

The effect of bilingualism on the cognitive brain: To what extent does bilingualism affect cognitive processes of the brain?

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Table of Contents

Introduction.....	2
Monolingual Language Acquisition.....	2
Theories on how Language and Thought are Connected.....	4
Bilingualism Development.....	7
Strengths of Bilingualism on Cognition.....	8
Limitations of Bilingualism on Cognition.....	13
Conclusion.....	14
References.....	17

Introduction

Monolingualism is the ability of a person to speak one language fluently, where bilingualism is the ability of a person to speak two languages fluently. Approximately 40% of the world's population is monolingual; approximately 43% of the world is bilingual. This means that 43% of the world can speak two languages at about the same level (ilanguages.org, 2016). The most widely spoken native language is Chinese (all dialects) with approximately 1.39 billion speakers worldwide. However, English is the most learned second language around the world, with around 1.5 billion learners (Noack and Gamio, 2015).

Cognitive processes of the brain involve how the brain thinks about and senses the world. Some of these processes include IQ, memory, and problem solving. The use of language is involved with these processes as well. Areas of the brain such as Broca's area and Wernicke's area assist in speech production. Many studies have explored the relationship between cognitive processes and bilingualism, particularly in children, and most come to the conclusion that there is some sort of correlation between the two processes. Yet, some argue that there are only some cognitive processes that being bilingual effects, such as metalinguistic awareness and development. Therefore, psychologists have experimented to examine: to what extent does bilingualism affect cognitive processes of the brain?

Monolingual Language Acquisition

According to the American Speech-Language-Hearing Association (ASHA), language can be defined as the meaning of words, how to make new words or put multiple words together, and how to combine words in different sentences for different meanings. Though children

develop at different rates, the ASHA has developed a list of certain milestones children must meet in their developing ages to be considered on the “right track” for communication. If children do not meet these milestones, they are considered at risk for developing a language or speech disorder (ASHA, 2017). In order to be considered fluent in a language, literacy and pragmatics must be mastered (ASHA, 2017).

Language learning is optimal when children are exposed to an enriching environment full of different sights and sounds, and when they are exposed to the speech and language of others. If a child is not placed in an enriching environment, their language development could be seriously set back, causing problems with language learning in the future (NIDCD, 2017).

One of the first discoveries of how language develops in the brain was made by Marc Dax in 1836, when studying a group of patients who experienced brain damage. All patients had experienced brain damage to the left side of their brain, and experienced problems with their speech. From this observation, Dax made the connection between language development and the left side of the brain, which was later confirmed by Paul Broca in 1861. Broca discovered that one of his patients could only say one word : “tan.” After this patient had died, Broca had examined his brain and discovered that the left frontal cortex of his brain was damaged. Broca’s area, as it is now known, is involved in the development of language and language processing (NIDCD, 2006).

Wernicke’s area, also located on the left side of the brain is used for the processing of speech. Wernicke’s aphasia, a syndrome in which individuals cannot understand language in its written or spoken form, is caused by damage to this area. Though Wernicke’s area is critically involved in speech production, it is not critically involved in word comprehension (Binder,

2015). The Auditory Association Area is used for “storing” past sounds. This area works with Broca’s and Wernicke’s areas to interpret sounds and understand speech and differentiates between sounds, such as speech, music, or other languages (Chiu, 2016).

Broca’s area is located on the left side of the frontal lobe of the brain, where Wernicke’s and the Auditory Association Area are located in the left temporal lobe of the brain. The frontal lobe controls mainly cognitive skills in the brain, including memory, problem solving, and language. The temporal lobe is responsible for receiving sensory information, and understanding the auditory signals entering the brain. Because of where Broca’s area, Wernicke’s area, and the Auditory Association Area are located, psychologists began to theorize a link between cognitive processes and bilingualism.

