

The Effects of Bilingualism and Multilingualism on Cognitive Development

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Abstract

The relationship between language and the human mind is undeniable. However, does the knowledge of one, two, three or more languages affect the mind differently? Some past research suggests that the learning of more than one language may be harmful to the development of the mind. Newer research has emerged that contradict this theory, stating that the effect may not be detrimental. This paper will attempt to portray evidence in support of the hypothesis that the effect of multilingualism on cognition may have positive gains on some domains such as mental flexibility, concept formation, and cognitive reserve, by reviewing theoretical, behavioral and neuroimaging studies conducted in the field. An attempt will also be made to hypothesize the possible causes of these effects by applying some ideas discussed in psychology, linguistics and cognitive science.

Keywords: bilingualism, multilingualism, cognition, cognitive science, linguistics

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Introduction

All across the world, humans made of similar biology and neurology, speak many different languages. Everybody knows a language, and we take it for granted. But learning a language is no easy feat. Philosophers have debated over how exactly language is acquired since the days of Plato, who believed that there was some innateness to language acquisition. Later, Descartes agreed with Plato, stating that there is some universality behind language. Their views were contradicted by Locke's view of Tabula Rasa, which is that humans start off as 'blank slates', and that sensation and reflection leads to experience which are the basic components of the mind. Even till today, scientists and linguists are attempting to answer this question. Skinner (1957) claimed, according to his behaviorist views, that children use reinforcement and association for the process of language acquisition. According to his theory, positive reinforcement by the parents or teachers will result in a stronger association between word and meaning, and vice versa. However, with the cognitive revolution of the 1950's, Noam Chomsky's theories came into light. Chomsky argued that infinite sentences cannot be learned simply through association and instead theorized a Universal Grammar, a set of rules of transformation and combination innate to humans (Cowie, 2017). This, among his other contributions to the field, made Chomsky the most well-known linguist of all time, and spurred scientists to investigate the validity of his argument. This theory has continued to be dominant till the present; however, recent research is starting to suggest the lack of a module in the mind associated with language and instead claims that language is acquired through the facilitation of general cognitive and learning capabilities. As it can be seen, language is a complex phenomenon that is difficult to conceive a model of.

As fascinating as this problem may be, it is not yet possible to solve it in entirety. However, there are some angles of examining the problem that can provide at least a little insight into solving the ultimate mystery of language and its acquisition. Linguists examine the structure or syntax of languages and how they combine with the meaning or semantics. Philosophers of language debate various theories of language, language acquisition and their implications. Computer scientists attempt to model a structure of human language and analyze its behavior. Psychologists relate language to the mental faculties and attempt to find its relationship with cognition. Neuroscientists analyze the brain and neurotransmitters to see what language does at a biological level. As parts tend to form a whole, studying different aspects of language, however small it may be, would one day contribute to our complete understanding of it.

Following Chomsky's upheaval of Skinner's work (Cowie, 2017), many cognitive scientists began to support 'nature' in the nature vs nurture argument and started working under the assumption of language capabilities being innate to the human mind. Cognitive Scientist Steven Pinker (1994) articulated this view to the general public with the analogy, "people know how to talk in more or less the sense that spiders know how to spin webs. Web spinning was not invented by some unsung spider genius and does not depend on having had the right education or on having an aptitude for architecture or the construction trades. Rather spiders spin spider webs because they have spider brains, which give them the urge to spin and the competence to succeed". Cognitive scientists have modelled many different theories relating language and the human mind, as they seem almost intertwined and inseparable. One such theory is the Sapir-Whorfian Hypothesis; the strong version of which states that the language one speaks determines their thoughts and world views, and the weak version which states that the language spoken by a person would influence their thoughts and decisions (Werner, 1997). Jerry Fodor (1975)

articulated a somewhat different relationship between language and thought, claiming that thought itself was structured similar to language with syntactic and semantic processes, together with rules of transformation, but with the basic units being mental states, such as beliefs and desires, instead of phonemes or morphemes like in natural languages. Evolutionary psychologists use Fodor's (1983) ideas of the modularity of mind to claim that the mind is made of a large number of modules with very specific capabilities, with language being one of them (Robbins, 2017). If examined carefully, it can be seen that these views all hold the common assumption of innateness. However, the relationship between language and the human mind is also a very broad domain which, similar to language as a whole, has to be studied reductively to be understood accurately.

