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A review of the neuroscience of second language acquisition

Adrienne Cruz

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Abstract

In exploring the neuroscience of second language acquisition, this literature review draws on published studies to discuss whether there is a "best" age to acquire a second language based on its impact on brain activity and structures of the brain. This project examines whether an individual's age of second language acquisition makes a significant impact on the brain that would impact other areas of that bilingual individual's life. This project then makes a connection to the topic's relevance in speech-language pathology through issues of referral and identification.

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Audrey Farrugia-Bernard, Ph.D., CCC-SLP

Second Advisor

David C. Winters, Ph.D.

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A REVIEW OF THE NEUROSCIENCE OF SECOND LANGUAGE ACQUISITION

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Adrienne Cruz

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Table of Contents

Neuroscience of Second Language Acquisition

It is a widely shared notion that the ability to speak more than one language provides an advantage for human learning. Schoolchildren in America are often encouraged to take foreign language classes every year in the interest of improving cultural awareness and cognitive development. The exact degree, however, to which bilingualism affects our potential for learning and functioning on a daily basis is yet to be discovered or agreed upon. Within this last decade, there has been a surge of empirical research concerning second language acquisition and its effects on the brain. Previous research focused mainly on the acquisition and implications of a first language (Abutalebi & Green, 2007). Because bilingual speakers operate between two different language systems at the same time, bilingual language production is complex to the point where one bilingual speaker cannot be equated to two monolingual speakers in terms of brain function and development. As the field knowledge and technology that are involved in neuroimaging and analysis continue to develop and expand, we are able to learn more about the neurological structures and patterns relative to the acquisition of a second language.

Findings in the psycholinguistics of bilingualism, such as those by Abutalebi and Green (2007) and Oller, Pearson, and Cobo-Lewis (2007), have had tremendous impact on how our society would prioritize the learning of a second language. If bilingualism could be a proven factor in the positive development of brain structure or activity compared to monolingualism in areas such as cognitive control or neural organization, the conversation could shift to re-acknowledge the untapped potential of the human brain (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009). This then raises some questions: if a bilingual brain is suggested to have a stronger framework for receiving and processing information, what criteria makes up that "bilingual" brain? Do the neural advantages apply to the same degree in two individuals who acquired a second language at different stages in their lives from childhood to adulthood? Furthermore, if a period during which it is optimal to take advantage of the positive effects of bilingualism on the brain exists, then it could be hypothesized that there may also be a peak timeframe during which one may learn language most efficiently and proficiently.

According to current research surrounding the cognitive neuroscience of second language acquisition and the critical period hypothesis, the best timeframe for a person to learn a second language is during childhood when the brain is in a state of optimal neuroplasticity (Klein, Mok, Chen, & Watkins, 2014). Because there is so little empirical research surrounding the topic, researchers in the field have varying views to whether peak timeframes for language learning can be proven true (Abutalebi & Green, 2007). Researchers of current studies surrounding the topic argue whether the period of neuroplasticity ends at the age of five or whether it extends into puberty. Whatever the period, once this critical period ends, the brain's capacity to process new language systems begins to diminish (Stein et al., 2012). While it is not impossible for even slightly older individuals to gain proficiency in new languages, it becomes increasingly more difficult as the individual ages. This paper will explore questions surrounding the neuroscience of second language acquisition by introducing the background information necessary to understanding the cognitive neuroscience of second language acquisition, presenting the literature surrounding second language acquisition, and offering suggestions for the ways in which speech-language pathologists can use this information in evidence-based practice.

Definitions

Age Hypothesis and Stage Hypothesis. Known formally as the Age of Language Acquisition Hypothesis, this states that patterns of brain activity relative to language change depending on the respective acquisition ages of the first and second language. The lengths of time between acquiring proficiency in the first and second language will determine different patterns of lateralization from one individual to another. This is due to differences in cognitive ability and the maturation of the brain (Hull & Vaid, 2007).

The Stage of Language Acquisition Hypothesis suggests that an individual's relative proficiency in the second language is a more important determiner of functional language lateralization, regardless of the temporal proximity of first and second language acquisition (Hull & Vaid, 2007).

Bilingual versus monolingual. A person with fluency or proficiency in two or more languages is referred to as being bilingual. A bilingual speaker ties two or more words from different lexicons to a single concept (Abutalebi & Green, 2007; Garbin et al., 2010).

Monolingual, or sometimes unilingual, is the term used to refer to a person with fluency or proficiency in a single language (Garbin et al., 2010).

Brodmann areas. The cerebral cortex of the human brain is divided into regions known as Brodmann areas (BA), to which different functions correspond (Hernandez 2009). Each Brodmann area is assigned a number, in a system widely used amongst neuroscientists. Neuroimaging data revealing activity in BA 6, 44, 45, and 47, for example, has allowed researchers to attribute those regions to speech and language functions (Tagarelli, 2014).

Cortical thickness. The cerebral cortex is the outermost layer of the foremost part of the brain, and is composed of gray matter. Cortical thickness is defined as a morphometric measure used to describe the combined thickness of the layers of the cerebral cortex, and is associated with higher cognitive ability (Klein, Mok, Chen, & Watkins, 2014).

Code-switching. This is the act of alternating between two languages or dialects of language in conversation, often depending on the environment. Bilingual speakers, among others, are experts at code-switching because they have learned to communicate with at least two different populations using two different sets of language (Wilson & Gick, 2013).

