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Article 1

The Bilingual Brain

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Abstract

This literature review explores the neurocognitive effects of the bilingual brain. Many areas of bilingualism are examined such as age of acquisition, which is when the second language is attained, and memory. The three types of bilingual memory are implicit memory, which is procedural memory, explicit memory, which is declarative memory, and episodic memory, which is autobiographical memory. In relation to the bilingual brain, cognition, control, and /lateralization are also reviewed. Finally, second language (L2) learning strategies are considered. The objective of this study is to obtain an understanding on how two or more languages are acquired and processed in the brain from a biological and psychological perspective by examining age of acquisition, memory, cognition, and lateralization.

Keywords: bilingual, memory, language, neuroscience

The Bilingual Brain

How is one classified as bilingual? A bilingual person is someone who can use two languages fluently. Arguably, the term bilingualism is a relative term which is why proficiency tests are utilized to examine the relative amount of knowledge one has of a second language.

Throughout this paper, many areas of bilingualism are examined. Bilingualism is multifaceted with several subtopics such as age of acquisition, memory, cognition, control, lateralization, and language learning strategies.

The most basic and possibly most important factor in bilingualism is age of acquisition, which is simply defined as a time when one attains a piece or pieces of information. The age of acquisition of a second language effects many areas of the brain as well as proficiency in grammar and communication. As the brain ages, changes occur. Therefore, there are critical periods in which learning information, language specifically, occurs.

Critical Periods

Bilingual language representations are driven by the time in which a language is learned. Ribot (1881) deemed this as a natural extension of the organization of memory. Ribot discovered that when patients had difficulty finding words, they would show the same order of loss: proper names, common nouns, adjectives, verbs, interjections, and finally gestures. In Ribot's (1881) study, patients would forget their most recent memories and their earliest memories last. The new, complex, and least organized memories would falter before the old, simplistic, automatic memories from childhood. Ribot (1881) suggests that the age of acquisition played a profound role in the formation of memories (as cited in Hernandez, 2013).

Over 100 years later Newport and Johnson (1989) researched the critical periods in second language acquisition. A group of Korean-English bilinguals, who immigrated to America between the ages of 3-39, were studied. Half of the subjects arrived before the age of 15 whereas the other half arrived after the age of 17. These subjects were given sets of sentences and were asked to deem the sentence grammatically correct. The results showed that the early learners (ages 3-7) and monolinguals scored 269 out of 276, those who arrived between the ages of 8-10 scored 256, those who arrived between 11-15 scored 236, those who learned between 17-39 scored 210 out of 276 (Johnson & Newport, 1989). This data indicated a clear age of acquisition effect. The group of early learners did not show differences in score when compared to native speakers. However, the scores drop after the age of seven dramatically. Newport and Johnson (1989) concluded that the critical period for language acquisition is from birth to age seven.

Further tests on determining the critical periods for learning a second language occurred when Karl Kim, Relkin, Lee and Hirsch (1997) tested the brain bases in bilinguals by using fMRI scans. Kim et al. (1997) asked two cohorts, early bilinguals and late bilinguals, to say in their head what they did the day before after a cue that was given (morning, afternoon, evening) and in a particular language (first or second). The Broca's area and Wernicke's area were observed to examine whether the neural activity of each language revealed two distinct areas of activity or just one area of usage. In Wernicke's area, an overlapping of activity in all people, early and late learners, was observed (Kim et al., 1997). Unlike the Wernicke's area, the Broca's area showed distinct differences in early and late learners of a second language. Early bilinguals showed two overlapping areas in the Broca's area of the two languages. In the late bilinguals, the

Broca's area showed two distinct, adjacent separate areas of activity (Kim et al., 1997). The results suggest that both early and late bilinguals use neural systems that are overlapping in areas devoted to comprehension (Wernicke's area), but in areas devoted to language production (Broca's are), late bilinguals use separate areas for each language. The Broca's area may be an indicator of the specialization in learning new memories of language at a younger age (Kim et al., 1997).

Not only does the age play a role in learning a new language, the acquisition context plays a valuable role. An example of acquisition context would be if the second language was obtained in the same or different cultural settings. The more the two language acquisitions differ, the more likely the two languages will be stored independently (Macnamara, 1967). A compound storage would be developed in which both languages are learned in the same context, such as a bilingual household. With a compound storage system, two word labels code the same meaning. An example of this would be a Spanish/English child learning the meaning of the word "love". They would arrive at the conclusion that "love" and "amor" are interchangeable. Thus, explaining the love he or she feels about soccer would be described in the same way: "I love soccer" vs. "Yo amo fútbol" (Heredia and Brown, 2013). This translation appears as though it would be correct. He or she loves soccer. However, in the English language, the word "love" is semantically unconstrained; all things can be loved. However, in the Spanish language, "amor" is constrained to animate objects and more specifically, human beings (Heredia and Brown, 2013).