Of particular interest to some researchers is the innate human ability to learn not just one, but two or even more languages, and how it may or may not impact the human mind. There has always been widespread debate as to whether the consistent practice of one language was better than switching between two or more languages, or if language affected cognition at all. Past research suggested that being bilingual or multilingual may be detrimental to cognitive functioning (see: Saer, 1923; Jones & Stewart, 1951; Altus, 1953; Darcy, 1946), but Peal and Lambert (1962) were able to turn this view around with their paper *The Relation of Bilingualism to Intelligence*. Since then, research has emerged that suggest that knowing two or more languages may actually have a positive effect on some domains of cognitive functioning. However, there is also research that suggest that there is no significant difference between bilinguals and monolinguals. This paper will attempt to justify the hypothesis that, bilingualism and multilingualism does have an impact on some cognitive domains, and this impact is mostly positive in nature, by summarizing findings form research that speak for and against this

hypothesis, and providing justification for their results or reasons for their shortcomings, with hope that it will contribute to the greater goal of understanding language as a whole.

Past contradicting research and turning point

Research conducted on bilingualism's relationship to cognition date back to the 1920s. Early research concluded that being bilingual does impact cognition, however, most of this research indicated this impact as being detrimental. Diaz (1983) believes that these findings may have contributed to what he believes to have been a bigger "attack" on bilingualism which can be explained in social, political and cultural terms. Tucker and D'Anglejan (1971) summarizes the views held about bilinguals, in the early 1990s, as follows

- "1) Children who are instructed bilingually from an early age will suffer cognitive or intellectual retardation in comparison with their monolingually instructed counterparts.
- 2) They will not achieve the same level of content mastery as their monolingually instructed counterparts.
- 3) They will not acquire acceptable native language or target language skills.
- 4) The majority will become anomic individuals without affiliation to either ethnolinguistic contact group."

As such, the studies conducted before the 1960s, may have either been influenced by these views, or contributed to the influence of these views.

Of the early studies regarding bilingual cognition, some research directly claimed that bilingualism was detrimental to both linguistic and non-linguistic cognitive domains. One such

notable study was conducted by Saer (1923), on English-Welsh children, in which he concludes that bilinguals show an intelligence deficit compared to monolinguals. His conclusion also entails that they demonstrate confusion in writing and a lack of vocabulary knowledge, along with the belief that these adverse effects are persistent, as the results can also be replicated for university students. It must be noted that these results were only significant for children in rural areas, and no difference was found for children in urban areas. Jones and Stewart (1951) found similar results on a study conducted on English-Welsh monolinguals. Even after hypothesizing that monolinguals are only superior to bilinguals on verbal intelligence, their results indicated that monolinguals were superior in both verbal and non-verbal domains.

There were also studies whose results supported the hypothesis made by Jones and Stewart (1951), that bilinguals only lacked verbal intelligence. These studies indicated that while bilinguals and monolinguals do not differ in performance at non-verbal tasks, monolinguals are significantly better at tasks of linguistic nature. An early example would be of Pintner and Keller (1922), who conducted a study comparing English-speaking children with bilingual children. In this study, they found that English-speaking children performed significantly better at a Stanford-Binet test of intelligence than did bilinguals. Subsequently, many studies concluded that bilingualism may be detrimental to linguistic capabilities in domains such as vocabulary, articulation, writing composition and grammar (Diaz, 1983). It was also often assumed that this language deficit extended over to other domains, causing a general cognitive deficit in bilinguals.

However, these past studies were erroneous and contained a number of methodological problems. One confounding factor that has been identified as being significant is the Socio-Economic Status (SES) of the children being tested (Diaz, 1983; Peal & Lambert, 1962). Jones and Stewart (1951) initially concluded that bilingualism was detrimental to intelligence, but later

reviewed his study and discovered that the results may have been due an occupational variable instead (Peal & Lambert, 1962). In a similar manner, many of the studies conducted before the 1960s did not appropriately control for SES among the samples that were tested, which may have led to unreliable results. Another factor that may have skewed the results in the early studies is the assessment of bilingualism. Diaz (1983) provides a few extreme examples of poor judgement of bilingualism in studies, that used measures such as the foreignness of parents, family names, or place of residence as indications of bilingualism. Peal and Lambert (1962) provides an example of a study conducted by Pintner (1932) that assessed bilingualism by looking at the participating child's name. Such shallow measures of bilingualism may have been contributing factors to the unreliability of past research in the field.

A turnaround of these views was seen in 1962, when Peal and Lambert's (1962) paper was published, which took into account the methodological shortcomings of previous research. They stated that "The important variables to control seem to be socioeconomic class, sex, degree of bilinguality, age, and the actual tests used". Their use of the phrase 'degree of bilinguality' ties to the need for the strict assessment of bilingualism that was not correctly conducted in previous studies. For this reason, they emphasize on the clear distinction between *bilingualism* and *pseudo-bilingualism* which they attribute to O'Doherty (1958). According to this definition, a pseudo-bilingual is someone who knows one language fluently, and rarely uses the other language in communication, while a genuine bilingual is fluent in both languages and uses them both in everyday communication. Through this, they hypothesized that cognitive advantages can only be seen in genuine bilinguals.

