains continue to show activation during language tasks, signaling better establishment or representation. Monolinguals with language-related brain lesions, on the other hand, perform poorly. Dr. Blekher agreed that SLA can postpone the onset of NDDs and that bilinguals have higher gray matter density.

Figure 9 illustrates that 80% of the respondents in the questionnaire were aware to that SLA can help prevent NDDs. The finding is significant because it informs people that engaging in SLA not only equips them with a new skill (which can also be transferred to other skills, as seen in the interviews) but also safeguards against cognitive decline. In fact, Dr. Blekher pointed out that SLA builds what is known as "cognitive reserve," which creates some sort of protection against brain deterioration.

Besides, both doctors pointed out that SLA can also slow down neural connection loss. As they explained, the more one practices something, the more neural connections are formed, working on brain plasticity. However, when passing this question to the general public (*see Figure 13*), only 35 participants believed that adult SLA could reduce neural connection loss, while 26 believed that it is something that remains unknown. Once again, learning is a great activity to keep the brain active and involved, only bringing positive things with it.

In addition to the theory section, the participation of professionals and of people from Catalonia helped to gain a broader knowledge of SLA. It was remarkable to see what people think about SLA in the different age groups. Despite being aware of the benefits associated with SLA, it is surprising that more people are not trying to learn an L2. Many simply assume that the opportunity for SLA has passed and believe it is too late to start. However, comprehending the cognitive benefits of SLA can inspire individuals of any age to initiate the learning process, disregarding any concerns about age limitations.

4.1. Limitations of the study and implications for further research

To strengthen the significance of the thesis, conducting additional interviews with professionals from other fields, such as neuroscientists or neurologists, would have been advantageous. Moreover, the researcher merely presented the questionnaire responses using descriptive statistics in the results section. If this were a master's thesis, the researcher would have probably gained the expertise to employ alternative analytical methods like inferential statistics. Furthermore, a longitudinal study monitoring the brain activity of adult L2 learners could yield insights into the brain's long-term structural and

functional changes. Regrettably, due to a lack of knowledge in medicine or neuroscience, the researcher could only rely on theoretical and expert-based evidence for their findings.

5. Conclusion

Acquiring an L2 is a cognitive exercise that promotes neuroplasticity regardless of age. Engaging in activities that require learning and remembering keeps the brain active and strengthens or expands neural connections. The findings from this project challenge the misconception that adults cannot learn an L2 later in life, as they can still derive benefits from SLA, although with investable differences compared to children. Besides enhancing linguistic skills, research has suggested that bilingualism can be a neuroprotective factor against NDDs, including Alzheimer's. Additionally, in people with brain injuries like aphasia, having an L2 can facilitate recovery. To maximize the advantages of SLA across different age groups, it is crucial to adapt teaching methodologies accordingly, tailoring L2 instruction to meet the needs and capabilities of learners. Therefore, it would be vital to encourage people to learn additional languages to benefit from them.

6. References

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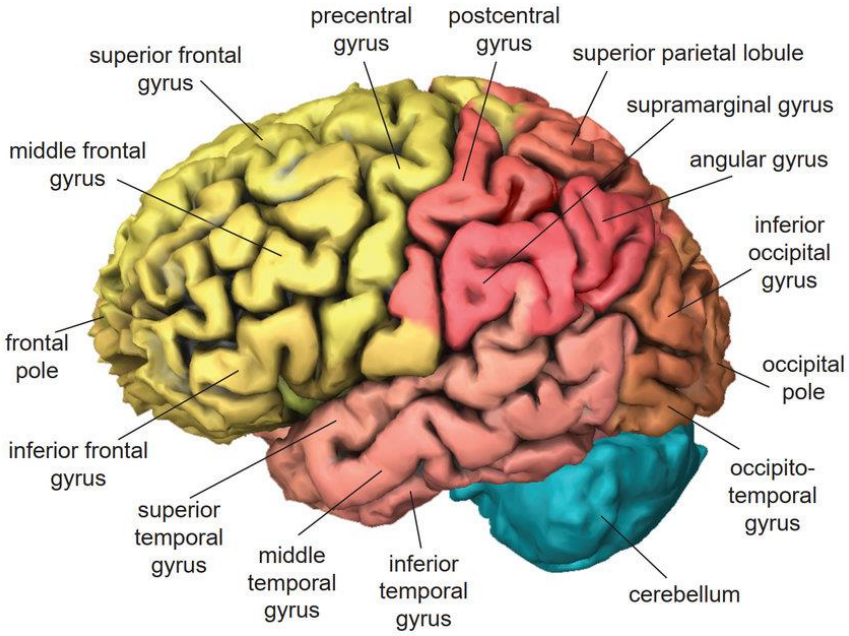
Appendix A

Figure 14. *Lateral view of the left hemisphere of the human brain.*



Note: Frontal lobe (yellow), parietal lobe (red), temporal lobe (pink), occipital lobe (salmon), cerebellum (turquoise).

Image retrieved from

https://www.researchgate.net/publication/349258287_Virtual_reality_for_neurorehabilitation_and_cognitive_enhancement

Appendix B

Figure 15. *Anatomy of the cerebral cortex.*

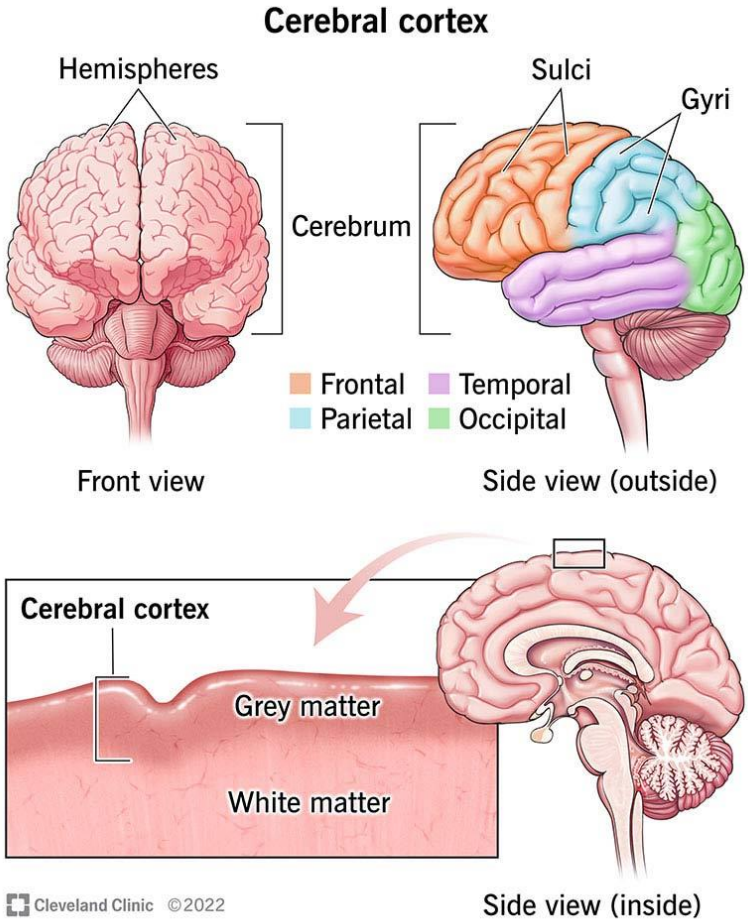


Image retrieved from https://my.clevelandclinic.org/health/articles/23073-cerebral-cortex