L2 Brain Structures Across Ages

Over time, many things in the body age and go through attrition. Bone density, muscle mass, eye sight, the elasticity of tendons, and metabolism decreases when a person ages. Similar to many other structures in the body, the brain also changes. Between the ages of 20-90, there is a 5-10% loss of brain weight. Specifically, the temporal lobe stays relatively stable up until the 60s where then it becomes flattened. The prefrontal cortex in the frontal lobe shows a rapid decrease in volume after the age of 20 and accelerates even more after the age of 60 (Hernandez, 2013).

It has been shown that the rate of brain maturation influences the extent of language acquisition. The brain has achieved 90% of its adult maturity markers by six years of age (Fabbaro, 2001). Therefore, if second language acquisition occurs after six years of age, then it is less likely to be influenced by brain maturation factors. It has been suggested that early bilinguals acquire their second language informally just like their first language (Fabbaro, 2001). The second language in early bilinguals is represented in subcortical structures, the basal ganglia and the cerebellum. Late second language learning is represented in a wider representation in the cerebral cortex (Fabbro, 2001). A fMRI study demonstrated that late bilinguals have a spatially separate area of L1 and L2 in the Broca's area, but not in the Wernicke's area. The early bilinguals have shared neural substrates for both the Broca's and Wernicke's area (Kim et al., 1997).

Communication

Speech is a very important part of communication. It is used daily in formal and informal contexts. Speech is best learned without much conscious intention and at a young age. However, many people do not learn their second language in childhood.

Archila-Suerte, Zevin, Bunta and Hernandez (2012) sought to determine if age of acquisition and proficiency of the processing of speech sounds were correlated. Archilia-Suerte et al. (2012) presented monolinguals, early learners, and late bilinguals with pairs of sounds that had the same (saf and saf) and different (saf and sef) vowel sounds. The results concluded that monolinguals and high proficient early learners paired the clusters in four different groups that the sound could be associated with (saf, sef, sof, and suf). However, late learners and low proficient monolinguals produced more varied results (Archila-Suerte, et al., 2012). This study concluded that proficiency was not associated with the tightness of clusters and that late learners do not have speech sound categories that are formed in childhood unlike monolinguals and early learners.

Memory

The age of acquisition effects more than just brain structures; it effects memory. Memory plays a very important role when learning languages. In the field of biopsychology, memory is explained with three subunits: working memory, short-term memory, and long-term memory. Cognitive psychologists theorize memory which includes encoding, storage, and retrieval. Encoding is the process of transducing physical stimuli into cognitive structures. Storage maintains the memory traces over time, via processes such as rehearsal. Retrieval is accessing the stored memory for present usage (Heredia and Altarriba, 2014). The three types of memory explained in this article are implicit memory (procedural), explicit memory (semantic memory), and episodic memory (autobiographical memory).

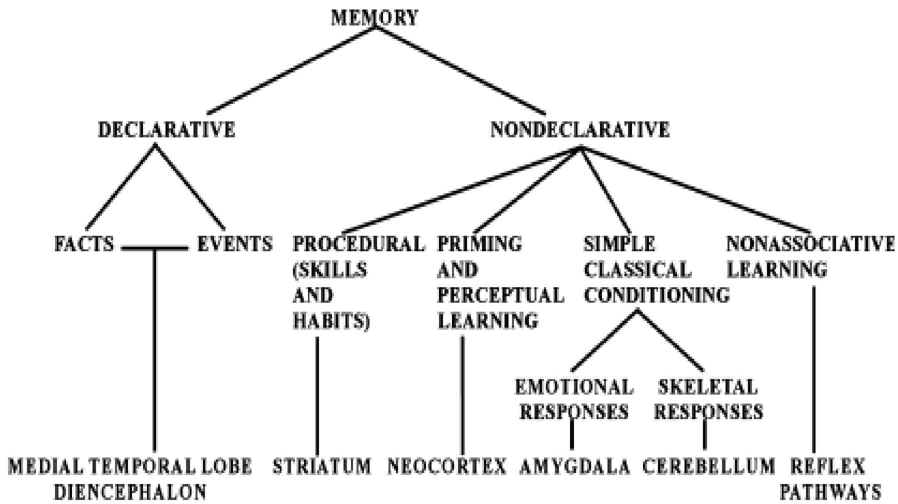
Implicit Memory

The native language is encoded by implicit memory (procedural) so that the first language is automatic; thus it does not require conscious control. Many parts of the prefrontal cortex are critical for procedural memory, which is a part of the long-term memory responsible for motor skills (Squire and Zola, 1996). Examples of procedural memory would be remembering how to drive a car, find your way to class, or tie your shoes. The areas of the brain involved in procedural memory would be portions of the frontal cortex including the Broca's area and the supplementary motor area (Squire and Zola, 1996). The second language is usually learned formally and is hypothesized to be encoded in the explicit or declarative system.