Critical Period Hypothesis. This psychological hypothesis, first proposed by Eric Lenneberg in 1967, states that the acquisition of language must occur within the first few years of infancy through puberty, or else it may not only be an inefficient endeavor, but an impossible one at that. This work has been challenged by researchers who are concerned with whether or not this hypothesis extends to second language acquisition (as cited in Redmond, 1993).

Elective bilingualism versus circumstantial bilingualism. Elective bilingualism occurs when an individual chooses to learn a second language out of personal interest or as the result of an extracurricular goal. Circumstantial bilingualism, on the other hand, arises out of an individual's need to acquire a second language in order to communicate and function within a specific cultural or geographical setting (Mahendra & Namazi, 2014).

Expressive language. This refers to the communicative information put out by the speaker, and includes speech and writing abilities. Broca's area in the frontal lobe of the brain's left hemisphere is responsible for expressive language. Damage to this area can result in expressive aphasia, wherein a person is unable to produce language to communicate his or her thoughts (Gibson, Peña, & Bedore, 2014).

First language versus second language. First language, abbreviated throughout this review as L1, refers to a speaker's native language. Second language, abbreviated as L2, refers to a speaker's additional acquired language after mastery of L1 (Tagarelli, 2014).

Gray matter. This is the darker neural tissue of the brain that contains nerve cell bodies, dendrites, synapses, and capillaries, and therefore is a key component of the central nervous system (Stein et al., 2012).

Language acquisition. This is the process of establishing proficiency in a language from gathering a lexicon to employing grammatical and syntactical rules. This review attempts to outline the distinction between the acquisition of a first language and that of a second language (Klein, Mok, Chen, & Watkins, 2014). Second language acquisition refers to the process of gaining proficiency in a different language after already having had established fluency in one language. The acquiring of a second language may occur simultaneously with the learning of the first language, or up to decades after (Klein, Mok, Chen, & Watkins, 2014; Tagarelli, 2014).

Lateralization. The brain is divided into its left and right hemispheres, each associated with its own set of functions. Lateralization refers to the patterns by which a certain hemisphere of the brain dominates an activity (Hull & Vaid, 2007).

Lexicon. This term is used to refer to a person's vocabulary within a language (Abutalebi & Green, 2007).

Neuroscience. The branch of science related to the study of the anatomy, biology, or physiology of the brain is known as neuroscience. Neurocognition stems from neuroscience, and deals specifically with the cognitive functions of the brain (Abutalebi & Green, 2007; Tagarelli, 2014).

Neuroplasticity. This refers to the brain's ability to form and reform synaptic connections over a lifetime. It is because of neuroplasticity that the intact brain is able to learn information, and the damaged brain is able to relearn (Stein et al., 2012).

Psycholinguistics. Also known as the psychology of language, this refers to the study of the acquisition, use, comprehension, and production of language by humans. This ties the bond between the "what" and the "how" of language (Abutalebi & Green, 2007).

Receptive language. This refers to the ability to take in and process information in the form of written or spoken language. The area of the brain associated with receiving and understanding language is called Wernicke's area, in the cerebral cortex at the junction of the temporal, parietal and occipital lobes. Damage to this area can result in the language disorder called receptive aphasia, wherein a person is unable to process received information as it is written or spoken (Gibson, Peña, & Bedore, 2014).

Receptive-expressive language gap. This is the delay or difficulty that occurs during a speaker's word-finding or a receiver's processing (Gibson, Peña, & Bedore, 2014).

Sequential bilinguals: early versus late. Sequential bilinguals are bilingual speakers who acquired their first and second languages at separate times. The term early sequential bilingual refers to individuals who gained their first language starting at birth, and acquired proficiency in a second language by the age of seven years old (Klein, Mok, Chen, & Watkins, 2014). The term late sequential bilingual refers to individuals who gained their first language starting at birth, and later acquired a second language any time after 11 years old (Klein, Mok, Chen, & Watkins, 2014).

Simultaneous bilinguals. In contrast to sequential bilinguals, simultaneous bilinguals are bilingual speakers who acquired their first and second languages concurrently. This is often due to a family speaking a language at home that is different from the native language of their geographic location. Children would have to learn both languages in order to function at home as well as independently outside of the home (Klein, Mok, Chen, & Watkins, 2014).

Speech-Language Pathology. The clinical field in which an accredited practitioner may evaluate, diagnose, and treat individuals with speech, language, and swallowing disorders. (American Speech-Language Hearing Association, 2017).

White matter. This is the pale tissue within the brain and spinal cord. Most of the brain is made up of white matter, as it is composed of myelinated axons which connect the gray matter and facilitate the travel of nerve impulses between neurons (Stein et al., 2012).

Literature Review

Is there a "best" age to acquire a second language?

The critical period hypothesis, first proposed by Lenneberg in 1967, drew an analogy between the human development of language and the wild animal's attachment phenomenon called imprinting (as cited in Redmond, 1993). The idea was that the wild animals who do imprint must do so within the first few hours after their birth, or else the newborn animal would forever be deprived of the opportunity to imprint because it had missed its window, therefore missing its chance to make a social attachment (Redmond, 1993). Likewise, when used in the context of language, the critical period hypothesis is the idea that humans have a specific timeframe, early in our development, in which we must acquire language. After that period has ended, language acquisition may be anywhere from difficult to impossible, depending on factors such as the age of acquisition and the intensity of language learning. The critical period hypothesis has evolved over the years, with researchers debating when the critical period starts and ends, and how strongly the claim should be applied, especially in the context of acquiring a second language (Redmond, 1993). If one has already developed a lexicon and understanding of grammatical rules in one language, is it truly then impossible to develop a second one for a different language outside of the critical period? This question poses interest as to the limits of the brain, and whether our receptive and expressive language functions are able to process understanding and production of a second language after a certain stage of development (Redmond, 1993).