Appendix C

Figure 16. *Human Brain Anatomy: The four lobes of the brain*

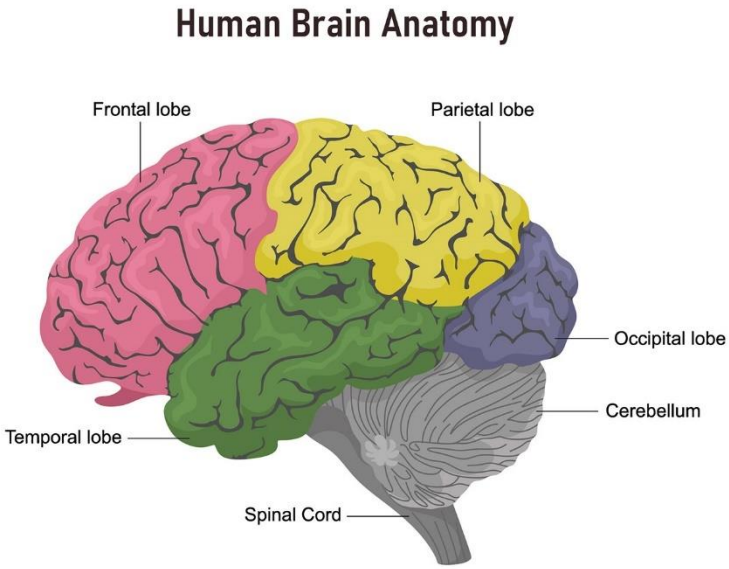


Image retrieved from https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

Appendix D

Figure 17. *Broca's area (a) and Wernicke's area (b)*

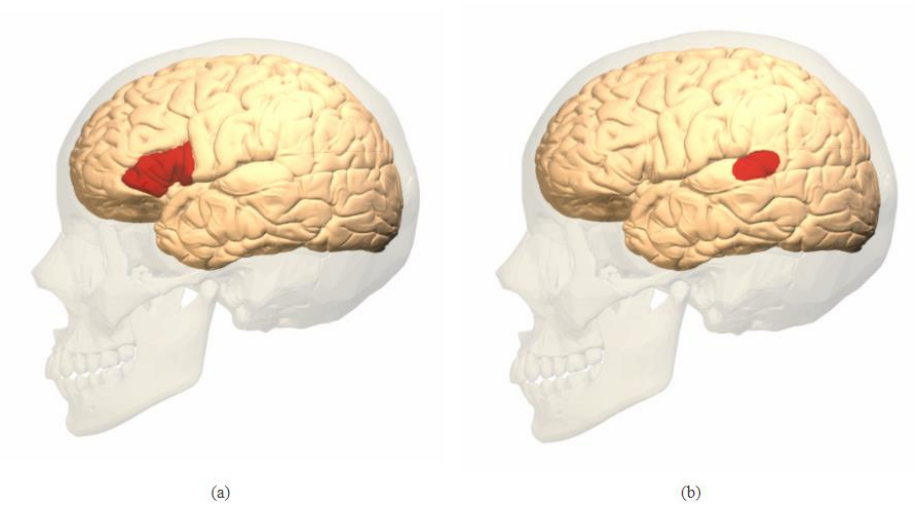
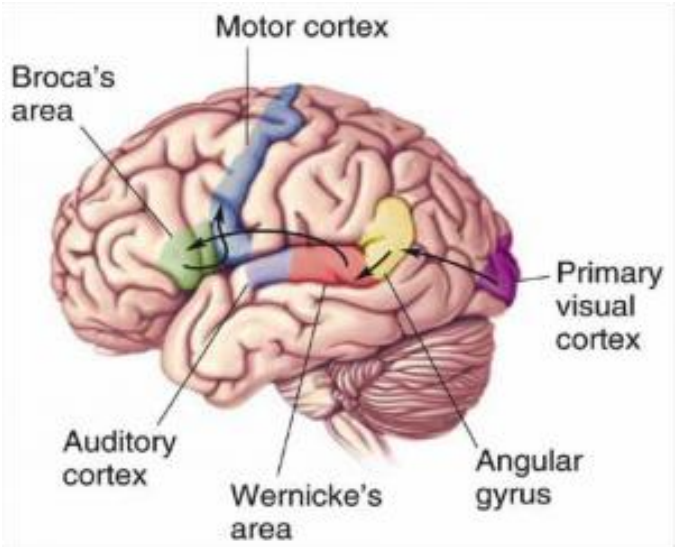


Image retrieved from https://opentextbc.ca/psyclanguage/chapter/language-in-the-brain/

Appendix E

Figure 18. *Language-related brain areas.*

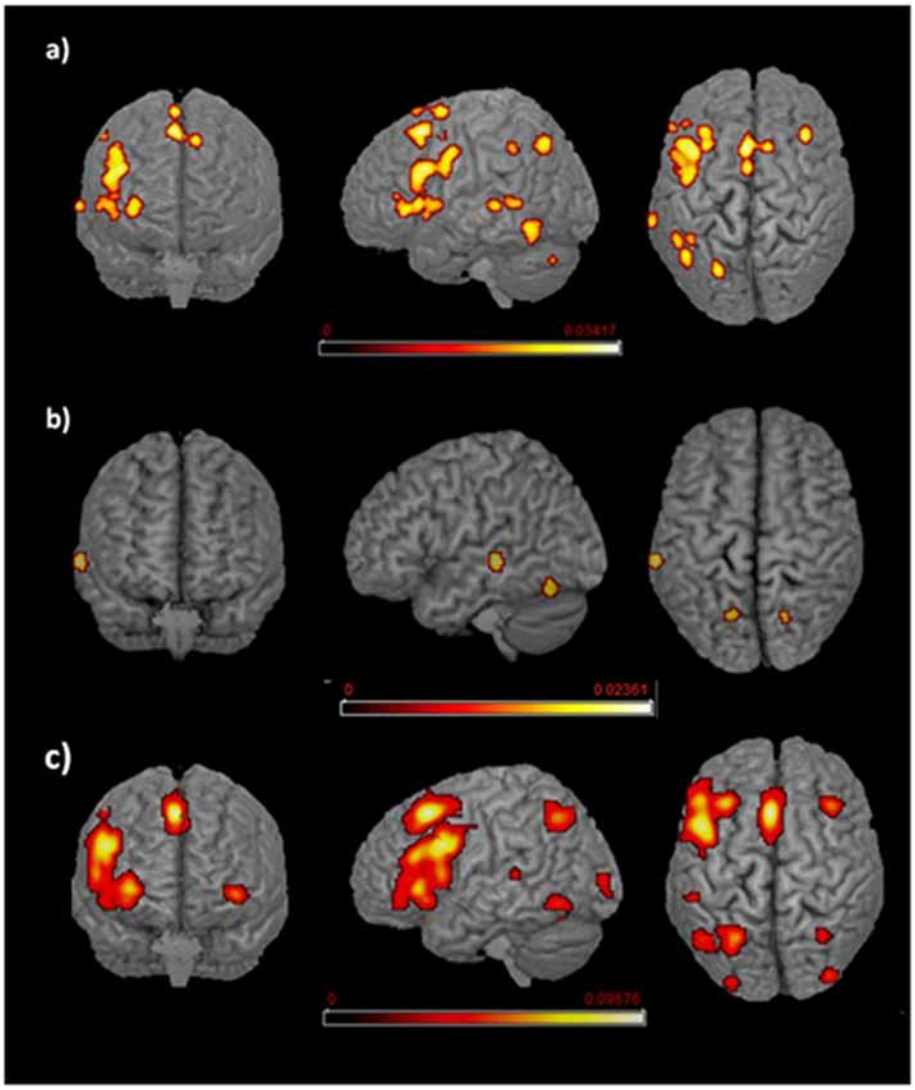


Note: The primary visual cortex and agular gyrus are involved in reading.

Image retrieved from https://www.yalescientific.org/2014/12/uncharted-waters-in-dyslexia-research/

Appendix F

Figure 19. *Language networks associated with different age of appropriation.*



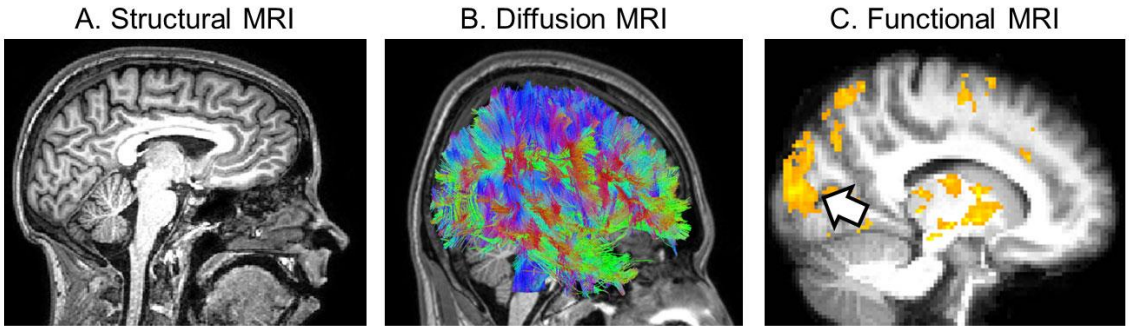
(A) Early bilinguals, (B) Very early bilinguals, (C) Late bilinguals

Image retrieved from

https://www.frontiersin.org/articles/10.3389/fnhum.2019.00154/full

Appendix G

Figure 20. *MRI based imaging techniques.*



(**A**) Structural MRI shows the anatomical structure of the brain.

(**B**) Diffusion MRI shows the layout of WM connections and pathways within the brain, each color representing a different WM pathway.

(**C**) Functional MRI reveals areas of the brain activation (shown in yellow) when performing a particular task.