Explicit Memory

The explicit system indicates that usage of language is conscious and is represented by facts in a semantic form and events stored in an episodic form (Norman, 2002). Declarative memory is usually stored in the medial temporal lobe and the cortical areas adjacent to the hippocampus. The ability to retrieve declarative memories is performed in the anterior prefrontal cortex. When one searches for a word or saying in their second language, the right cerebellum is involved (Norman, 2002). Explicit memory is controlled by short-term memory being encoded to long-term memory.

Short-term memory is highly prone to deterioration over the course of only a few minutes. It has a small capacity of storage of information. Carlson (2004) hypothesizes that the prefrontal cortex plays a role in determining the amount of time the information remains in memory. Unlike the short-term memory, long-term memory stores information more permanently and has a limitless storage capacity. Usually, as a short-term memory becomes consolidated, it transforms from a short-term memory to a long-term memory. Carlson (2004) further hypothesizes that the hippocampus plays a major role in the consolidation process. All in all, retrieval of a long-term memory is dependent on how the memory was encoded.



(Squire and Knowlton, 1994)

Episodic Memory

The first step in encoding a memory of an event is placing one's attention to the various aspects of the occurrence while it occurs. For example, if one is driving and his or her visual and cognitive attention is focused on something other than the road (texting a friend, putting on makeup, etc.) a recording of a car accident would not be encoded well. However, if one is focused and all attention is devoted to the event, the various components of the event are hyper-focused and can be encoded well. That encoding is then transformed to a mental representation that can be stored further as a memory (Heredia and Altarriba, 2014).

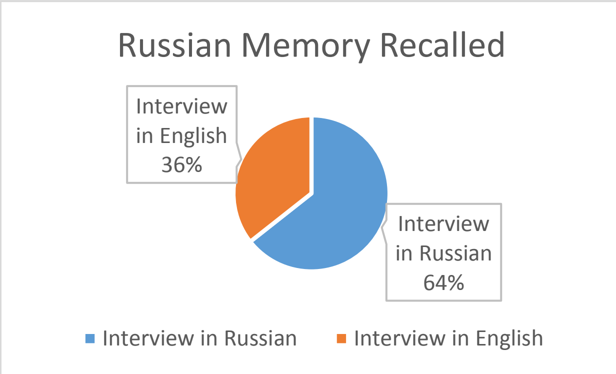
Sensory and perceptual information can help encode events as well. This information can be auditory, visual, gustatory, haptic, as well as olfactory. To continue the example of the car crash, a person can hear the screeching of the tires and the yelling of bystanders. They can smell the burnt rubber on the ground. They can see the person's face to be able to further recognize at a later time (Heredia and Altarriba, 2014). These various sensory and perceptual stimuli are processed in similar ways. They are processed in the frontal lobe, which controls the executive functioning process involved in encoding (Blumenfeld and Ranganath, 2007). Specifically, these stimuli vary in location within the brain. The temporal lobes are primarily devoted to the auditory input. The occipital lobes are devoted to the visual input. The linguistic side of encoding the event would be primarily in the left hemisphere and the non-linguistic information would be located in the right hemisphere (Kelley et al., 1998). The hippocampus further processed the information and is very important in episodic memory formation. The case study of Henry Molaison, whose medial temporal lobe was removed, illustrates this notion (Squire, 1992).

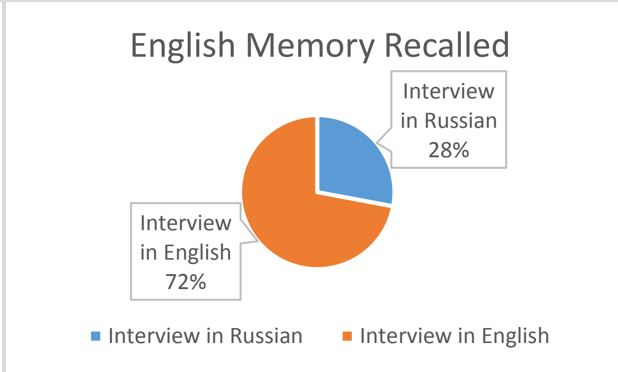
After Molaison's brain surgery, he was unable to attain new episodic memories, which is called anterograde amnesia. Squire (1992) hypothesizes that the hippocampus plays an important role of binding all the aspects of an event into a single intergraded memory. Not only does the hippocampus combine auditory, visual, and all sensory stimuli into one single event, it also plays a role in memory retrieval after encoding (Squire, 1992). After Henry Molaison's brain surgery, he experienced retrograde amnesia, difficulty recalling events that were held previous to the surgery. This type of amnesia holds memories that were encoded during childhood, but memories that were encoded a few years prior to the surgery were impaired (Heredia and Altarriba, 2014). Since he experienced retrograde amnesia, this suggests that episodic memory relied on the hippocampus for an extended period of time after encoding and eventually the memory becomes independent of the hippocampus (Alvarez and Squire, 1994).