Research connecting the critical period with second language acquisition provides evidence to support the validity of the critical period hypothesis (Redmond, 1993).

According to the critical period hypothesis, a younger language learner should have a less difficult time acquiring language than an older language learner would. "Younger" and "older" are relative terms, as there is no standard time for bilingual speakers to acquire their second language (L2). The younger language learner in question, does however correspond to first language (L1) acquisition, which most often begins at birth. Because many bilingual speakers did acquire their L2 after the end of puberty and still achieved high proficiency, Redmond (1993) acknowledged that the critical period for language may more accurately be termed as the critical period for phonology. This would be because L2 speakers would have already achieved phonology through their L1, and still have a potential to gain L2 proficiency years after the end of puberty. The argument then, becomes whether that L2 proficiency will ever reach a state of nativeness (Redmond, 1993).

How does second language acquisition impact brain activity?

A study by Tagarelli (2014) investigated the neurocognition of second language (L2) to examine the proposed impact that increased exposure and proficiency in another language would have on neural structures and cognitive processes. This study combined behavioral measures with those of functional magnetic resonance imaging (fMRI) measures to more fully examine the impact of L2 learning. This use of combined measures would ideally lead to the reveal of a correlation between behavioral and fMRI data.

The participants in Tagarelli's (2014) study were fifteen monolingual English speakers who were all right-handed, normal hearing, post-secondary educated young adults aged 18 to 26. None of the participants were considered fluent in any language other than English. During the study, the participants were all trained in a subset of the Basque language (referred to as "Mini-Basque"), with continuous monitoring of behavioral and fMRI measures. Introduction of this "mini-language," or simplified version of a natural language, allowed researchers to recreate and monitor the process of L2 acquisition within their participants by presenting a smaller set of the language that could be learned within a shorter timeframe (Tagarelli, 2014). The three main tasks used to train and assess participants on Mini-Basque involved picture matching, grammatical violation, and speech production. While participants were challenged in mastering morphosyntactics, they achieved high proficiency in grammar and vocabulary. During this process of L2 learning, researchers detected fMRI activity in areas of the brain connected to L1 processing, particularly, Brodmann's areas (BA) 45 and 47 for semantics, and BA44 and 6 for grammar. This evidence suggested that even late L2 learners were able to access and modify the pre-established L1 regions, but the activation of additional regions, such as the hippocampus and basal ganglia, revealed that the L1 regions alone are insufficient for L2 learning and processing (Tagarelli, 2014). Since new areas of the brain were engaged during L2 learning in addition to those used in L1 learning, this research suggested that the adult brain's ability to adapt to new language systems could circumvent the otherwise necessary neuroplasticity of the critical period.

While Tagarelli (2014) recognized that the goal of second language acquisition for general individuals is not to intentionally exhibit a particular brain pattern, but to become proficient in the L2, the magnetic resonance data collected from this study supported the idea that increased proficiency in L2 would inevitably lead to functional changes in the brain.

How does second language acquisition impact structures of the brain?

Aiming to approach the topic from a new angle, Stein et al. (2012) conducted a study that would instead look for structural changes in the prefrontal and temporal cortices of the brain due to second language acquisition, rather than changes in activity. The study set out to use magnetic resonance techniques to map a correlation between proficiency in an L2 with changes in the structure of the brain or in density of gray matter. While gray matter constitutes much of the brain's activity, it only makes up a small percentage of the physical brain. The rest of the pale tissue making up the brain and spinal cord is the white matter. White matter is composed of myelinated axons which connect the gray matter and facilitate the travel of nerve impulses between neurons.

Stein et al. (2012) conducted a study that involved the participation of ten teenage native English speakers ages 16 to 18 who were learning German during an exchange program in Switzerland. While less than half of the participants had very minimal prior exposure to the German language, none of the participants were considered to be proficient in German as an L2. All participants attended a three-week German language intensive course upon arrival in Switzerland, and it was immediately after this period that researchers of this study collected data for their first "day one" measurement, in the form of multiple choice, complete-the-sentence language tests. "Day two" data was collected about five months after the first measurement, using the same test. While this test measured syntactic and semantic skills, a second test was administered also on both day one and two that measured vocabulary. Two versions of this test were created and distributed simultaneously to the participants, with half receiving version one on day one and version two on day two, and the other half receiving the complementary halves on the corresponding days (Stein et al., 2012).

Researchers Stein et al. (2012) were able to measure brain activity using magnetic resonance imaging (MRI) and voxel-based morphometry (VBM). The MRI would capture three-dimensional images that provided sagittal views of the brain activity of each patient. VBM analysis would then use those high-resolution images to monitor changes in the density of gray matter between the two periods of measurement. At the end of the study, researchers found that participants did increase L2 proficiency between Day 1 and Day 2. During language comprehension tasks, they observed higher brain activation in individuals with higher L2 proficiency as opposed to those with lower L2 proficiency. Researchers were then able to draw a correlation between increased L2 proficiency and increased gray matter density. Again, this evidence of the brain being so susceptible to change even after the critical period is telling of its ability to process L2 (Stein et al., 2012).