Image retrieved from https://www.hoajonline.com/psychiatry/2055-3447/2/7/figure/f1

Appendix H

Figure 21. *GM volume in bilinguals vs. monolinguals.*

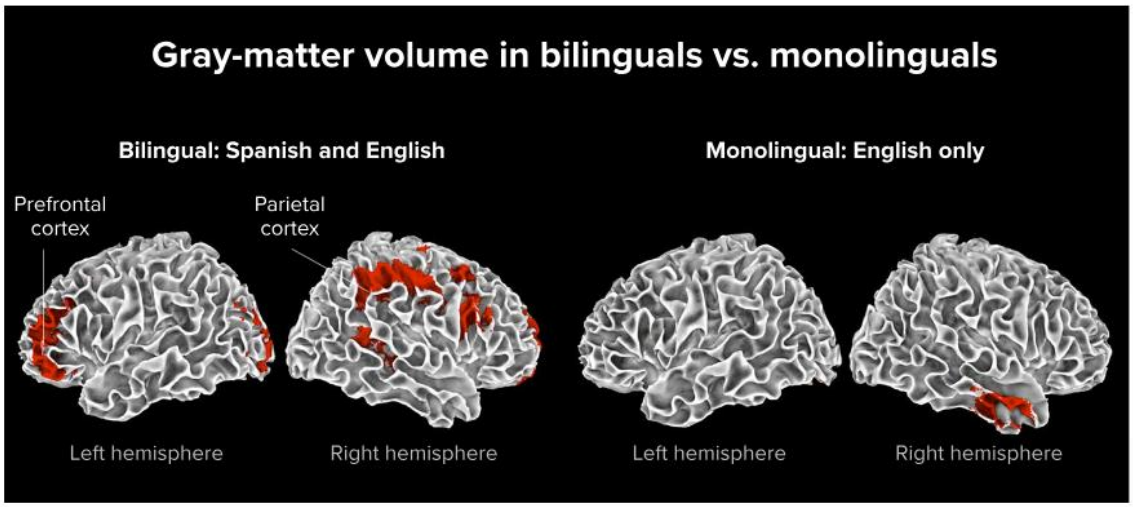


Image retrieved from https://knowablemagazine.org/article/mind/2018/how-second-language-can-boost-brain

Appendix I

Figure 22. *Contrasting activation of bilinguals and monolinguals when hearing the same language.*

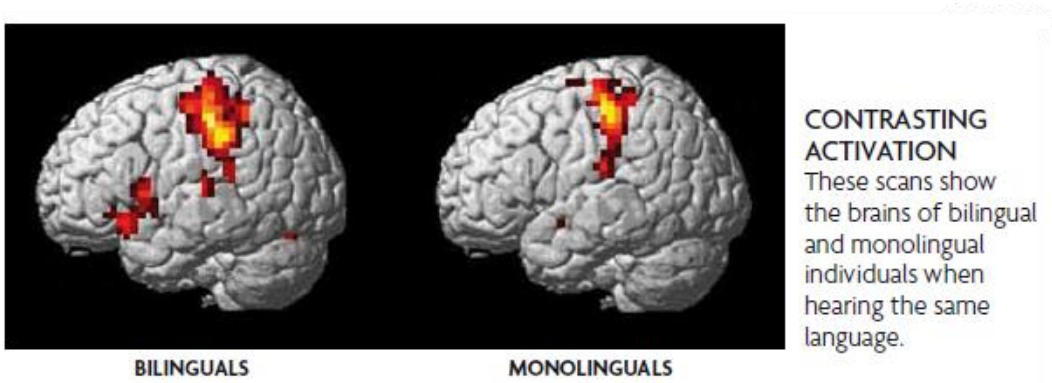


Image retrieved from Carter, R., Aldridge, S., Page, M., Parker, S., Frith, C. D., Frith, U., & Shulman, M. B. (2009). *The Human Brain Book*. Dk Pub.

Appendix J

Figure 23. *Areas activated in monolinguals and bilinguals.*

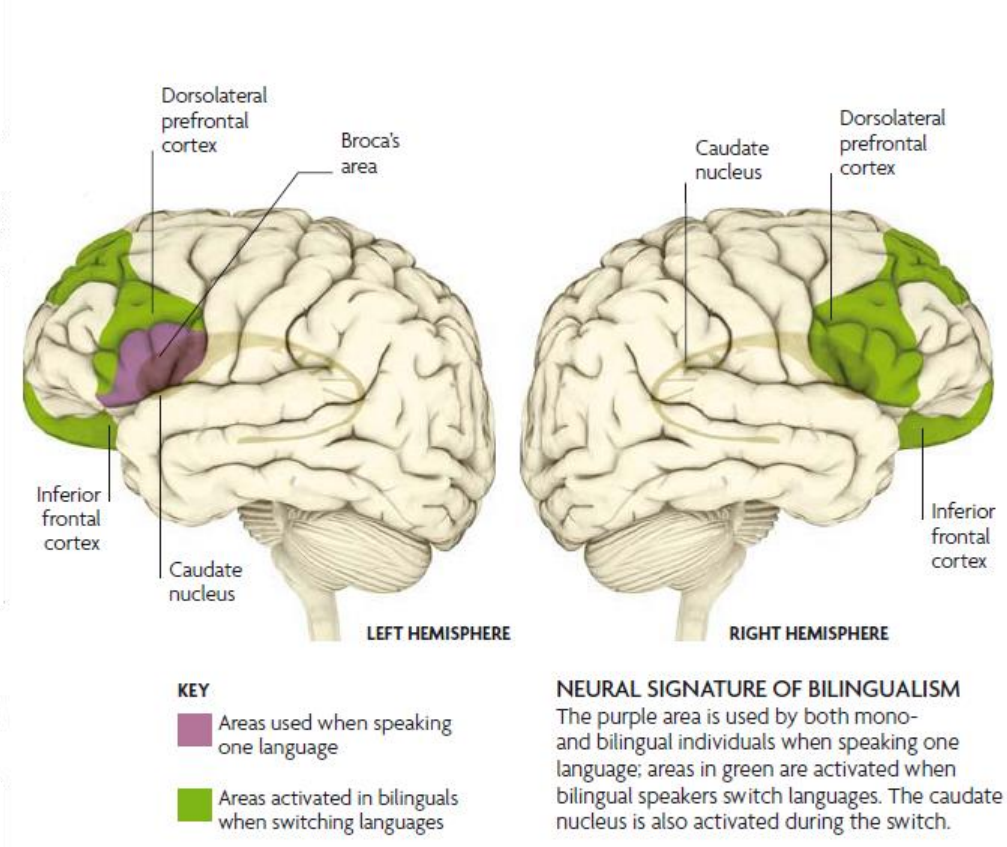
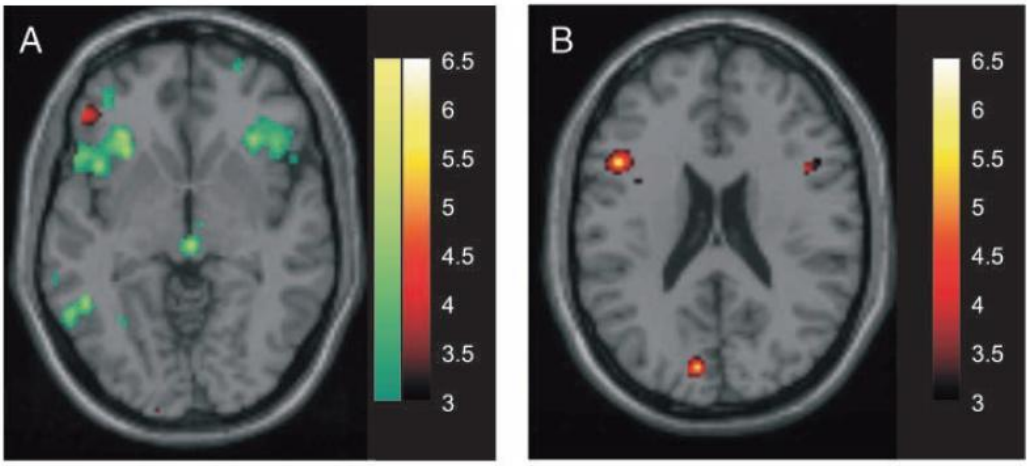


Image retrieved from Carter, R., Aldridge, S., Page, M., Parker, S., Frith, C. D., Frith, U., & Shulman, M. B. (2009). *The Human Brain Book*. Dk Pub.

Appendix K

Figure 24. *Activation in bilinguals > monolinguals contrast for English language.*



Note: Red colors refer to activation unique to bilinguals, green colors refer to the shared activation between bilinguals and monolinguals on a syntactic task in English (bilinguals in Spanish and English vs English monolinguals).