Once the memory becomes independent of the hippocampus, the episodic retrieval depends largely on cues that are present at the time. Context-dependent memory is a process where the cues trigger memory retrieval for the event (Heredia and Altarriba, 2014). These are the factors that coincide with the event such as the mood of a person, the smells of the area, and even the noises of the scene. These factors then become cues for the event. Studies have shown that the language used at the time of an event becomes a strong cue for the memory. Thus when one of the two languages of a bilingual is used at retrieval, the memories accessed are the memories encoded in that linguistic context (Heredia and Altarriba, 2014).

Marian and Neisser's study (2000) tested this notion. Marian and Neisser (2000) prompted Russian-English bilinguals with cue words ranging from "friend", "birthday", and "frightening." From these cue words, they were given the task to report their first memory that came to mind. The results of this study showed that when the interview was completely conducted in Russian, the majority of the memories retrieved were taken place when Russian was primarily used. Similarly, when the interview was completely conducted in English, the memories that were recalled were encoded when there was an English-speaking context being used (Marian and Neisser, 2000).

A follow-up experiment sought to determine if the language of a cue word prompted a memory retrieval of that language even if the interview was conducted in the other language. The experimenter gave instructions in Russian and the participant responded in Russian, but the cue word was either Russian or English. The results of this follow up study indicated that the language of instructions and communication between participant and experimenter held a stronger connection to the memory rather than the cue word given. The general linguistic ambience at retrieval guided the participant to retrieve a memory during the same linguistic context. The participants recalled Russian-context memories whether the cue word was in Russian or English (Marian and Neisser, 2000).





Cognition

Cognition is largely due to the size of the prefrontal cortex, which is the anterior portion of the frontal lobe. The fissure that separates the frontal lobe and the parietal lobe is the central sulcus. The further away from the central sulcus, the more complex the motor processing becomes. The premotor areas that are directly in front of the motor strip are involved in planning movement. The motor planning involved in language processing is in the Broca's area (Hernandez, 2013).

The human brain is composed of one fourth of the prefrontal cortex. This large area of the brain is involved in planning complex cognitive behavior, personality expression, decision making, and moderating social behavior. The two areas in the prefrontal cortex that are larger in humans than in other higher primates are the ventromedial portion and the dorsolateral portion (Hernandez, 2013). The ventromedial cortex is involved in object perception and in regulation of internal states by the use of the limbic system. The ventromedial cortex connects to the inferior posterior temporal regions. The ventromedial cortex also is crucial for social reasoning. This region is used to interpersonally evaluate one's own thoughts and feelings as well as inferring what others are thinking and feeling (Hernandez, 2013).

Control and Lateralization

Hernandez (2013) explains Jersild's 1927 study, Mental Set and Shift concerning how neural activity is involved in language switching. This study expounds on the notion that switching from one rule to another rule involves both the frontal and parietal lobes of the brain (as cited in Hernandez, 2013). The need to control is invoked. One must then make an adjustment to ignore one of the two stimuli. An example of control causing an adjustment would be switching languages while talking with a grandparent while talking to a friend. The control of choosing the language causes an adjustment in action.

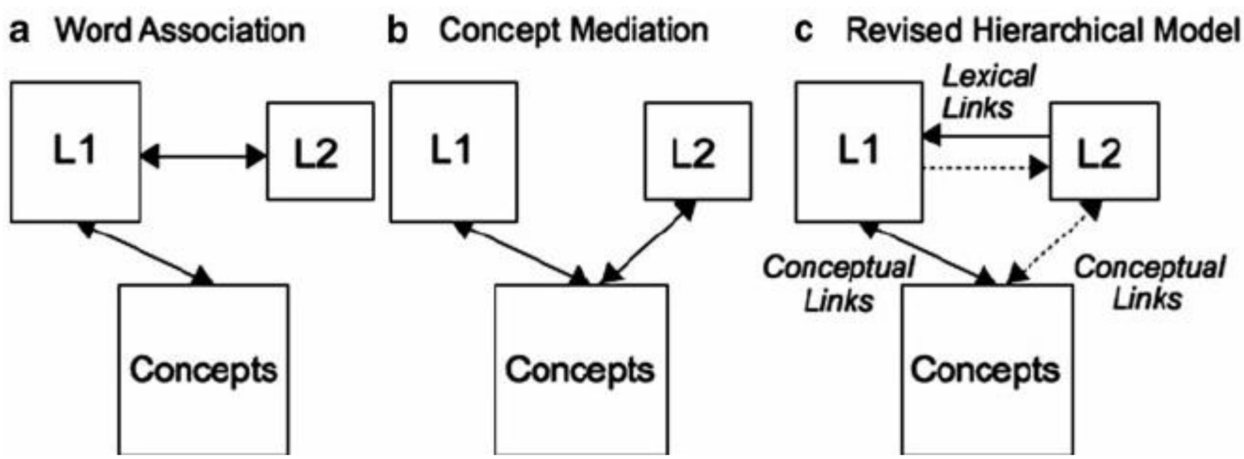
Sussman, Franklin, and Simon (1982) compared 40 bilinguals to a group of English-speaking monolinguals to test the lateralization of languages across hemispheres. The findings in the study suggest that bilinguals' lateralization was dependent on the age in which the second language was acquired. Early bilinguals that had a strong concurrent acquisition for both languages had weaker lateralization for their first language. Late bilinguals, who learned the second language after a strong proficiency in their first language, showed more symmetry in language representation implicating equal involvement of both dominate and non-dominate hemispheres in language function (Sussman et al., 1982). This study explains that early bilinguals showed less lateralization between the left and right hemispheres causing less involvement of the brain to process language. The late bilinguals recruit other areas in the brain by lateralization across hemispheres to be able to process their second language.