Peal and Lambert's (1962) study displayed significant advantages for bilinguals, in both linguistic and non-linguistic domains. More specifically, their results indicated that bilinguals

were more adapt at *concept formation*, showed greater *mental flexibility*, and demonstrated some linguistic benefits. Despite having some methodological problems in their study too, Peal and Lambert's results, along with their clear identification of confounding factors, and their distinction between bilingualism and pseudo-bilingualism, turned around the views of the community, and led to many recent researchers replicating results that indicate bilingual advantages in similar domains.

Bilingualism and Mental Flexibility

One of the domains Peal and Lambert (1962) discovered as being affected by bilingualism was that of 'mental flexibility'. To state this in different terms, one of the domains they assumed to have contributed to the bilinguals performing better on non-verbal tasks, was that of mental flexibility. While they did not have the means of measuring this concept, they believed that bilinguals tend to switch the language they think in, when attempting to solve problems. Repeating this process consistently would act to train the mind to be more flexible when it comes to manipulating representations or concepts, as well as discarding useless information, compared to monolinguals who do not experience this opportunity.

While it is difficult to conceive of an operational definition for this concept of mental flexibility, it can be tentatively thought of as the ability to efficiently organize representational elements in the mind. Many studies have provided results that indicate an effect of bilingualism on tasks that tie to this concept. Ben-Zeev (1977) conducted a study on 96 Hebrew-English children and concluded that "Two strategies characterized the thinking patterns of the bilinguals in relation to verbal material: readiness to impute structure, and readiness to reorganize". This conclusion was drawn from the fact that bilinguals performed significantly well in tasks

concerning the reorganization of syntactic rules such as *verbal transformation test* and *symbol substitution test* as well as in some areas of visual reorganization tasks such as *Ravens progressive matrices test*. Landrey (1974) provides similar results in a different domain where he examines bilingualism's impact on divergent thinking in problem solving. This study indicates that bilinguals enrolled in a language immersion program performed significantly better in the *Torrance tests of creative thinking*, which measure children's verbal and figural, fluency, flexibility, originality, and elaboration. A review by Bialystok (2005) also indicate a bilingual advantage of manipulating quantitative elements, leading to an increase in performance of mathematical tasks.

To attempt to explain this phenomenon, it may be important to investigate the nature of language representation in bilingual brains. In the present, it is a common consensus that both languages are active in parallel during language production and comprehension (e.g.: Marian & Spivey, 2003; Costa, 2005; Dijkstra, 2005; Kroll, Bobb & Wodniecka, 2006). Assuming this model, most researchers are also inclined to hypothesize that instead of switching to and from languages, bilinguals adapt an inhibitory mechanism to suppress the language not being used (e.g., Green, 1998; Hermans et al., 1998; Meuter & Allport, 1999; Guo et al., 2011).

Extending this thinking into that of mental flexibility, researchers have begun to see a general cause-effect relationship, as hypothesized by Peal and Lambert (1962). The process of inhibiting one language to use the other, trains the bilingual brains to be more adapt at inhibition in general, and better inhibition leads to the ability to better suppress unnecessary information in solving problems, allowing for more efficient representation of ideas that are relevant to the task at hand. Ben-Zeev's (1977) study indicates that bilinguals were able to better perform the symbol substitution task which required them to ignore usual syntactic rules. They attribute this as being

due to a highly analytical nature of syntactic processing found in bilinguals, but it may also be due to bilinguals being able to better suppress their usual syntactic rules in order to solve the problem. Bialystok (2005) states in her review of studies on bilingualism, that bilinguals seem to be more adapt at tasks that require the inhibition of misleading information in three domains: quantitative concepts, task-switching and concept formation. Engel de Abreu et al. (2012) demonstrates that bilinguals excel in cognitive control in the forms of selective attention and interference suppression, as bilinguals performed better on *The Sky Search task from the Test of Everyday Attention for Children*, which measures selective attention, and a modified version of the *flaker task* which measures interference suppression.

Bilingualism and Concept formation

Concept formation is defined in Wikipedia based on Bruner, Goodnow and Austin (1967) as the process of searching for attributes that can distinguish exemplars, or typical examples, of various categories (“Concept Learning”, 2017). Diaz (1983) states that the most detailed explanation of concept formation was given by Jean Piaget. Piaget stressed on the importance of assimilation, accommodation, and equilibrium in forming concepts where assimilation was the use of existing mental representations to deal with novel situations, accommodation was the changing of existing mental representations to accommodate novel situations that do not work under the existing representation, and equilibration is the process of balancing assimilation and accommodation until learning has occurred. Another view of concept formation is derived from Lev Vygotsky, who stresses the importance of social interaction in cognitive development and concept formation. With regards to language, Vygotsky believed that language depends on

thought for development, and that cognitive development comes from an internalization of language.