Image retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2643466/

Appendix L

Figure 25. *Activity in healthy and aphasic brains during different tasks.*

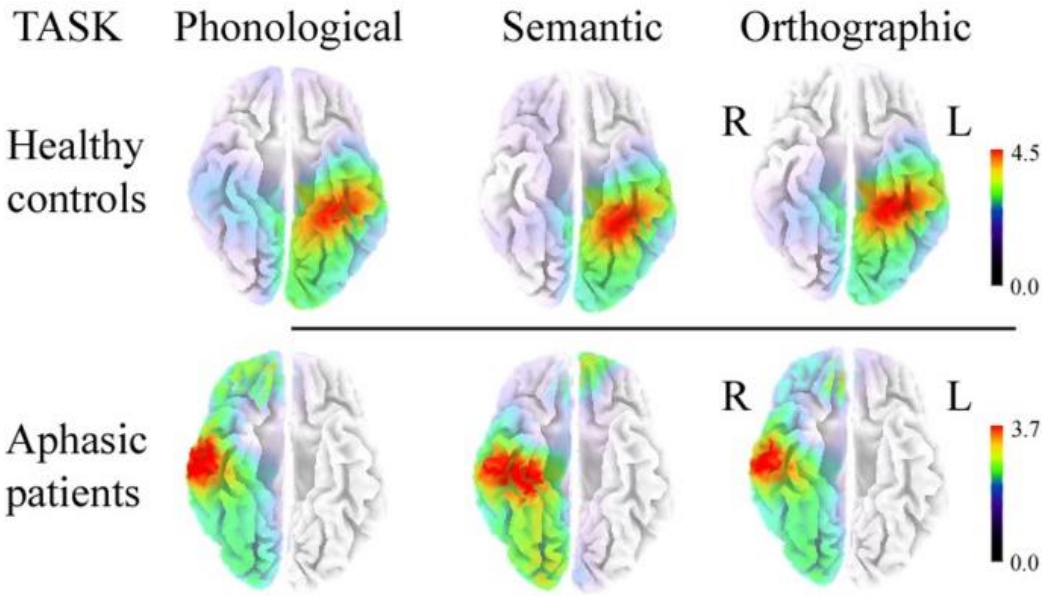
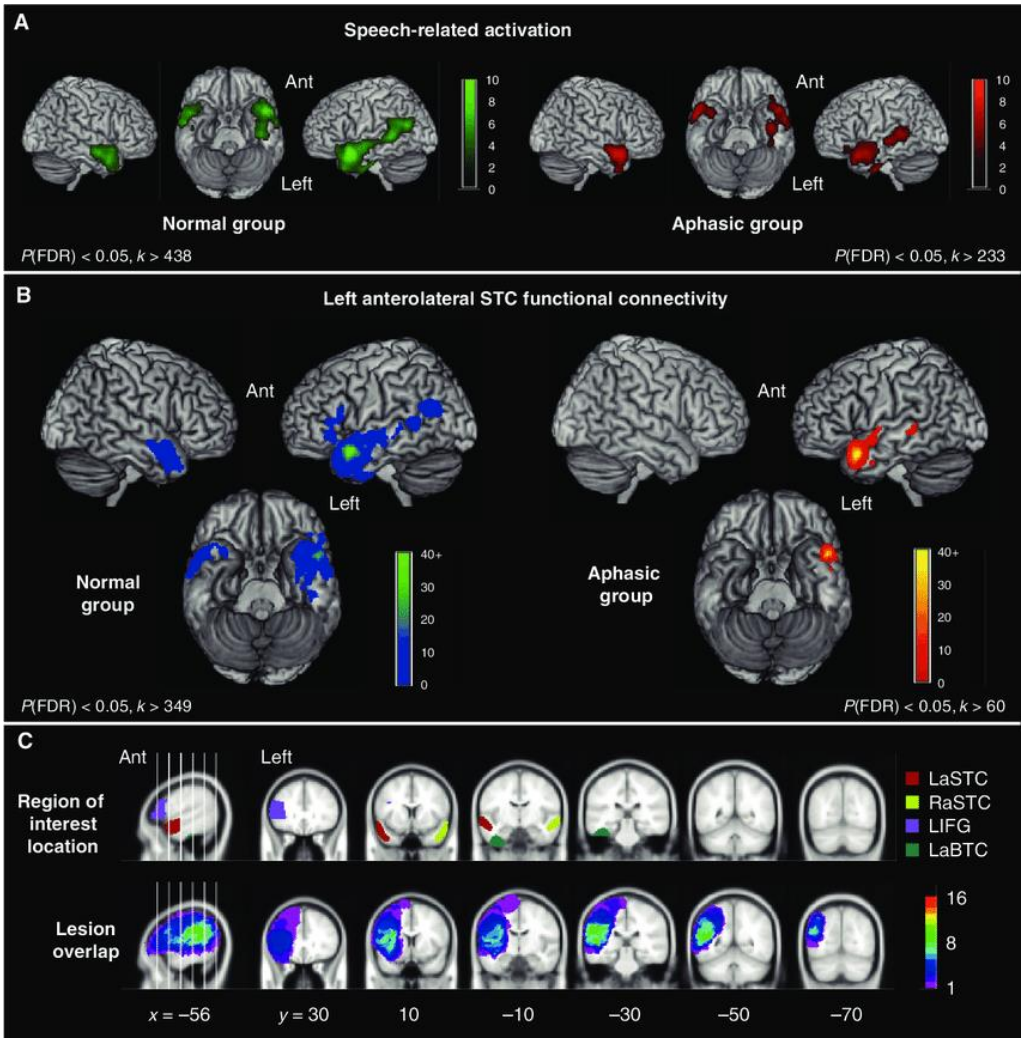


Image retrieved from https://www.nature.com/articles/srep12541

Appendix M

Figure 26. *fMRI in normal and aphasic brains.*



(A) Activation related to speech comprehension in the normal (green) and aphasic (red) group. **(B)** Left anterolateral superior temporal functional connectivity in the normal (green-blue) and aphasic (red-yellow) groups. **(C)** Location of anatomical regions used in the region of interest analyses (upper row), displayed for comparison with the distribution and overlap of stroke lesions in the aphasic group (lower row).

Image retrieved from https://www.researchgate.net/figure/Functional-imaging-data-in-the-normal-and-aphasic-groups-A-Activation-related-to_fig1_38080463