However, upon considering the uncontrolled environment in which the participants were situated throughout the study, Stein et al. (2012) reconsidered outside factors that may have contributed to the structural changes in the brain. They acknowledged the argument that the simple fact of living for several months in a foreign country may well be a sufficient stimulus leading to heightened brain activity, causing structural changes. The second argument considered the age of the participants and acknowledgement of what is often a transitional period, and cited maturational effects as a potential cause for structural changes as well. The researchers then concluded that exposure to an enriched environment, whether geographically or personally, can contribute in part to the observed changes in gray matter, at least in the left anterior temporal lobe (ATL). In the left anterior frontal gyrus (IFG), however, the explanation of maturational effects does not apply. Previous studies have indicated that the volume of gray matter in the frontal lobes specifically peaks around the age of 11 or 12, which we recognize as the end of the critical period, and constantly declines from there. Therefore, changes in gray matter density in the left IFG can be attributed to an individual's L2 proficiency (Stein et al., 2012).

Martensson et al. (2012) conducted a study of adult L2 acquisition, with specific interest in the increased cortical thickness and volume of the hippocampus. Researchers based their study on the knowledge that adult-acquired sensorimotor skills and concepts change the structure of the brain's gray matter, hypothesizing then that L2 acquisition even in adulthood would increase gray matter volume in areas involved in L1 acquisition. As found in Tagarelli's (2014) study, this hypothesis has proven true. The method used in the Martensson et al. (2012) study, however, involved a group of 14 interpreters and 17 controls, all within the age range of 18 to 20 years old, with similar levels of education. Recruited from the Swedish Armed Forces Intelligence and Security Centre, each of the interpreters had been studying an L2 upon entry into the academy. The languages included Russian, Dari, and Arabic, and none of the interpreters had any previous experience with these languages before their training in the academy. The monolingual control group consisted of medical and cognitive science students from Sweden's Umea University.

Behavioral measures for the Martensson et al. (2012) study included anxiety ratings, proficiency tests, level at which each participant struggled, and MRI data. Before testing, there was no significant difference in the cortical thickness or hippocampal volumes between the interpreter group and control group. The results of this study revealed that the cortical thickness of the individuals in the interpreter group displayed significantly large increases due to their L2 exposure, in comparison to that of the control group, which actually showed small decreases over time. These changes were observed in three regions in only the left hemisphere. Hippocampal volume was also noted to increase significantly for the interpreter group, and these changes, were subtly more pronounced in the right hemisphere rather than the left. Martensson et al. (2012) concluded that L2 acquisition in young adults is bound to result in increased gray matter density and hippocampal plasticity, but caution that results may vary for older adults.

Does age of second language acquisition make a significant impact on the brain?

Researchers Klein, Mok, Chen, and Watkins (2013) conducted a cortical thickness study to explore how an individual's brain structure may be shaped depending on their age of L1 and L2 acquisition. Previous research upon which these researchers had built their study consistently confirm that bilingual language experience leads to unique patterns of brain activity and structure as compared to a monolingual experience (Klein, Mok, Chen, & Watkins, 2013). This study in particular examined individuals who differ in regards to the age at which they acquired an L2, and whether or not that acquisition was simultaneous to their L1 learning, and then compared that data to a group of monolinguals. Because monolinguals and simultaneous bilinguals share the factor of exposure to language early in life, they are aptly compared to one another in contrast to early sequential bilinguals and late sequential bilinguals. In the context of this study, language acquisition in early life is defined as the period from birth to 3 years, while early childhood is defined as 4 to 7 years, and late childhood is defined as 8 to 13 years (Klein, Mok, Chen, & Watkins, 2013).

Of the 88 participants in this study, 66 were bilingual and 22 were monolingual (Klein, Mok, Chen, & Watkins, 2013). At the time of their magnetic resonance imaging (MRI) scans, the participants ranged in age from 18 to 48, averaging around 26 years. Since the participants were recruited from Montreal, all bilinguals were speaking and using English and French in their everyday lives, though they ranged in proficiency and degree of usage. Those variables were accounted for using a short questionnaire to self-rank comfort in writing, speaking, and comprehending the languages. It also inquired details about respective family linguistic background and individual history of language acquisition (Klein, Mok, Chen, & Watkins, 2013).

After collecting MRI data from each participant, the researchers tested for cortical thickness differences across groups, particularly the monolingual group in contrast to the simultaneous, early sequential, and late sequential bilingual groups. The two regions of the brain in which differences were recorded were the left and right IFG. The left IFG was found to be thicker in early and late sequential bilingual groups in comparison to the monolingual group. Interestingly enough, the opposite was found in the right IFG, as the monolingual group showed higher cortical thickness than their bilingual peers in this area (Klein, Mok, Chen, & Watkins, 2013).

Researchers then searched for a correlation between cortical thickness and age of L2 acquisition. They found a positive correlation, noting that left IFG cortical thickness in sequential bilinguals increased the later the L2 was acquired after proficiency in L1. In other words, early and late sequential bilinguals showed more cognitive activity in the left IFG compared to monolinguals and simultaneous bilinguals. This was consistent with the earlier assertion that simultaneous bilinguals would show similar results to monolinguals due to early exposure to the language systems. However, a negative correlation was found in the right IFG. While later L2 acquisition seemed to be an asset in the left IFG, it was a handicap in the right IFG, leading to thinner cortical thickness in the area the later the age of L2 acquisition (Klein, Mok, Chen, & Watkins, 2013).