Cieslicka and Heredia (2011) further explored the idea that different factors of language may activate and cause lateralization in the bilingual brain. The results of their experiment showed that literal and figurative components of language have different effects on the brain. For the first language, figurative meanings are more prominent and always activated the right hemisphere and literal meanings of sayings or slang activated the left hemisphere (Cieslicka and Heredia, 2011). This suggests that the right hemisphere controls the automatic processing when interpreting figurative meanings of idioms in the first and second language. The left hemisphere is more involved when one deriving a controlled literal meaning for the idioms.

The research shows that over the past decades, theories have shifted concerning lateralization in the bilingual brain. The shared hypothesis holds the belief that both languages are located and shared in the dominate hemisphere of a bilingual brain (Heredia and Altarriba, 2014). However, since then, the age in which the second language was learned plays a larger role in lateralization of the two languages across hemispheres. The latest research from Cieslicka and Heredia (2011) showed that factors such as salience of literal and figurative language affects the lateralization of the brain. Overall, these studies have shown that both hemispheres are involved to a varying degree depending on the various factors involved such as age of acquisition.

L1 and L2 Lexicons

Learning a new language later in life takes a set of already existing skills and then refiguring them into a new set of skills. Since each language is a separate entity, a disjointed nature of language processing occurs. Researchers have concluded that bilinguals have a singular set of concepts that both languages draw vocabulary from to use in conversation and put in practice (Altarriba, 1992). The concepts that each language are built on and depend on the same world knowledge. Even though both languages rely on the same world knowledge, bilinguals show differences in linking concepts together in each language. The variable that connects the concept to the words is proficiency.



Retrieved from https://www.researchgate.net/figure/283569070_fig6_Fig-6-Three-hierarchical-models-of-bilingual-memory-representation-where-L1-and-L2

Kroll and Stewart (1994) adapted a three hierarchical model of bilingual memory representation. In this model, L1 and L2, lexicons represent the lexical level and the concepts represent the conceptual level. In figure a, word association is portrayed. Here the bilingual's L2 lexicon is subordinate to the L1 lexicon, the mental dictionary for the first language. There is no access from the L2 lexicon to the concept storage, unless the L2 is translated into L1 first. This model represents those who are at an early stage of L2 learning, where the second language is parasitic on the first. An example of this is how many second language learners report that they need to translate the second language to the first language in order to fully understand the word.

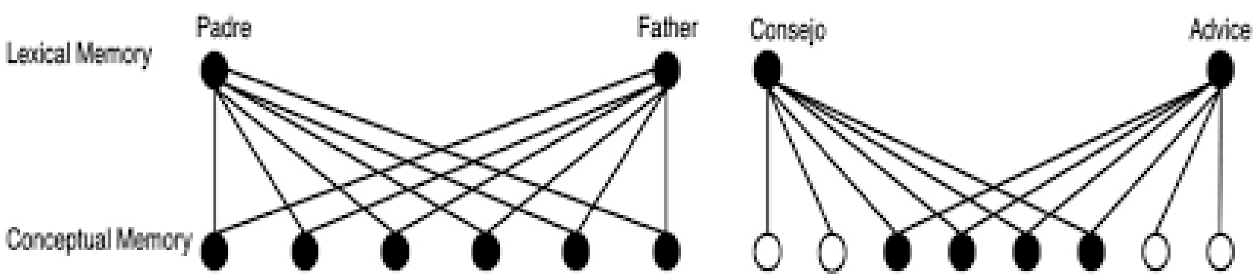
In figure b, concept mediation, the two lexicons, L1 and L2 are independently linked to the concept storage. Here the words in each of the bilingual's two languages are directly linked with a shared concept storage that is common to both languages. This model represents bilinguals with a high L2 proficiency.