Appendix N

Figure 27. *Types of Aphasia.*

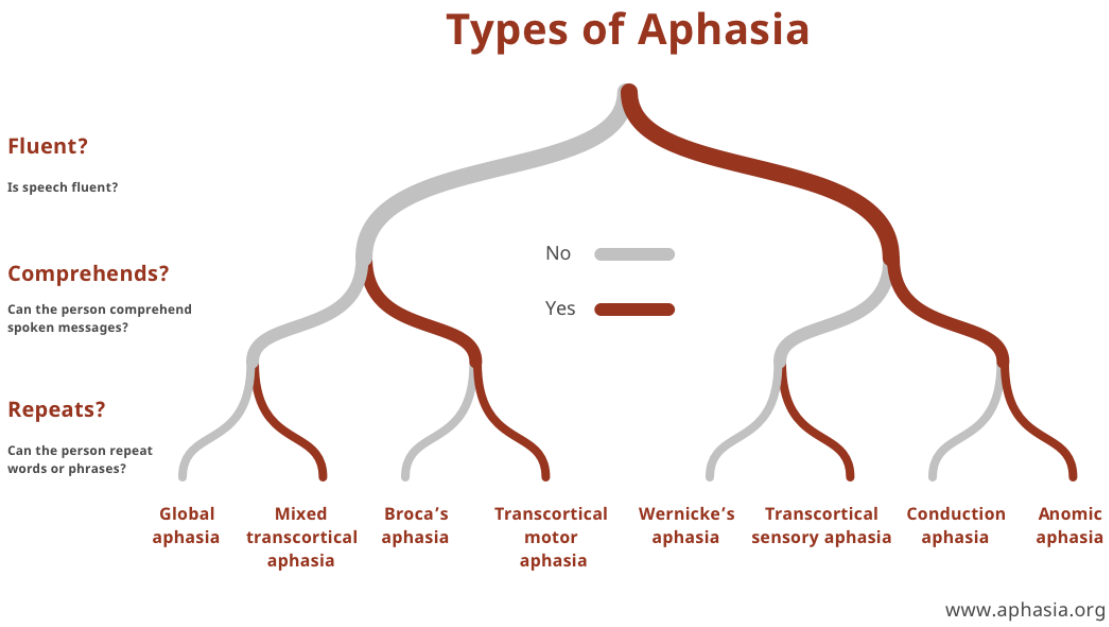


Image retrieved from https://www.aphasia.org/aphasia-definitions/

Appendix O

Figure 28. *Location of aphasias.*

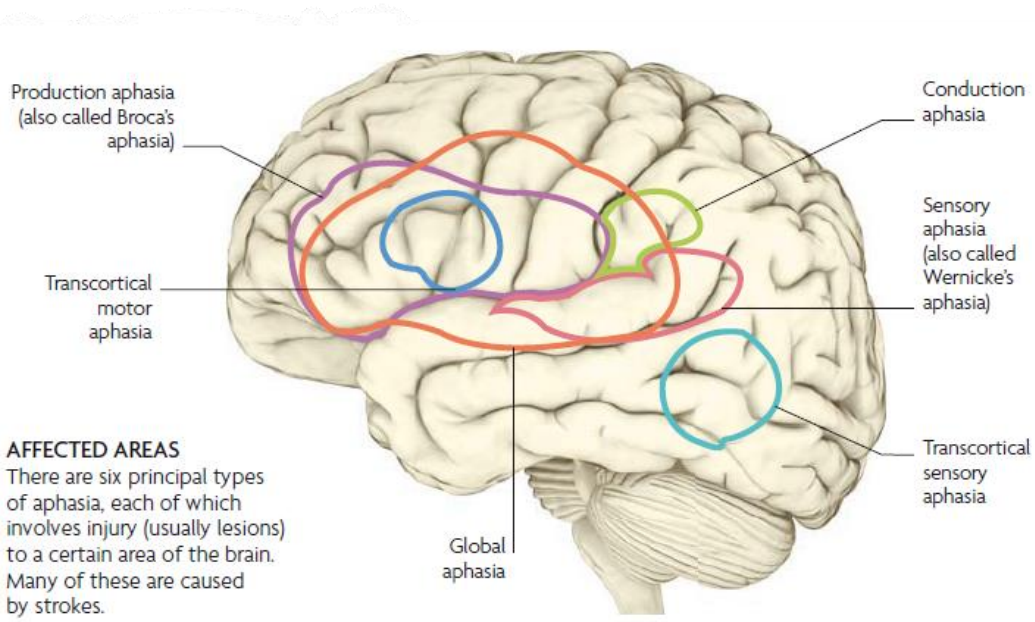
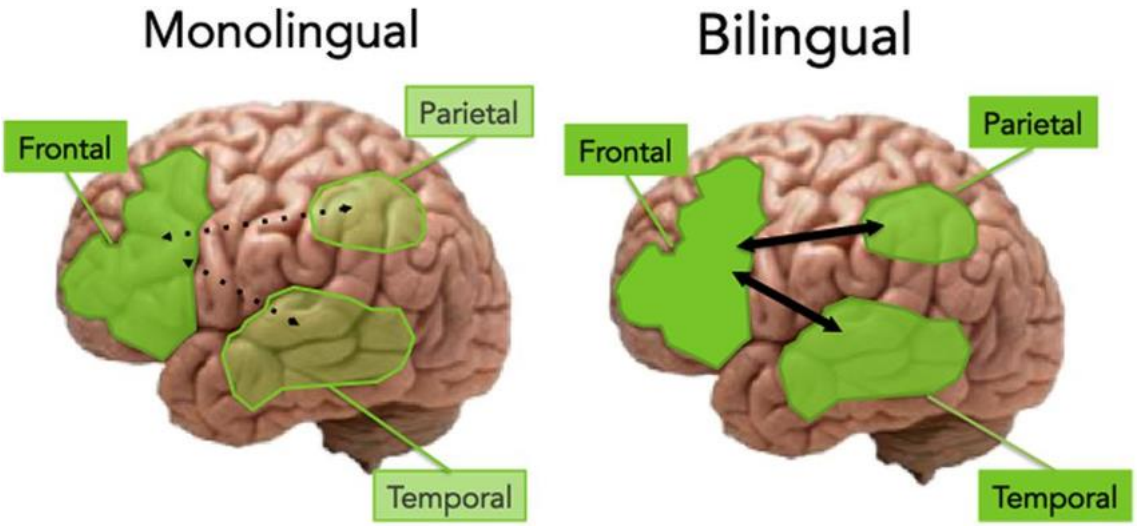


Image retrieved from Carter, R., Aldridge, S., Page, M., Parker, S., Frith, C. D., Frith, U., & Shulman, M. B. (2009). *The Human Brain Book*. Dk Pub.

Appendix P

Figure 29. *Monolingual vs. bilingual aging brain.*



Aging in monolinguals is associated with an increased reliance on the frontal regions. In bilinguals, however, the aging brain shows preservation of the posterior regions (temporal and parietal cortex), and increased connectivity between frontal and posterior areas, leading to cognitive reserve.

Image retrieved from https://www.researchgate.net/figure/An-illustration-of-the-monolingual-vs-bilingual-aging-brain-In-monolinguals-aging-is_fig3_268333350

Appendix Q

Figure 30. *Comparison of a normal brain and degeneration from severe AD.*

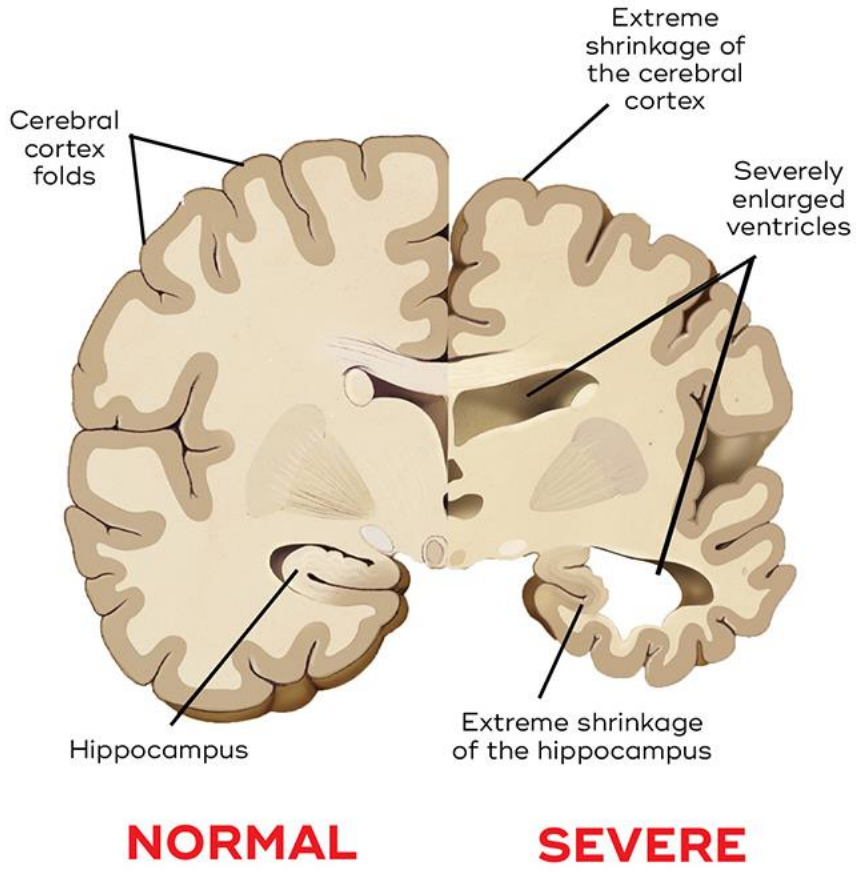


Image retrieved from https://qbi.uq.edu.au/dementia/dementia-causes-and-treatment