The results suggested that, due to the inverse correlation of cortical thickness in the left and right IFG with respect to the age of L2 acquisition, there could be a finite period at which an individual's brain activity would be most conducive to L2 acquisition (Klein, Mok, Chen, & Watkins, 2013). For example, if an individual was proficient in L1 by early childhood, and acquired an L2 by the end of late childhood, the individual may have found a period that was late enough after gaining L1 proficiency so as not to cause language delay, but not so late that he or she would have been unable to take advantage of the period of neuroplasticity or growth of cortical thickness. This revelation was consistent with the data from the Martensson et al. (2012) study in which the young adult participants learning an L2 only displayed increased cortical thickness in the left hemisphere. In Klein, Mok, Chen, and Watkins' (2013) study, however, there was not enough data to support an idea of exactly what age period would be most beneficial for L2 acquisition. This was due to having to apply controls on chronological age, language proficiency, and years of L2 exposure due to the widely varying language experiences of each participant in the study. The inverse directions of left and right IFG cortical thickness in this study were found to be consistent with previous studies of bilingual adults (Hull & Vaid, 2007; Klein, Mok, Chen, & Watkins, 2013).

The conclusion of Klein, Mok, Chen, and Watkins' (2013) study went on to cite a meta-analysis by Hull and Vaid (2007) that provided further support to the argument of a critical period for L2. By conducting a meta-analysis of existing literature on bilingual behavior, Hull and Vaid (2007) found that both hemispheres of the brain were involved when utilizing two languages as long as both L1 and L2 were acquired by six years of age. Those with an age of L2 acquisition after six years, however, showed left hemisphere dominance for both languages. This was consistent with the previous study showing higher cortical thickness in the left IFG as time went on, as opposed to the decline in thickness in the right IFG after establishing L1 proficiency (Klein, Mok, Chen, and Watkins, 2013). Hull and Vaid (2007) discussed both the Age and Stage Hypotheses in this analysis.

This study by Hull and Vaid (2007) was met with criticism by Paradis (2008) who published an article outlining his counterargument to the meta-analysis. Paradis (2008) was skeptical of the meta-analysis' lack of validity, and disproved of the fact that Hull and Vaid (2007) did not address the criticisms of bilingual measures of laterality. Based on the methods Hull and Vaid (2007) followed to achieve their study's results, Paradis (2008) was unsure that they could claim to be able to distinguish between groups of bilingual speakers, as "degrees of ear, half visual field, or tapping advantage have not been shown to correspond to differences in degrees of cerebral lateralization" (Paradis, 2008, p. 1588). Paradis (2008) suggested that the sources cited in the meta-analysis evaded correlating the degree of ear advantage to the degree of laterality, and focused more on detection of speech dominance.

A study by Li, Legault, and Litcofsky (2014) examined neuroplasticity in the context of gaining L2, through the brain's anatomical changes as well as its neural patterns. Recognizing that anatomical changes in the brain may occur in the density of gray matter, cortical thickness, and even the integrity of white matter, the researchers performed a review of previous studies that have explored these three key aspects. As previously discussed, gray matter density and cortical thickness are commonly examined for what they may reveal in anatomical brain changes and cortical morphology, respectively. White matter integrity, on the other hand, is found using diffusion tensor imaging (DTI), which measures the diffusion of neural water molecules in order to find a value called fractional anisotropy (FA). Higher FA values, on a scale of 0 to 1, correlate to higher white matter integrity. Along with reviewing the previous literature, Li, Legault, and Litcofsky (2014) aimed to identify the common factors that cause changes in the structure and function of the brain in order to better relate both types of changes to the behavior outcomes of the individual.

Do these changes in activity and structure impact other areas of the bilingual individual's life?

Some researchers in the field focused less on the factor of bilingualism as the primary reason why different patterns of brain activity are found in L2 speakers (Garbin et al., 2010; Tagarelli, 2014). In a study by Garbin et al. (2010), 40 participants from the University Jaume I of Castello de la Plana were separated into two relatively equally-sized groups: Spanish-Catalan bilinguals and Spanish monolinguals. All participants were on average 20 years old. The Spanish-Catalan bilinguals were considered early bilinguals, meaning they had acquired and used their L2 within the first 4 years of life, whether at home or in school, and continued to use both their L1 and L2 with high proficiency throughout young adulthood. What was different about this study compared to previous ones examined in this review was that individuals in the monolingual group reported some experience in an L2 such as English or Catalan, but with very low proficiency, and therefore low use (Garbin et al., 2010).

Another unique feature of the Garbin et al. (2010) study was the method used to gather data from the participants. Instead of the participants engaging in a language-based task, they were prompted to point at certain colors or shapes based on the stimulus. The idea was to measure how well each participant was able to switch from one task to another, and how the quickly the brain could discern whether it needed to find a color, or a shape, or another color afterwards. Participants were scored on accuracy and reaction times.

While not explicitly stated in the Garbin et al. (2010) study, the idea was similar to the task faced by bilinguals in everyday situations, called code-switching (Wilson & Gick, 2014). Code-switching occurs whenever a bilingual individual is using one language system and manner of speaking in one environment (for example, speaking Catalan at home with family), then has to switch to their other language system when speaking with people in a different environment (speaking Spanish in school with professors and classmates). Bilingual speakers, among others, are experts at code-switching because they have learned to communicate with at least two different populations using two different sets of language. From the results in this study, it was evident that the bilingual individuals must have had practice with switching tasks prior to the study (Garbin et al., 2010). Their fMRI results showed that only the left IFG was activated during the switching tasks, as opposed to the right IFG, anterior cingulate cortex, and the left inferior parietal lobe activated in the brains of the monolingual speakers. This apparent difference in brain patterns between the two groups was telling of the difference between how a bilingual brain works in comparison to a monolingual group. The perceived advantage bilingual speakers have in cognitive control revealed itself in the results, as the monolingual speakers had more trouble completing the switching tasks without sacrificing time or accuracy (Garbin et al., 2010).