Theories on how Language and Thought are Connected

Lev Vygotsky, a Soviet psychologist, believed that language played a large role in communicative and cognitive development. He believed that language was the main means by which adults provide information to children, and can become a potential tool of intellectual adaptation. Particularly in children, he believed that outward speech was the means that children could problem solve on their own. Vygotsky theorized that there are three types of language: social, (involving interactions), private, (directed to oneself), and silent inner speech, (thoughts). These types of speech are listed in order of when they are learned, Vygotsky theorizing as one gets older, their speech and problem solving becomes more individual and internalized. He believed that private speech plays a critical role in communication development, as this is when children begin to externalize their internal thoughts and feelings (Carruthers, 2012).

Vygotsky also introduced the concept of the “zone of proximal development,” an idea that learners can do different tasks with help, with guidance, or without either of these. He argued that language spoken by adults can hinder children’s development of this zone, and that what children do or say is not an accurate representation of what they understand within a language (Carruthers, 2012).

Jean Piaget was a Swiss psychologist whose main focus was on cognitive development whilst growing. He introduced the idea of four stages of language development: sensorimotor, preoperational, concrete operational, formal operational. The sensorimotor stages typically lasts from birth to about two years of age, and children experience motor activity without the use of symbols during this stage. Infants learn through trial and error since they cannot predict what might happen in certain situations. Early language development also occurs. The preoperational stage occurs roughly between the ages of two to seven. Children begin to use language during this stage, as well as begin to understand the differences between past and present. Child’s memory and imagination develops during this stage. The process of thinking includes external events, and is more logical and systematic, and occurs between the ages of seven to eleven during the concrete operational stage. The formal operational stage occurs from adolescence until adulthood. People in this stage use symbols to construct and understand abstract concepts (Wood and Smith, 2001).

Unlike Vygotsky, Piaget believed that the development of private speech showed that the speaker could not interpret the perspective of another person, which caused problems in communication. Piaget also theorized that private speech declines with age. Vygotsky however

theorized that private speech increases when one is younger, yet will decline and turn into inner speech as one gets older (Wood and Smith, 2001).

Noam Chomsky was an American psychologist who argued that language acquisition is an innate ability of the brain; humans are born with the ability to learn language. Before his time, it was widely believed that the ability to learn language was learned over time. Chomsky introduced the idea of the “optimal learning age,” the idea that there is a certain age that children can grasp the fluency of a language. He proposed that after this age, it is impossible to completely grasp the fluency of a language. Another argument Chomsky made about innate language acquisition is that children learn to speak on their own. Parents do not need to coax a word out of a child; the child speaks when they are ready to. Certain factors can speed up this process, such as the parents speaking in “baby talk,” but the child will speak regardless of these factors (Crabtree, 1999).

The “threshold hypothesis” was invented by professor Jim Cummins in 1976, who theorized that in order for a learner to reap the benefits from a second language, they must reach a “threshold” level of second language proficiency obtained. This theory has been cited and approved by numerous psychologists, and has been used to analyze studies involving bilingualism as well. David Lasagabaster from the University of the Basque Country used Cummins’ theory to formulate a study on the subject of three-language-in-contact school systems, or schools in which students are learning three languages: their native tongue and two others. In this study, two languages are the official languages, Basque and Spanish, and English is taught as a foreign language. The study consisted of 252 students: 126 aged ten and eleven, in their second year of learning English, and 126 aged thirteen and fourteen, in their third year of

learning English. The subjects completed English, Spanish, and Basque tests throughout the study, a background questionnaire, and Raven's Progressive Matrices Test, which tests the taker's reasoning ability. Contrary to what the research originally believed, the original thresholds of the subjects seemed to only be modified, rather than having one for each language. These findings support Cummins "threshold hypothesis" (Lasagabaster, 1998).

Bilingualism Development

Many people who are bilingual are taught both languages from the start of their lives. One language is normally spoken at home, and the other is spoken at school. Bilingual children are raised learning two words for one object, whereas monolingual children are raised learning only one word per object. For example, a bilingual child learning both French and English would learn that "house" and "maison" are the same object. Yet a monolingual English speaking child would only learn the one word: "house." Because of this, bilingual children must learn twice the amount of words than monolingual children. Bilingual children must then apply this vocabulary to two different language systems (Marian, 2009).