Finally, the revised hierarchical model, figure c, represents a cognitive view in which the bilingual's lexicons are bi-directionally linked. The lexical link between L2 and L1 is solid representing a stronger relationship than the L1 to L2 link, which is depicted by the dashed line. The L1 link to the concept storage is strong and represented with a solid line, while the L2 link to the concept storage is relatively weak, being depicted with a dashed line (Kroll and Stewart, 1994).

The Distributed Feature Model

The Distributed Feature Model (DFM) is a widely cited model of bilingual memory representation. This model takes in account processing differences between languages. In this model, there are two types of words: concrete and abstract (Heredia and Altarriba, 2014). The concrete words are words that are easy to form an image. Concrete words are also nouns that can be experienced through one's senses, with a nature of being specific and tangible. They also provide a specific meaning (Abstract v Concrete). Some examples of concrete word phrases are "a large cup of coffee" and "32 degrees Celsius." Concrete words are much faster to be translated than abstract words. Abstract words are unclear, indefinite, and insufficiently factual. Abstract words are known through abstract concept formation. Some examples of abstract words would be honor, truth, love, and grace. Abstract words are rated low in concreteness and are difficult to form an image for the corresponding word (Abstract v Concrete). Concrete translation equivalents have much more semantic similarity compared to abstract words (Heredia and Altarriba, 2014).

Concrete words share more conceptual nodes compared to abstract words (de Groot, 1992). The figure below portrays the concrete word father (padre) and the abstract word advice (consejo). The concrete word, father (padre), has more shared conceptual nodes since it is objective. The abstract word, advice (consejo), shares less conceptual nodes since it is more subjective to the person. There is a greater overlap between “father” and “padre” than “advice” and “consejo”. An increase of semantic overlap between the concrete words has a direct impact on spreading activation which causes faster translation (de Groot, 1992).



(de Groot, 1992)

Learning Theories

Learning a language takes time and effort. Jared Linck, Karen Sunderman, and Judith Kroll (2009) worked and studied bilingual cognitive mechanisms to explore the optimal way to learn a second language. They compared two cohorts of adult second language learners. The first cohort learned in a classroom setting, the second group learned abroad and was tested abroad. Both groups were tested in their second language knowledge and the amount of time they had studied the language. There was no difference between the two cohorts of quality language exposure. The cohorts were tested on a sets of words that were and were not related to each other. Furthermore, they were given a category cue and were asked to give as many examples from that category. The results showed that those immersed in Spanish produced more items in Spanish and less items in English than the classroom learners (Linck et al., 2009).

Moreover, immersion strengthens language connections. Kroll and Stewart's model (1994) expresses that the two languages' word storage and concept storage connection becomes stronger when one is immersed in the language and uses the language for tangible, concrete things and ideas. The connections between the two languages tend to dampen, while the connection from the concept storage strengthens with the second language (Kroll and Stewart, 1994).

Practice

Does language require training? Does practice really make perfect? The trait of a language expert is measured by the amount of time spent on learning new material. Ericsson, Krampe, and Tesch-Romer (1993) estimate that expertise in any skill arises after approximately 10,000 hours of practice. The most important factor of improvement in an area is a person that engages in deliberate practice of the area. Ericsson et al. (1993) also argue that feedback is an essential component for those who wish to continually improve. Another crucial aspect of learning a new language is that in practice one must set a goal. Once the goal is set, feedback should be given about whether the goal is reached or not. For an example, surgeons improve with practice and age. Surgeons must make adjustments when something goes wrong during surgery. This constant feedback and the feedback after surgery helps develop surgeons into better surgeons with practice and time (Ericsson et al., 1993).

One main factor that has been linked to language development is the amount of speech that is directed at the child. Children from different cultures, countries, and classes receive different types of linguistic input. For example, in the United States it is common to change the tonal inflection when speaking to an infant. These modifications help an infant understand and comprehend each word separately. When children are not spoken to directly, they tend to memorize larger chunks of speech. Since these larger word phrases are not word passed, they are more fragmented and less analytical (Hernandez, 2013).

Furthermore, social economic status (SES) is a main factor within cultures that affects language environment. The amount of speech varies between various families in different social economic statuses. Hart and Risley (1995) conducted an analytical and quantitative study on social economic status on families. They collected samples of conversations inside homes in three different SES with a child under the age of 2. The social economic status was low SES (on public assistance), mid-SES (working class), and high SES (professionals). The results displayed a great difference in the number of words heard in each household. The highest word count was at 215,000 words and was in the high SES, the next was 125,000 words which was in the mid SES, and finally the low SES was at 62,000 words. In conclusion, a higher SES leads to a greater exposure of words (Hart and Risley, 1995).