Appendix R

Figure 31. *Brain atrophy in advanced AD.*

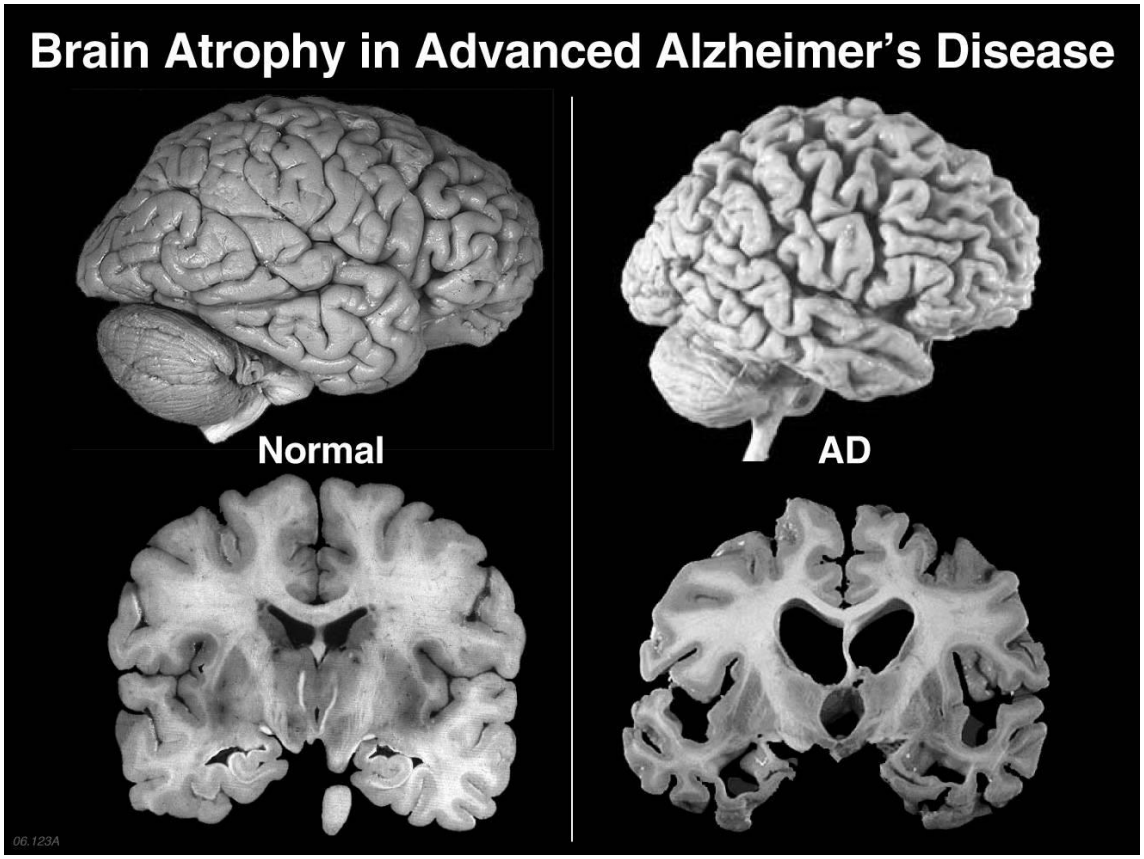


Image retrieved from https://www.brightstarcare.com/locations/chattanooga/about-us/blog/studies-on-alzheimers-disease/

Appendix S

Interview with Dr. Kim

I. Are you aware of any differences when adults learn foreign languages compared to children growing up bilingual?

P. Children's brains are very plastic. When they grow up bilingual, the development of the language network in the brain happens simultaneously for both languages. In contrast, adults already have an established language network, so learning a new language means overlaying it on the existing foundation. Thus, adults find it harder to acquire languages than children.

I. What parts of the brain benefit from learning foreign languages?

P. When learning languages, an auditory signal comes in through your ears, activating the auditory cortex (in the bilateral temporal lobes) and the auditory association areas (like Wernicke's area). The frontal areas are involved in speaking, particularly the left inferior frontal gyrus (Broca's area), which is important for language production. The motor cortex coordinates the movement of articulators. Other regions widely distributed throughout the brain are important in semantics and meaning. When learning languages, new labels are acquired for concepts we already know. These established brain areas are equally activated in children and adults during language acquisition.

I. Should adults over 40 try learning a new language, and if so, why?

P. Absolutely! There is evidence to suggest that keeping active in cognitive skills as we age is extremely beneficial and learning languages is a fantastic way to exercise the brain. Moreover, it is a gateway to having a different social experience and meeting new people.

I. Can learning languages in adulthood help to prevent neurodegenerative problems like dementia or Alzheimer's disease?

P. The theory of cognitive reserve suggests that people with higher levels of education, who remain active in learning new things or using cognitive skills into older adulthood may have a reduced risk of developing dementia and Alzheimer's disease. Learning a new language is a fantastic way to engage the brain and cognitive systems, preventing neurodegenerative issues.

I. When someone learns languages as an adult, can this help to have less or slower neural connection loss?

P. Yes. The more you practice something, the more your neural connections are established in the brain. People with brain injuries provide evidence for this. Bilingual or multilingual individuals may find the L1 more accessible than later learned languages, allowing them to work on the structures of other languages. The well-established neural structures work as a key to unlocking this L2. Learning a language, just because you are learning a new skill, works on neuroplasticity and brain changes, increasing neural connections and protective factors.

I. Does learning a foreign language improve memory?

P. It depends on the kind of memory you are talking about. There are diverse types of memories, such as episodic memory, short-term memory, procedural memory, and working memory, among others. Learning languages activates what is known as semantic memory, which stores everything one knows, including meaning and definitions. However, other types of memory involve different brain systems that are probably not affected by language acquisition.

I. Do you believe there is a critical period for learning languages?

P. It is not that you cannot learn languages after a certain age, but it becomes more difficult. Children and teenagers learn way more easily than adults do.

I. What are the brain differences that language learning has in children and adults? Why is it easier for kids to learn languages?

P. Children form new connections in the brain as they learn, whereas adults have to change or add new things to established connections, which is more challenging. Imagine building Lego: it is easier to build it for the first time than taking it apart and changing and adjusting an already-built structure. The language network or areas of the brain that are activated during language acquisition are the same for children and adults. However, adults learning new languages might have to work harder. For instance, they might think about something in their L1 and then translate it. The process requires more cognitive involvement for adults.

I. Is it possible to achieve high proficiency in a foreign language learned during adulthood, or is this only possible during childhood?

P. It depends. Certain factors can be manipulated to make sure that you get higher proficiency. The basic principles of neuroplasticity include repetition, intensity, salience, and practicing in different environments and with different people (generalization). Adults who have those conditions emergent – like moving to a place where that is the only language spoken, and you must use it to get anything done, or people in your life speak that language and you want to be able to communicate with them – they have many opportunities to practice. All those things can lead to a really good proficiency as an adult.

So, it is not so much the age as it is all those other factors – practicing with enough sufficiency and intensity and all in varied contexts.

I. What are the differences between a monolingual and a bilingual brain observed through fMRI?

P. I am not certain about this because I am not up to date on the latest research. But I think bilingual individuals often have greater representation in both the right and left hemispheres compared to monolinguals. Based on my experience working with people who have brain injuries, I can say that bilingual individuals still have activation when they do a language task, suggesting that it is better established or represented. In contrast, for monolinguals with a brain injury in language areas and you give them a language task, they may struggle and not perform as well. Therefore, it seems plausible to say that bilinguals have more representation in the brain compared to monolinguals.

I. Should adults be taught languages using the same teaching methodology as children, or should they do different activities?

P. Adult learners are different that children. Adults usually engage more of their cognitive abilities, including metacognition. They think about learning or what they are doing. Adult learners want to know why. With children, you can just give them something and they do it without having to explain why you are doing it that way. But adults want to be involved. I do think there are some different techniques for teaching adults. You need to make things meaningful for adults and teach them things that are going to be useful in their daily lives, like how to order coffee or social phrases.

I. Once an adult has learned a foreign language, can this help to improve other abilities?

P. I am not sure if there is a real neural basis for that, but I think the fact that adults can employ cognitive strategies to learn new skills can be transferred to other things. Learning a language is a skill. So, if they feel successful with that, they could feel empowered to do other things as well.

I. Do you know someone who has gone through some of these situations?

P. I know people who are using Duolingo to learn a new language. It depends on how proficient they want to become. For example, my cousin married an Italian Canadian and she took language classes as an adult to learn Italian. She even went to Italy to do an immersion experience, so now she can speak Italian with her husband's family.

Appendix T

Interview with Dr. Blekher

I. Are you aware of any differences when adults learn foreign languages compared to children growing up bilingual?

P. Research demonstrates that adults who learn a second language and children growing up bilingual have some differences. One main factor is biological constraints like brain lateralization concerning language. According to The Critical Period Hypothesis, age is crucial in language acquisition. Children possess a natural ability to learn languages and can achieve native-like pronunciation. Studies have shown that there is a window of opportunity for language acquisition, which closes at the age of 12 or earlier. While other factors, such as adult self-awareness of the learning process and children's intuitive learning might affect language acquisition, evidence indicates that children have an easier time learning languages and often surpass adults in language proficiency, regardless of the situation.

I. What parts of the brain benefit from learning foreign languages?

P. Ellen Bialystok, a Canadian linguist and psychologist, studied the cognitive effects of bilingualism on children and older adults. Bilingualism enhances “cognitive reserve,” which relates to the executive function of the brain like selective attention and the ability to ignore distractions. Bilingual individuals demonstrate these cognitive advantages, especially if they learn two languages at an early age. This “cognitive reserve” can offer protection against dementia and Alzheimer’s disease, potentially delaying their onset. While learning a second language is beneficial for the brain, starting later in life may not provide the same cognitive advantages.