Bilingual children, tend to have a lower vocabulary level than their monolingual counterparts. Vocabulary is defined as the number of conceptual representations that have lexical labels, not the number of lexical items. Monolinguals learn more lexical labels for words than bilinguals; bilingual learners learn more lexical items than monolingual learners. Because of this, bilingual children tend to have a lower vocabulary level than monolingual learners. Bilingual children are also normally tested in school in only one language, which provides an inaccurate representation of their language skills (Marian, 2009).

Second language acquisition occurs when a second language is introduced to a child after the first language has already been established. It is more difficult for a child who experienced second language acquisition to become fluent like a child who has been bilingual essentially from birth. Many factors can contribute to this decline in language learning ability (Karavasili, 2017). Children who grow up bilingual are able to use both sides of their brains due to the plasticity of their brains. Those learning a second language after puberty tend to only use the left side of their brains since they have less plasticity in them. This is believed to be the cause of Cummins' threshold theory (Nacamulli, 2015).

Strengths of Bilingualism on Cognition

A study by Debbie Gooch tested 243 children who were at risk for developing dyslexia, a learning disorder involving problems with reading, along with a control group that did not appear to be at risk. There were three groups of subjects: those with family history of dyslexia, those with language development considered slower than normal, and the control group (those who appeared to be developing normally). Subjects took a test assessing their executive function and language skills at the ages of four through six. At the ages of six and seven, parents and teachers rated the subject's behavior and attention skills assessing their executive function. There appeared to be a strong correlation between executive function and language at each of the testing stages. Executive function is defined as a construct that involves processes such as memory, attention control, and behavioral inhibition. The subjects' executive function scores from their tests at age six were good indicators of their behavior and attention skills at ages six and seven, but language scores did not have an affect. From this study, it appears that executive

function and language seem to be connected during early years of childhood, as subjects with language disabilities also had attention and behavior deficiencies (Gooch et al., 2016).

Psychologist Sandra Ben-Zeev conducted a study involving the relationship between cognition and bilingualism. The hypothesis being studied in this experiment was the idea that bilingual children process syntactic rules with special flexibility, as well as the effects of bilingualism on semantic processing. The study was conducted between two Hebrew/English groups. One group was bilingual with two subgroups, tested in both the United States and Israel. The other was monolingual with a native Hebrew subgroup and a native English subgroup. Monolingual English speakers were studied in the United States, and monolingual Hebrew speakers were studied in Israel. There were 96 subjects used in this study. The average age was seven years old. The majority of bilingual subjects tested in the United States attended Hebrew day school, and spoke Hebrew and English throughout the school day. The bilingual group of subjects tested in Israel lived in neighborhoods in which both English and Hebrew were understood and spoken, yet only spoke Hebrew in the classroom. All subjects were tested either at home or at school (Ben-Zeev, 1977).

The experiment was conducted using a 15-item translation test in which all subjects were asked to translate sentences from one language to the other. Monolingual students who showed any potential for understanding some of the words in the opposite language were not included in the sample, or if monolingual students could speak another language other than English or Hebrew. Bilingual subjects who could not translate more than two sentences and those whose translations were literal and forced were also removed from the study. The bilingual groups then went through a second, 18-item word association test. The scores from these two tests measured

the degree of bilingualism in each of the subjects. A high score from this test resulted in subjects who either responded consistently with the same language that was spoken to them, or equally switched back and forth between languages. The researchers also looked into the bilingual balance of each subject, adding a “plus” or a “minus” if the subject skewed towards one language. High balance was represented with a score close to zero (Ben-Zeev, 1977).

Bilinguals made more verbal transformations than monolinguals, and began hearing different forms of words earlier. There were no differences in hearing the number of meaningful forms in either language. The age of the subject was associated with the number of transformations heard, as the older the subject, the more transformational activity. Bilingual subjects would transform a word into the other language at the level of either an older child or a young adult in their native language. This act corresponded to high IQ. This was not the case for the monolingual subjects. Bilinguals also were superior on the symbol substitution task, using more advanced sentence syntax. The bilingual group showed more advanced processing of verbal material, perceptual distinctions and situations, and capacity to reorganize their perceptions (Ben-Zeev, 1977).