A study by Szaflarski et al. (2011) explored the advantages of bilateral brain hemisphere activity by comparing left-handed individuals with their right-handed counterparts who matched them in age and gender. All participants were English L1 monolingual children between 5 and 18 years of age. The study based its work on the knowledge that handedness has served, albeit somewhat unreliably, as an indicator of language dominance in the hemispheres of the brain, because of its correlation with lateralization. Language function is typically mapped in the left hemisphere of the brain, and if it is not, it will more often find equal representation throughout both hemispheres than it will find dominance in the right hemisphere (Szaflarski et al., 2011). Despite this, Szaflarski et al. (2011) hypothesized that, when compared to right-handed participants, the left-handed participants would reveal more dominant language patterns across both hemispheres, but especially in the right hemisphere. The researchers then removed the factor of handedness to hypothesize that language lateralization patterns would change with age in all participants. While conducting the study, Szaflarski et al. (2011) controlled for factors such as sex and head size in order to remove their potential influence to skew the results, as these have been known to contribute to lateralization of language. Participants completed tasks in verb generation, and their data was collected using MRI technology. Szaflarski et al. (2011) found that the patterns of language lateralization in left-handed children were atypical compared to those of their right-handed counterparts, which supported their first hypothesis. The left-handed children were actually found to exhibit higher proportions of language function activity in the right hemisphere and bilaterally. Their second hypothesis regarding the effect of age on language lateralization was found to be inconclusive, as it was found that other factors such as the characteristics of language tasks and the modality of task presentation had a stronger impact on lateralization. Nevertheless, this correlation between handedness and language lateralization suggested that the time and manner of acquiring language could have a significant impact on which hemisphere dominates language function (Szaflarski et al., 2011).

A comparative study on the development of working memory in monolingual versus bilingual children was conducted in 2013. Researchers Morales, Calvo, and Bialystok (2013) based their study on the hypothesis that patterns of brain development are modified by cognitively demanding experiences. Bilingualism, which requires constant attentiveness in one language system while remaining alert for symbols of the other system, fosters a neural environment that routinely challenges the brain to perform cognitively demanding tasks. Because of this, Morales, Calvo, and Bialystok (2013) hypothesized that bilingual children have a more highly developed working memory as compared to their monolingual peers, specifically in conditions involving executive control. The weight of this hypothesis, if proven correct, would have an impact on several areas of study surrounding this topic. Because it plays such a large role in various cognitive abilities. working memory is a significant predictor of children's cognitive and academic outcomes.

Morales, Calvo, and Bialystok (2013) conducted this study with 56 kindergarten students at an average age of 5 years; 27 of whom were bilingual and 29 of whom where monolingual. Each student came from a middle-class socioeconomic status with similar levels of education. Participants took three tests as part of the study, which were the English subtest of the *Peabody Picture Vocabulary Test,* the Matrices subtest of the *Kaufmann Brief Intelligence Test*, and a Simon-type picture task. With the participant sample containing so many young children, Morales, Calvo, and Bialystok (2013) wanted to focus on measuring working memory itself rather than language, since monolingual and bilingual students alike would still be gaining proficiency at that age.

Morales, Calvo, and Bialystok (2013) found that the bilingual students outperformed monolinguals overall, as they were recorded to not only respond more quickly, but more accurately throughout the tests as well. This clear advantage in the area of executive functioning in bilingual individuals confirmed the study's hypothesis.

Relevance in Speech-Language Pathology

Issues in Referral

Studies of bilingualism in children have yielded disparate conclusions as to whether L2 acquisition at an early age is beneficial for cognitive development, or may even pose a hindrance to lexical acquisition (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009). Increased brain activity in the bilingual brain has been found to lead to advantages such as delayed onset of dementia, improved performance in divergent thinking, greater ease in filtering vocabulary, and more, when compared to monolinguals (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009). Another advantage was that when bilingual speakers would hear a word in one language, they would activate both lexicons to come up with the word for the same item in their other language (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009; Bialystok, 2011). The automaticity of this process in bilinguals contributed to their potential for higher cognitive function. This was also what led to bilingual adults being more easily able to learn new words as opposed to monolingual adults (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009).

The proposed benefits of bilingualism by Bialystok (2011) and Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, and Sheng (2009) provide encouragement for individuals aiming to acquire an L2 on an elective basis. Among the diverse population a speech-language pathologist will work with, however, many bilingual students will have acquired an L2 on a circumstantial basis (Mahendra & Namazi, 2014). Circumstantial bilinguals, having grown up in families where English is the L2, would have acquired their L1 and L2 simultaneously. Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, and Sheng (2009) reported that this kind of exposure to two languages from an early age left children vulnerable to confusion and language delay.