Language Proficiency

Weber-Fox and Neville (1996) conducted a study to test EEG waves on subjects who read sentences that held semantic violations such as “The scientist criticized Max’s event of the theorem” and sentences that held no violation such as “The scientist criticized Max’s explanation of the theorem” (Hernandez, 2013). An increase in the negative wave, N400, is caused by the semantic error. This wave usually peaks at 400 milliseconds after viewing the error. Weber and Neville (1996) sought to find if age of acquisition plays a role in the size of the N400. The results showed that changes in the N400 were only noted in those who learned a second language after the age of 11. This shows that proficiency plays a role for semantic processing (Weber-Fox and Neville, 1996).

Furthermore, Wartenburger, Heekeren, Abutalebi, Cappa, Villringer, and Perani (2003) conducted another study to test language proficiency. In their experiment, participants were given sentences that made no sense semantically such as “the car drove the man” as well as ones that made sense such as “the man drove the car”. The results suggest that the high proficiency late bilinguals showed more neural activity in the right fusiform gyrus, which processes visual information (Delvin et al., 2006). The lower proficiency bilinguals displayed an increase neural activity in the superior part of the Broca’s area, which is involved in motor planning of verbal responses (Wartenburger et al., 2003). Looking at both studies, a conclusion can be reached that late learners have an initial reliance on their native language until direct links of the second language are tied to concrete concepts.

The Maximization of Grammar

Vocabulary words are different in each language, and so is the semantics of grammar. In romantic languages, such as Spanish, the gender of a noun can be either masculine or feminine and also agree in number with the adjective that qualifies it (Bates, 1992). The Spanish phrase “El chico alto” translates to “the$_{masc}$boy$_{masc}$tall$_{masc}$” This allows native Spanish speakers to refer to an object without actually mentioning. For an example while tending to the farm one may exclaim and point to the cow and say “mirala” which means look at the cow (Bates, 1992).

Spanish nouns carry an –a ending for feminine nouns and an –o ending for masculine nouns. However, the Spanish language also has irregular endings for nouns such as s, t, z, n, r and e. These words can either be masculine or feminine. For example, el coche (the car) is masculine whereas la Fuente (the fountain) is feminine. Arturo Hernandez, Kotz, Hofmann, Balentin, Dapretto, and Bookheimer (2004) studied a group of Spanish monolinguals to test whether a noun in Spanish was masculine or feminine during a fMRI scan. Half of the tested words were masculine and half were feminine with irregular endings and normal endings such as –o and –a (Hernandez et al., 2004).

The results showed an increase of neural activity in three areas: the anterior insula, anterior cingulate gyrus, and the superior and inferior portions of the Broca's area (Hernandez et al., 2004). The anterior insula is involved in articulation, which is the physical movements that are associated with speech. The anterior cingulate gyrus is involved with cognitive thoughts and processes. The inferior portion of the Broca's area is associated with motor planning of speech. The superior portion of the Broca's area is associated with accessing the speech sounds of a word (Hernandez, 2013).

Conclusion

The critical time to learn a second language is between the ages of 3-7 years old (Johnson & Newport, 1989). The early learners, ages 3-7, and late learners, 7+, shared neural activity in the Wernicke's area; however, the Broca's area showed distinct differences in early and late learners. It is noted that the setting and culture of second language acquisition also plays a role in if the Wernicke's area and the Broca's area share neural activity in early and late learners (Kim et al., 1997).

Memory was also extensively studied. The implicit memory is automatic and does not require conscious control. Various areas in the prefrontal cortex are used when a bilingual uses its implicit memory (Squire and Zola, 1996). The explicit memory is represented by facts and is conscious. The anterior prefrontal cortex retrieves declarative memories (Norman, 2002). Finally, episodic memory is autobiographical and recalls events of a person's life. Sensory information encodes these memories. The frontal lobe, which controls the executive functioning process, processes the sensory stimuli. The temporal lobe processes the auditory input; the occipital lobe processes the visual input (Blumenfeld and Ranganath, 2007).

Furthermore, cognition and control has also been shown to be processed and integrated in the frontal areas of the brain. Switching languages or language rules occurs in both the frontal and parietal lobes of the brain (Hernandez, 2013). This language lateralization occurs across both the right and left hemispheres. Different factors such as literal and figurative components of language effect the brain differently (Cieslicka and Heredia, 2011).

References

Abstract v Concrete. (n.d.). Retrieved March 25, 2016, from http://www.palomar.edu/administrationofjustice/reportwriting/abstract.htm

Altarriba, J. (1992). The representation of translation equivalents in bilingual memory. In R.J. Harris (Ed.), *Cognitive processing in bilinguals* (Vol. 83, pp. 157-174). Amsterdam: North-Holland.

Alvarez, P., & Squire, L.R. (1994). Memory consolidation and the medial temporal lobe: A simple network model. *Proceedings of the National Academy of Sciences, 91*, 7041-7045.