Barik and Swain conducted a study in Canada consisting of a French immersion group and an English immersion group of children, from when they were in kindergarten to fourth grade. The study took place in both Ottawa and Toronto, using similar immersion programs. The French immersion group had all of their courses taught in French, except for an hour long English Language Arts class which was introduced in either second or third grade. The test was stopped after the subjects' fourth grade year, as the courses were then taught 50% in English and

50% in French throughout their fifth grade year. Subjects in the English immersion program were given a one-hour French lesson throughout their school day (Barik and Swain, 1976).

The Ottawa French immersion school being tested in this study underwent some changes during the study, as some of their programs relocated. Because of this, not all subjects tested were the same throughout the study. After each year of schooling, the subjects in both test groups were administered an IQ test. Year by year, there was no significant difference in IQ test scores between the French immersion and the English immersion group. Results fluctuated between significant and nonsignificant differences between the two groups. The French immersion subjects scored slightly higher on the IQ test than the English immersion pupils, but not enough to be statistically significant (Barik and Swain, 1976).

When analyzing this study, Barik and Swain refer back to Cummins, who stated that when learning a second language, students must attain “both [thresholds] in order to avoid cognitive disadvantages and allow potentially beneficial aspects of becoming bilingual to influence their cognitive functioning” (Cummins, 1976). This is referring back to his threshold hypothesis. Barik and Swain argue that subjects who have attained this threshold in both languages will perform better on cognitive tasks than those who have not. Through the IQ tests that subjects were given, the data supports Cummins’ hypothesis. There was not a significant difference in IQ test scores each year, but the French immersion group showed an overall higher IQ than the English immersion group over the five year process (Barik and Swain, 1976).

Antonio F. Jiménez Jiménez conducted an experiment in which thirty Spanish-English bilinguals were given a problem solving activity in Spanish. The study consisted of three experimental groups; a Spanish-dominant group, an English-dominant group, and a group that

was equally confident in both English and Spanish. Jiménez Jiménez tested the participants' use of private speech, what Vygotsky believed to be the most important in language development. This was measured by recording what the subjects said out-loud when problem-solving the question before them (Jiménez Jiménez, 2015).

Each participant was presented a series of fifteen difficult problem-solving questions, all in Spanish. These questions fell in the category of mathematics, visual-spatial context, or kinship problems. For example, one kinship question could be "I am a man. If Carlos' son is my son's father, what relationship am I to Carlos?" (Jiménez Jiménez, 2015). The subjects were secretly audio recorded, and the researchers calculated the percent of time in which the subjects spoke Spanish versus English. Jiménez Jiménez found that the Spanish-dominant group spoke 97.54% of the time in Spanish when trying to problem solve, where the English-dominant group only spoke Spanish 68.5% of the time. The group that felt equally confident in both languages spoke Spanish 81.3% of the time. These results suggest that the language bilinguals say they are more confident in plays a major role in their vocalized thinking. Their less-confident language allowed them to employ different cognitive strategies and resources that were used when they were needed (Jiménez Jiménez, 2015).

Vygotsky's theory that private speech plays a critical role in language development in children, can be used to analyze this study. This experiment demonstrates this importance, as the groups who felt more confident in a particular language tended to reason and express emotion in this language. However, the group that felt equally confident in both languages showed no preference for language with private speech (Jiménez Jiménez, 2015). This suggests that in bilinguals who are equally skilled at both languages, private speech can be used in both

languages. This would allow these bilinguals to easily express thoughts and feelings in either language, and reason as well, enhancing their cognitive abilities.

Limitations of Bilingualism on Cognition

As mentioned above, Ben-Zeev conducted a study in which bilinguals and monolinguals were tested on their language processing skills. Though bilinguals did show more advanced communication processes, their vocabulary levels were lower than that of the monolingual groups. Bilinguals also did not give more paradigmatic (denoting the relationship between a set of linguistic items that form independent choices in syntactic roles) associations than monolinguals. Bilingual subjects tended to give an immature response when taking the association test, which indicated that the task was especially hard for them. The vocabulary scores of bilingual subjects were lower than those of the monolingual subjects (Ben-Zeev, 1977).