While bilingual children, whether elective or circumstantial, have the advantage of understanding that a single concept can be addressed by more than one label, this cognitive ability is not always celebrated and reinforced in traditional public school classrooms in the United States. Depending on the student's L1 and L2, and the language of their institution, they may appear to function at a lower linguistic or cognitive level even if it is not the case. Because an individual's vocabulary is measured not by how many words one knows across languages, but by how many conceptual representations one has attached to a lexical label, bilingual children may not have an opportunity to efficiently showcase their learning (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009). If a bilingual child's progress is measured in only one language, even if it is the language in which they are most proficient, this measurement does not provide an accurate representation of his or her linguistic or cognitive development (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009). This puts the child at risk for diagnosis of a language impairment they may not have, causing misdirection of the resources and time of all parties involved. As speech-language pathologists, it is important to recognize this discrepancy in order to provide the most appropriate level of support for a client.

Issues in Identification

Gibson, Peña, and Bedore (2014) conducted a study comparing the receptive and expressive language gap in bilingual children with and without primary language impairment (PLI). This study was comprised of 37 Spanish-English bilingual children between the ages of 7 and 10 years old. Gibson, Peña, and Bedore (2014) began by acknowledging the receptive-expressive gap that may already exist in typically developing (TD) bilingual children, as previously discussed, due to the constant juggling of two lexical systems. However, this receptive-expressive gap also occurs in children who are monolingual and are diagnosed with PLI. Gibson, Peña, and Bedore (2014) then set out to explore how the factors of bilingualism, monolingualism, PLI, and TD influenced the receptive-expressive gap in children.

Results of the study showed that bilingual children with PLI had a larger receptive-expressive gap compared to bilingual children with TD, but only in their L2 which was English, and not in their L1 Spanish (Gibson, Peña, & Bedore 2014). This is significant because it conveys how the advantages of bilingualism can combat the issues presented by PLI. Clinicians are therefore advised to learn more about the receptive-expressive language gap, and to even expect it when working with bilingual students. This knowledge can help to prevent misdiagnoses of PLI.

According to the National Center for Education Statistics, Spanish-speaking families are among the fastest-growing group of English-language learners, or ELLs (as cited in Wood & Peña, 2015). Wood and Peña (2015) used this knowledge to examine the factors playing into errors made by Spanish-English-speaking children on the *Peabody Picture Vocabulary Test—4th edition (PPVT-IV)*. Wood and Peña (2015) hypothesized that the following three factors could render the test ineffective for students of such diverse populations: interplay between languages, cultural and linguistic (test content) bias, and uneven distribution of difficulty. The interplay between languages refers to a bilingual child's tendency to call upon both lexicons for his or her L1 and L2, when only one is needed. This dual-activation process may affect a bilingual student's lexical performance, but does not necessarily reflect his or her cognitive or linguistic abilities (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009; Wood & Peña, 2015). The cultural and linguistic bias refers to test content reflecting an assumption that all individuals responding to the standardized test will have been exposed to the same concepts, vocabulary, or life experiences (as cited by Wood & Peña, 2015). For example, Wood and Peña (2015) cited the findings of Bialystok et al. (2012), which revealed that bilingual speakers scored consistently lower than monolingual speakers on similar items pertaining to the food and home category. The final factor, uneven distribution of difficulty, stems from the fact that items on standardized tests such as the *PPVT-IV* are organized in a manner that progresses from the least to the most difficult. Depending on how a bilingual speaker attains English as their L2, however, their standards of "least" and "most" difficult will not likely mirror those of a monolingual speaker (Wood & Peña, 2015).

To account for this discrepancy in assessing whether a bilingual child may have specific language impairment (SLI) or cognitive impairment, organizations such as the American Speech-Hearing Language Association have released testing materials for bilingual assessment. The idea is that if practitioners are able to assess a student in both their L1 and L2, we will be able to see a full picture of the child's academic abilities (Paradis, 2014). As effective as this method may be, it is not easily accessible for all populations. Bilingual assessment would require administration by a bilingually-trained speech-language pathologist or para-professional personnel, which are not easily found in every school district. Additionally, with the variety of languages in which a student could be bilingual, it would not be feasible for every school district to have the testing materials and resources available in every language (Paradis, 2014). In a presentation given by Paradis (2014), she outlined research done in her lab between students who are English-language learners (ELL) and those with SLI. Based on this research, Paradis (2014) and her colleagues developed resources specifically for the effective testing of ELL children, emphasizing the importance of unbiased measurement, and of collecting information on a student's family's language history through parent questionnaires.

Muñoz, White, and Horton-Ikard (2014) echoed the necessity of assessing bilingual students in a way that is unbiased and differs from the assessment of monolingual students due to needing different standards and levels of support. Otherwise, speech-language pathologists risk misdiagnosing students with SLI, or not diagnosing students who may have SLI and also happen to be bilingual. Clinicians are expected to be able to differentiate between a language disorder, a language delay, and a language difficulty. To do this, Muñoz, White, and Horton-Ikard (2014) described a six-step process for speech-language pathologists to follow, from using the pre-referral process to understanding the effects of second-language instruction models on language development. The first step, use of the pre-referral process, acts as the first line of defense when it comes to identifying a student's condition and need. The next two steps are reminders to "view speech-language development as a complex and dynamic process," and to "understand the social-cultural factors that may influence a child's development" (Muñoz, White, & Horton-Ikard, 2014, p. 4). Both steps encourage the clinician to bear in mind that the process of diagnosis and treatment is holistic and unique to each respective student. The fourth step is to have and apply knowledge of federal and state laws as they mandate assessment, particularly standardized testing. Once this is done, the fifth step is to identify and remediate sources of assessment bias where possible. By modifying biased assessment procedures that otherwise find unfair fault with students of diverse backgrounds, clinicians can balance the scale in order to accurately measure each student's level of ability. The sixth step, understanding not only the models of L2 instruction, but their effects on language development, places responsibility on speech-language pathologists to consider cultural and geographic factors playing into how a child acquires their L2 respective to other children (Muñoz, White, & Horton-Ikard, 2014).