Language processing in the brain involves two key regions: Broca's area, in the frontal lobe, responsible for production; and Wernicke's area, responsible for comprehension. Most people are left-lateralized for language, as much of our language processing occurs in the left hemisphere. However, research has shown that the right hemisphere may be involved even in monolinguals. In contrast, bilinguals have greater involvement in the right hemisphere than monolinguals, but early language learners have processing similarities with monolinguals compared to late learners. Bilinguals also have more diffused brain activation.

I. Should adults over 40 try learning a new language, and if so, why?

P. I do not see why not. I think any exercise for the brain is good. Again, although cognitive advantages are typically seen in balanced bilinguals in later adulthood, starting to learn a language at any age is still worthwhile. While life may bring other responsibilities, the cognitive benefits are still worth the effort. Moreover, in today's multilingual world, being able to communicate in multiple languages can have many advantages. So, my answer would be a definite yes.

I. Can learning languages in adulthood help to prevent neurodegenerative problems like dementia or Alzheimer's disease?

P. Yes. Again, I would refer to Ellen Bialystok, whose research over the last 20 years has focused on the impact of bilingualism on older individuals. Her findings show that proficient bilinguals can delay the onset of dementia and Alzheimer's disease. Compared to monolinguals, bilingual individuals tend to show symptoms at a later stage when diagnosed. Bilinguals normally outperform tasks that involve suppressing irrelevant information, such as the Stroop task, used in psychology since the 1930s, which involves

reading color names like blue or red, while the words are written in different ink colors. This task creates interference due to the meaning of the words, and bilinguals have been shown to manage this interference effectively.

When examining brain architecture, evidence suggests that bilinguals have higher gray matter density, which is usually used as a measure of intelligence. Research indicates a relationship between gray matter density and language proficiency, with greater proficiency in the second language correlating with higher gray matter density. The timing of second language acquisition also plays a role, as people who start learning earlier are more likely to have higher gray matter density. Moreover, there is a distinction between coordinate and compound bilinguals in terms of the processing and representation of languages in the brain. Coordinate bilinguals show greater separation in language processing areas, whereas compound bilinguals exhibit a more fixed representation. For compound bilinguals, direct electrical stimulation of the brain during surgery is more likely to disrupt both languages, indicating that activating one part of the brain can affect both languages. On the other hand, coordinate bilinguals are more likely to have separate and distinct representations for each language.

I. When someone learns languages as an adult, can this help to have less or slower neural connection loss?

P. Yes. Learning languages builds the cognitive reserve that I mentioned earlier.

I. Does learning a foreign language improve memory?

P. Semantic memory is the type of memory responsible for storing the language, as well as knowledge of subjects like math, physics, and other languages. Short-term memory is used for ongoing language processing, so holding temporary representations in the brain.

Valuable information is then transferred to our long-term memory for more lasting storage. Bilinguals need to store information from both of their languages, which can lead to better memory ability or capacity. Another common distinction is between declarative memory, which involves representation, and procedural memory, which relates to knowledge of how to perform tasks.

I. Do you believe there is a critical period for learning languages?

P. It is a complex issue, there is no black-and-white answer to that question. It depends on how you define this critical period. Hyltenstam & Abrahamson have a study from 2003 called *Age of onset and ultimate attainment in near-native speakers of Swedish as a second language.* In this study, they looked at second language learners of Swedish with various backgrounds to see if the concept of the critical period is true, and whether people who learn later in life can also reach elevated levels of proficiency.

I. What are the brain differences that language learning has in children and adults? Why is it easier for kids to learn languages?

P. Many reasons contribute to children's ability to learn more quickly than adults. Firstly, there are biological factors. Children are better at pronunciation, which can be seen as muscular activity, just like excelling in a high-achieving sport at a young age. If I started figure skating now, I would not perform at an expert level. The key is starting young. The same happens with pronunciation since it involves coordinating many muscles in the vocal tract and related areas. So, this is one of the main reasons, mainly rooted in biology.

Others say that the brain's predisposition is also significant. We possess a broad language faculty that needs to be triggered early in life to achieve native-like proficiency. Additionally, affective factors may come into play. Children are generally not self-aware.

They do not care what others think about them. While this explanation is not purely biological, it involves age-related factors rather than age itself. As a result, there could be many different reasons why children seem to have an easier time.

I. Is it possible to achieve high proficiency in a foreign language learned during adulthood, or is this only possible during childhood?

P. Yes. Multiple studies on exceptional language learners have demonstrated that some adults can achieve high levels of language proficiency. There is a special talent in languages known as language aptitude. Studies – including the major Swedish study I mentioned earlier – show that very few people who are perceived to be native-like actually perform in a native-like way on more stringent tasks. Those adults who demonstrated native-like performance had high language aptitude. Motivation is another factor that can help override some of the age effects. Another factor that has been looked at is intensive high-quality instruction, which can help. There is a lot of individual variation in second language acquisition compared to first language acquisition. So, it is hard to draw generalizations.

I. What are the differences between a monolingual and a bilingual brain observed through fMRI?

P. One of the differences between bilinguals and monolinguals is the more diffuse activation of the brain in bilinguals. This distinction is evident in fMRI. Functional MRI involves performing different cognitive tasks during the MRI, like translating during the MRI. But sMRI analyzes gray matter density without requiring any cognitive function. The findings obtained through fMRI demonstrate more diffuse activation in bilinguals

compared to monolinguals. However, it depends on the nature of the task, what they are asked to do, and the focus of the study.

I. Should adults be taught languages using the same teaching methodology as children, or should they do different activities?

P. Children are like “sponges” and can absorb information quickly. Adults, on the other hand, are more analytical and cognitively mature, with varying degrees of metalinguistic awareness. Bilingualism enhances this metalinguistic awareness. Consequently, teaching methods that rely more on metalinguistic abilities and the cognitive maturity of adults may hinder the progress and motivation of younger children.

Variation exists even among adults, and different methodologies exist beyond the traditional grammar-translation method. Communicative approaches emphasize authentic language use, balancing fluency, and accuracy. Some adults may like conventional methodologies that target grammatical competence, while others may not. The selected strategy is influenced by the aims of language acquisition. People who aspire to be professionals in L2 must work on accuracy and grammatical competence, while those who just want to communicate need to focus on conversation skills. In SLA compared to FLA, there is a lot more individual variety in the process and results in learning kinds, learning techniques, and learning goals.

I. Once an adult has learned a foreign language, can this help to improve other abilities?

P. Some studies link second language ability to mathematical or musical ability, for example. But I do not know what factor influences the other. Can we draw a cause-and-effect relationship? I am not able to directly answer this question, whether it is language

learning that led to that or the other way around. Or maybe another factor contributed to a greater ability in both.

I. Do you know someone who has gone through some of these situations?

P. Canada is a country of immigrants, so a lot of people have learned languages during adulthood. However, some people may have come here as adults but may have been exposed to the language earlier on, even if they did not use it daily. I cannot recommend anyone I know because there could be that contaminating variable, but it is a common experience, especially in countries with immigration like the United States and Canada. Additionally, people who retire might decide to start learning another language because it is something they have always wanted to do. For example, I am not close to retirement, and I can envision myself learning another language or two just for the fun of it and because I never had time for those languages early on.

Appendix U

Figure 32. *Informed Consent Form*

Formulario de Consentimiento

Título del Trabajo de Fin de Grado: *Neurolinguistics: Learning Languages as an Adult Rewires the Brain (Neurolingüística: Aprender Idiomas siendo Adulto Reconfigura el Cerebro)*

Datos de contacto del investigador: – Marina Palomo Martín, marina.palomo@estudiants.urv.cat

INFORMACIÓN SOBRE PROTECCIÓN DE DATOS

Datos El responsable de control de datos es la Universitat Rovira i Virgili con CIF Q9350003A, en Carrer de l'Escorxador, s/n, 43003, Tarragona.

Objetivo
Participar en el Trabajo de Fin de Grado en los términos descritos en la ficha de información del participante. Si el estudio tiene la intención de publicar, difundir y reutilizar los resultados obtenidos, incluidos los datos personales, los datos personales serán utilizados para estos fines siempre que el interesado haya dado su consentimiento.

Derechos
Las personas interesadas pueden ejercer su derecho de acceso, rectificación, supresión, movilidad, limitación u oposición al tratamiento de sus datos dirigiéndose por escrito al Registro General de la URV en el mismo domicilio de la URV, o personalmente en el Registro General de la URV o telemáticamente de acuerdo con las instrucciones en https://seuelectronica.urv.cat/registre.html.

Más información
Los participantes pueden encontrar información adicional sobre el uso de datos personales en el Trabajo de Fin de Grado de la URV y sobre sus derechos en el Registro de Tratamientos de la URV, que está publicado en https://seuelectronica.urv.cat/rgpd, donde también hallarán la Política de Privacidad de la URV. También pueden encontrar esta información en el Documento de información del participante sobre el estudio. Asimismo, podrán plantear a nuestros delegados de protección de datos cualquier cuestión relativa a la protección de datos personales enviando un correo electrónico a dpd@urv.cat.