Mitsunori Takakuwa of the University of British Columbia examines the extent to which cognitive processes are affected by bilingualism using studies examining these characteristics. Takakuwa believes that there are many limitations involved when studying cognitive development. First, they argue, how can one define the term “cognition?” Cognition can be defined as any human psychological process or activity, so if bilingualism improves cognitive development, then does bilingualism improve all human psychological processes and activities? (Takakuwa, 2000).

Secondly, Takakuwa questioned how one measures the development of cognition. Using Ianco-Worrall’s 1972 study involving bilingualism and cognition, the author analyzes how data was operationalized in the study. Ianco-Worrall claimed that the words “cap” and “can” were

related phonetically, where “cap” and “hat” were related systematically. Takakuwa argued that the data measurement was faulty, and lead to incorrect inferences about the subjects’ phonic or systematic word preferences in word relationships. The author concludes that Ianco-Worrall did not come up with content-related evidence, and therefore needed to do so in order for her to support her claim (Takakuwa, 2000).

Through this paper, Takakuwa concludes that the main cognitive process that is affected by bilingualism is metalinguistic development. Metalinguistic development is another theory created by Cummins in 1987, stating that “both the development of children’s awareness of certain properties of language and their ability to analyze linguistic input, i.e., to make the language forms the objects of focal attention and to look at language rather than through it to the intended meaning.” This provides a more precise way of looking into just how bilingualism affects cognitive processes of the brain. However this may not be applicable to all bilingual speakers, the author argues, as the studies conducted so far show little but positive correlation between the two, and do not show the extent of the positive effect (Takakuwa, 2000).

Conclusion

Throughout the history of psychology, studies have been done examining how bilingualism affects cognitive processes of the brain. From previous findings, it seems as though certain cognitive processes are affected by bilingualism ability, but not all processes appear to be affected by bilingual ability. In order to determine the extent to which bilingualism affects cognitive processes of the brain, Vygotsky’s, Piaget’s, and Chomsky’s language theories were examined, as well as Cummins’ “threshold” hypothesis.

Vygotsky's, Piaget's, and Chomsky's theories and ideas provided critical developments in the theory of language learning. Vygotsky's "zone of proximal development" suggests that children can learn and perform tasks with help, or guidance, or with neither of the aforementioned. His theory on the importance of private speech (one's own thoughts and feelings being externalized) contrasted heavily with Piaget's views on the subject. Where Vygotsky theorized that private speech was critical to language development, Piaget believed it was not. Piaget's theories of language development provided insight as to how language is learned and projected throughout childhood. Chomsky's theory that babies are born with the capacity for language also presented a new way to view language learning in the 20th century. Cummins' "threshold" hypothesis seems to be the basis for second language learning and acquisition. The hypothesis suggests that there is an age limit for one to fully grasp the fluency of a language.

There are some limitations to how bilingualism affects the cognitive processes of the brain. Bilinguals tend to have lower vocabulary levels than their monolingual counterparts, as observed in Ben-Zeev's 1977 study. Bilinguals can also have a more difficult time processing information in the language they are less confident in, and this can cause them to switch between languages in order to process this information easier (Jiménez Jiménez, 2015). Where monolinguals could solve a task such as this quicker, bilinguals most likely would have had to take more time to problem solve.

The bilingual brain has been shown to light up in different areas when using different languages. Due to the brain's ability to switch back and forth between languages, it has been theorized that bilingual brains can help delay the onset of Alzheimer's and dementia, by five

years (Nacamulli, 2015). The dorsolateral prefrontal cortex, the part of the brain involved with executive function, is potentially strengthened when switching between languages (Nacamulli, 2015). Executive function is the umbrella term for cognitive processes such as attention control, working memory, and cognitive flexibility. From the previously mentioned studies and evaluations, the cognitive functions that seem to be most affected by bilingualism are executive function, problem solving, and multi-tasking (Nacamulli, 2015).

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