Dynamic assessment is a form of assessment employing a test-teach-retest approach, and is designed to gather valid and unbiased data on what a particular child is capable of learning and accomplishing (Gorman, 2015). Gorman (2015) published an article exploring how speech-language pathologists could learn to confidently apply dynamic assessment to bilingual students in particular. As discussed in a previous study by Muñoz, White, and Horton-Ikard (2014), Gorman (2015) emphasized the necessity of the pre-referral and referral periods in appropriately selecting and targeting a student's area(s) of need. In the conclusion of the study, it was found that "children who respond well to mediated learning experiences are not likely to have true language impairments, while those who demonstrate difficulty learning and low modifiability are likely to be those with true language impairments" (Gorman, 2015, p. 119). This important distinction sheds light on what speech-language pathologists can expect to look for when tasked with diagnosing and treating a student who may appear to straddle the line between ELL and SLI.

While multidimensional assessment will help a speech-language pathologist more accurately differentiate between a child who is an ELL and a child who has an SLI, researchers are also finding key similarities and differences between the neuroanatomies of the two populations (Girbau-Massana, García-Martí, Marti-Bonmati, & Schwartz, 2014). Girbau-Massana, García-Martí, Martí-Bonmati, and Schwartz, R. G. (2014) used VBM to find that children with SLI revealed more right-lateralized language activity as well as increased gray matter in the right hemisphere as compared to their typically developing counterparts. Children with SLI also showed a lower cortical thickness in four separate regions of the brain (Girbau-Massana, Garcia-Marti, Marti-Bonmati, & Schwartz, 2014). These structural and functional changes differ from what previous studies in this review had revealed about the brain activity of bilingual speakers. As neuroimaging technology and research continues to develop, newfound knowledge can only enhance the approaches of speech-language pathologists in treating such diverse populations.

Discussion

Overall, the research found in the process of preparing this review supports the idea of a hypothetical critical period both for L1 and L2 acquisition. While these periods overlap, they would not necessarily be concurrent. If it is to be assumed that L1 is acquired by the age of three, then there are various possibilities for the acquisition of L2 depending on which factors are deemed most important. The age of L2 acquisition has been found to impact different aspects of cognitive development based on when it occurs on the timeline of a person's overall development.

If L1 and L2 are acquired simultaneously, then the brain activity for this bilingual individual ends up to be similar to that of a monolingual individual (Klein, Mok, Chen, & Watkins, 2013). Moreover, that individual is thought to be at more of a risk for language delay or difficulty due to simultaneous management of two separate lexical systems (Klein, Mok, Chen, & Watkins, 2013; Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009).

If an L2 is acquired by the end of early childhood, which was defined earlier as six to seven years old, then the individual has reached a point at which cortical thickness in both the left and right IFG align (Klein, Mok, Chen, & Watkins, 2013). This point is considered to be conducive to language learning because greater cortical thickness is associated with higher cognitive ability. L2 acquisition at this point would lead to more symmetrical lateralization throughout both hemispheres when using language. After this point, cortical thickness in the right IFG begins to decline. L2 acquisition after this age has been found to show dominance in only the left hemisphere of the brain (Hull & Vaid, 2007). While this decline in cortical thickness does not necessarily correlate to increased difficulty in acquiring an L2, it does signify that the point of peak involvement of both the left and right hemispheres has passed (Hull & Vaid, 2007).

If an L2 is acquired past the age of seven or into adulthood, it has been found that high proficiency is still attainable. Disadvantages of this later timeframe include increased difficulty during L2 acquisition, as well as the lateralization of language activity to the left hemisphere only, which may inhibit potential for developing equally lateralized brain patterns. However, MRI data from Tagarelli's (2014) study showed that the adult brain activates some new regions during L2 acquisition different from those (as well as in addition to those) activated during L1. This suggested that the brain maintains a level of neuroplasticity in order to adapt to new information even after the period of peak neuroplasticity ending at puberty. Adult L2 acquisition may even be considered an asset over simultaneous bilingualism, because these individuals will not have to endure the possibility of language confusion in their L1 (Marian, Faroqi-Shah, Kaushanskaya, Blumenfeld, & Sheng, 2009; Klein, Mok, Chen, & Watkins, 2013). Since the L1 has already been developed in an in-depth manner by adulthood, the individual would be able to focus more energy on the L2. While there is still a possibility of achieving proficiency at this later stage, depending on how much effort is put into doing so, a disadvantage may be that the adult-acquired L2 may never reach a state of proficiency that is near nativeness.

When it comes to identifying bilingual students with language impairments, neuroimaging data helps speech-language pathologists to see how certain activities trigger the brain (Girbau-Massana, García-Martí, Marti-Bonmati, & Schwartz, 2014). While this knowledge plays into how treatment methods can improve in the future, there are strategies for speech-language pathologists to be vigilant in assessing bilingual students at risk for language impairment. Dynamic assessment, for example, allows speech-language pathologists to compare students to their own accomplishments, instead of the norms set by their monolingual peers (Gorman, 2015). While there may be certain implications or added benefits depending on the time or circumstance, bilingualism at any age has been shown to improve cognitive control in comparison to monolingualism (Bialystok, 2011). The speech-language pathologist bears the responsibility of supporting each student and helping each one to reach that linguistic and cognitive potential.

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