* Required

Figure 33. *Informed Consent Form (Part 2)*

1. Por favor, escriba su nombre y DNI/NIF *

2. - He leído la copia que he recibido del documento de información del participante sobre el estudio.
- He podido preguntar y he recibido respuesta a mis dudas personales sobre el estudio y mi participación en el mismo.
- Entiendo que estoy participando en este estudio de acuerdo con las especificaciones en el documento de información del participante y de acuerdo con las respuestas que he recibido a mis preguntas y entiendo los riesgos y beneficios que esto conlleva.
- Acepto que mi participación es voluntaria y acepto libremente participar en el estudio.
- Entiendo que puedo retirarme en cualquier momento de participar en el estudio y que mi retiro no me afectará negativamente de ninguna manera.
- Una vez finalizada la investigación, los datos obtenidos pueden ser de interés para otros estudios relacionados. En este sentido, se ofrecen las siguientes opciones: *

   ◯ NO AUTORIZAR el uso de los datos en otros proyectos de investigación relacionados.

   ◯ AUTORIZAR el uso de los datos en otros proyectos de investigación relacionados.

3. Por favor, indique la fecha y ubicación (ciudad) *

4. Al escribir su nombre y enviar este formulario, acepta participar en este estudio. *

Appendix V

Table 2. *Translation of the Questions from the Questionnaire*

Questions	**Translation**
1. ¿A qué rango de edad perteneces?	1. What age range do you belong to?
2. ¿Con qué género te identificas?	2. What gender do you identify with?
3. ¿Cuántas lenguas hablas?	3. How many languages do you speak?
4. ¿Has aprendido o estás aprendiendo alguna lengua extranjera siendo adulto?	4. Have you learned or are you learning a foreign language as an adult?
5. ¿En qué parte del cerebro se encuentra el centro del lenguaje?	5. In which part of the brain is the language center located?
6. ¿Qué diferencias hay entre el cerebro de los niños y el de los adultos? Puede haber más de una opción correcta.	6. What differences are there between the brains of children and those of adults? There may be more than one correct option.
7. ¿Qué partes del cerebro se benefician del aprendizaje de lenguas? Puede haber más de una opción correcta.	7. What parts of the brain benefit from language learning? There may be more than one correct option.
8. ¿Existe un periodo determinado para aprender lenguas?	8. Is there a certain period to learn languages?
9. ¿Crees que el aprendizaje de lenguas en la edad adulta puede prevenir enfermedades neurodegenerativas?	9. Do you think that learning languages in adulthood can prevent neurodegenerative diseases?

10. ¿Es posible alcanzar un alto dominio en una lengua extranjera aprendida durante la edad adulta, o solo es posible durante la infancia?	10. Is it possible to achieve high proficiency in a foreign language learned during adulthood, or is it only possible during childhood?
11. ¿Se deberían enseñar idiomas a los adultos de la misma forma en que se enseña a los niños?	11. Should languages be taught to adults in the same way they are taught to children?
12. ¿Cuáles son las diferencias entre un cerebro monolingüe y uno bilingüe?	12. What are the differences between a monolingual and a bilingual brain?
13. Cuando alguien aprende idiomas siendo adulto, ¿puede esto ayudar a que la pérdida de conexión neuronal sea menor o más lenta?	13. When someone learns languages as an adult, can this help reduce or slow down the loss of neural connection?
14. ¿Aprender idiomas mejora la memoria?	14. Does learning languages improve memory?
15. Una vez el adulto ha aprendido una lengua, ¿puede esto mejorar otras habilidades?	15. Once the adult has learned a language, can this improve other skills?
16. ¿Hay alguna diferencia entre los adultos que aprenden idiomas y los niños que crecen siendo bilingües?	16. Is there a difference between adults learning languages and children growing up bilingual?

Appendix W

Table 3. *Translation of the Answers from the Questionnaire*

Answers	**Translation**
1. 18-24 25-34 35-44 Más de 45	1. 18-24 25-34 35-44 Over 45
2. Mujer Hombre No binario Otro Prefiero no decirlo	2. Female Male Non-binary Other I prefer not to say
3. 1 2 3 Más de 3	3. 1 2 3 More than 3
4. Sí, para enriquecerme a nivel personal. Sí, para conseguir más oportunidades profesionales. No, es muy difícil siendo adulto o no tengo tiempo. No es algo que me interese.	4. Yes, to enrich myself on a personal level. Yes, to get more professional opportunities. No, it is very difficult being an adult or I do not have time. It is not something that interests me.

5. En el hemisferio izquierdo. En el hemisferio derecho. En ambos hemisferios.	5. On the left hemisphere. On the right hemisphere. On both hemispheres.
6. El cerebro de los niños es más plástico. El cerebro de los adultos es más plástico. Aprender idiomas en adultos reorganiza las conexiones neuronales. El cerebro de los niños tiene más conexiones neuronales. Los niños tienen menos lóbulos cerebrales. Las áreas del cerebro que se activan durante la adquisición del lenguaje son distintas en niños y adultos.	6. Children's brains are more plastic. The adult brain is more plastic. Learning languages in adults reorganizes neural connections. Children's brains have more neural connections. Children have fewer brain lobes. The areas of the brain that are activated during language acquisition are different in children and adults.
7. El lóbulo parietal izquierdo (para la mayoría de las personas). La corteza auditiva (responsable de la audición). El área de Broca. El cerebelo. El hipocampo.	7. The left parietal lobe (for most people). The auditory cortex (responsible for hearing). Broca's area. The cerebellum. The hippocampus.
8. Sí, durante la infancia.	8. Yes, during childhood.

Sí, durante la adolescencia. No, se puede aprender a cualquier edad. Desde la infancia hasta la adolescencia.	Yes, during adolescence. No, you can learn at any age. From childhood to adolescence.
9. Sí / No	9. Yes / No
10. Sí, los adultos también pueden alcanzar un alto dominio. No, solo los niños pueden alcanzar un alto dominio. Depende de los factores individuales de cada persona.	10. Yes, adults can also achieve high proficiency. No, only children can achieve high proficiency. It depends on the individual factors of each person.
11. Sí, la metodología de enseñanza es efectiva para todos. Solo si el adulto tiene experiencia previa en el aprendizaje de idiomas. No, ya que los niños y los adultos tienen necesidades y habilidades diferentes. Depende del idioma que se esté enseñando.	11. Yes, the teaching methodology is effective for everyone. Only if the adult has previous experience in language learning. No, since children and adults have different needs and abilities. It depends on the language that is being taught.
12. El cerebro bilingüe tiene mayor actividad en determinadas áreas.	12. The bilingual brain has greater activity in certain areas.

El cerebro monolingüe tiene mayor plasticidad. Las mismas regiones cerebrales se activan en ambos tipos de cerebro. Los cerebros bilingües tienen menos volumen de materia blanca que los cerebros monolingües.	The monolingual brain has greater plasticity. The same brain regions are activated in both brain types. Bilingual brains have less white matter volume than monolingual brains.
13. Sí, retrasa o reduce la pérdida de conexiones neuronales. No, no tiene ningún efecto en la pérdida de conexiones neuronales. No se sabe con certeza si aprender idiomas en la edad adulta tiene efecto en la pérdida de conexiones neuronales.	13. Yes, it delays or reduces the loss of neural connections. No, it does not affect the loss of neural connections. It is not certain whether learning languages in adulthood influences the loss of neural connections.
14. Sí, puede mejorar cualquier tipo de memoria. Sí, puede mejorar la memoria semántica. No, aprender idiomas no tiene efectos en la memoria.	14. Yes, it can improve any type of memory. Yes, it can improve semantic memory. No, learning languages does not have effects on memory.
15. Sí / No	15. Yes / No

16. El cerebro de los niños que crecen siendo bilingües desarrolla habilidades lingüísticas para ambos idiomas al mismo tiempo. El cerebro de los adultos que aprenden idiomas desarrolla habilidades lingüísticas para los idiomas que conoce al mismo tiempo. Los adultos que aprenden idiomas y los niños bilingües tienen experiencias de aprendizaje de idiomas similares. Los adultos que aprenden idiomas entienden mejor las reglas gramaticales que los niños que crecen siendo bilingües.	16. The brain of children who grow up bilingual develops linguistic skills for both languages at the same time. The brain of adults who learn languages develops linguistic skills for the languages they know at the same time. Adults who learn languages and bilingual children have similar language learning experiences. Adults who learn languages better understand grammatical rules than children who grow up bilingual.