Archila-Suerte, P., Zevin, J., Bunta, F., & Hernandez, A.E. (2012). Age of acquisition and proficiency in a second language independently influence the perception of non-native speech. *Bilingualism: Language and Cognition, 15,* 190-201.

Bates, E.L. (1992). The acquisition of Walpiri. In D.I. Slobin (Ed.), *The crosslinguistic study of language acquisition* (Vol. 3, pp. 309-371). Hillsdale, NJ: Erlbaum.

Blumenfeld, R.S., & Ranganath, C. (2007). Prefrontal cortex and long-term memory encoding: An integrative review of findings from neuropsychology and neuroimaging. *The Neuroscientist, 13,* 280-291.

Carlson, N.R. (2004b, c). *Physiology of behavior* (8th ed., pp. 433-454). Boston, MA: Pearson.

Cieslicka, A. B., & Heredia, R. R. (2011). Hemispheric asymmetries in processing L1 and L2 idioms: Effects of salience and context. *Brain and Language, 116,* 136-150.

De Groot, A. M. B. (1992). Determinants of Word translation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18,* 1001-1018. (Page 90 Blue) (Copyright 1992 by the American Psychological Association).

Devlin, J. T., Jamison, H.L., Gonnerman, L.M., & Matthews, P.M. (2006). The role of the posterior fusiform gyrus in reading. *Journal of Cognitive Neuroscience, 18*, 911-912.

Ericsson, K. A., Krampe, R.T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Fabbro, F. (2001). The bilingual brain: Cerebral representation of languages. *Brain and Language, 79*, 211-222.

Hart, B., & Risley, T.R. (1995). *Meaningful differences in the everyday experiences of young American children*. Baltimore, MD: Brookes.

Heredia, R., & Altarriba, J. (2014). *Foundations of bilingual memory*, 268.

Heredia, R., & Brown, J. M. (2013). Bilingual memory. In T. K. Bhatia & W. C. Ritchie (Eds.), *The handbook of bilingualism and multilingualism* (2nd ed., pp. 269-291). Malden: Wiley-Blackwell.

Hernandez, Arturo E. *The Bilingual Brain*. New York: Oxford UP, 2013. Print.

Hernandez, A.E., Kotz, S.A., Hofmann, J., Balentin, V.V., Dapretto, M., & Bookheimer, S.Y. (2004). The neural correlates of grammatical gender decisions in Spanish. *Neuroreport, 15*, 863-866.

Johnson, J.S., & Newport, E.L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology, 21,* 60-99.

Kelley, W.M., Miezin, F.M., McDermott, K.B., Buckner, R.L., Raichle, M.E., Cohen, N.J., Ollinger, J.M., Akbudak, E., Conturo, T.E., Snyder, A.Z., & Petersen, S.E. (1998). Hemispheric specialization in human dorsal frontal cortex and medial temporal lobe for verbal and nonverbal memory encoding. *Neuron, 20*, 927-936.

Kim, K. H. S., Relkin, N.R., Lee, K.-M., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature, 388,* 171-174.

Kroll, J.F., & Stewart, E. (1994). Category inference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33*, 149-174.

Linck, J. A. Kroll, J.F., & Sunderman, G. (2009). Losing access to the native language while immersed in a second language: Evidence for the role of inhibition in second-language learning. *Psychological Science, 20*, 1507-1515.

Macnamara, J. (1967). The bilingual's linguistic performance: A psychological overview. *Journal of Social Issues, 2,* 58-77.

Marian, V., & Neisser, U. (2000). Language-dependent recall of autobiographical memories. *Journal of Experimental Psychology: General, 129*, 361-368.

Norman, J. (2002). Two visual systems and two theories of perception: An attempt to reconcile the constructivist and ecological approaches. *Behavior and Brain Sciences, 25*, 73-96 (discussion 96-144).

Squire L R, Knowlton B J. In: The Cognitive Neurosciences. Gazzinga M, editor. Cambridge, MA: MIT Press; 1994.

Squire, L. R., (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99*, 195-231.

Squire, L.R., & Zola, S.M. (1996). Structure and function of declarative and nondeclarative memory systems. *Proceedings of the National Academy of Sciences of the United States of America, 93*, 13515- 13522.

Sussman, H.M., Franklin, P., & Simon, T. (1982). Bilingual speech: Bilateral control? *Brain and Language, 15*, 125-142.

Wartenburger, I., Heekeren, H.R., Abutalebi, J., Cappa, S.F., Villringer, A., & Perani, D. (2003). Early setting of grammatical processing in the bilingual brain. *Neuron, 37,* 159-170.

Weber-Fox, C., & Neville, H.J. (1996). Maturational constraints on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. *Journal of Cognitive Neuroscience*, *8*, 231-256.