Using these theories, researchers have attempted to articulate a relationship between concept formation and bilingualism. Using tasks similar to those used by Piaget to assess children's geometric concepts, Liedtke and Nelson (1968) assessed children's concept of distance, by comparing the performance of monolinguals and bilinguals in 6 tasks; 4 of which assessed their ability to conserve length, and 2 of which assessed their ability to measure length. They concluded that bilinguals demonstrated superior performance in all the tasks.

Bain (1974) examined Piaget's and Vygotsky's ideas of *discovery learning* by testing monolinguals and bilinguals in their ability to solve linear numerical problems (e.g.: 1,3,7,15,31, ?). Discovery learning refers to the idea of the learner using past experiences to discover new facts and relationships. The testing was conducted on two different days, and on the second day, the children were asked to use the rules they learned on the first day, to solve the problems. This specifically correlates with Piaget's idea of assimilation, or the use of existing mental representations to deal with novel situations, and the researchers hypothesized that Vygotsky's idea of language influencing learning will be supported if bilinguals demonstrated an advantage over monolinguals. The children were judged by how soon they were able to solve the problems, and it was found that bilinguals were significantly faster than monolinguals at this task, possibly indicating that bilinguals may be more adept at assimilating concepts and supporting Vygotsky's view of language enhancing learning. Similarly, but without the emphasis on developmental theories, Peal & Lambert (1962) and Bialystok (2005) also attribute concept formation as being a significant bilingual advantage.

The reasons for this development in bilinguals are still speculative, but several hypotheses have been introduced that may provide some insight into why bilinguals may be better at forming concepts. According to the Sapir-Whorf hypothesis, the language a person speaks determines, or at least, influences their thought. This is consistent with the findings from Boroditsky (2001), which show that the conception of time is different for Mandarin speakers from that on English speakers. Boroditsky concludes that this shows that language may influence abstract domains of thought. In a sense, concepts can be thought of as abstract categorizations, so bilingualism having an impact on concept formation may be understood by extending Boroditsky's ideas. A similar hypothesis was first introduced by Leopold (1961) who studied his bilingual children and concluded that bilinguals appear to separate words from meanings (Peal & Lambert, 1962; Diaz, 1983). This would suggest that bilinguals have to conceptualize things in the environment without relying on linguistic grounding, thus relying more on the ability to understand abstract concepts. Vygotsky shared a view similar to this theory, suggesting that "bilingualism could orient the child towards more abstract thought processes 'from the prison of concrete language forms and phenomena'" (Cummings, 1976).

Bilingualism and Linguistic Ability

Bilingualism has been seen to demonstrate varied effects on linguistic ability. Some studies conclude that being bilingual is detrimental to this domain. Several studies indicate that bilinguals demonstrate a lack of vocabulary, compared to monolinguals. Bialystok (2005) pointed out that one area in which bilinguals have demonstrated consistent disadvantages, is receptive vocabulary, and this sometimes hampers educational demands such as solving math

word-problems. Ben-Zeev (1976) notes in her study that bilinguals demonstrate lower vocabulary levels although they process verbal material more fluently.

There are also studies that have investigated the relationship between bilingualism and linguistic abilities, to find no results. A study conducted by Hill (1936) with the subjects matched on many confounding factors revealed no differences between the groups, verbal, or non-verbal. However, the results may not have been significant because the participants were also matched on IQ, which may indirectly match them on linguistic ability (Peal & Lambert, 1962). A longitudinal study conducted by Barik and Swain (1976) indicates that, even in conditions where significant differences were found for classification and analogy tasks, no group differences were found in a task which required the following of verbal directions.

However, there are also studies that have concluded that bilinguals demonstrate a better linguistic capacity than monolinguals. Peal and Lambert (1962) hypothesized that monolinguals would have a linguistic advantage over bilinguals, but the results indicated what they later dubbed a “language asset” in bilinguals, due to superior performance by bilinguals in linguistic tasks. However, they point out that this may have been due to them trying to find genuine or balanced bilinguals for their experiment, as balanced bilinguals happen to be bilinguals who are equally proficient in both languages. Ben-Zeev (1976) shows that although bilinguals lack in vocabulary, they seem to be highly adept at the manipulation of syntactic rules. Diaz (1983) in his review, analyzes a few studies which show that bilinguals are more competent in equating words based on semantic relation, rather than phonetic similarity (e.g.: what is more similar to cap? *hat* or *cat*?) and that they are better at meta-linguistic analysis, which is the ability to look at language objectively and analyze its structure. This ability to analyze structure is consistent with Ben-Zeev’s results and could possibly be due to the aforementioned word-meaning

separation, which would allow bilingual children to identify language as just being a set of arbitrary symbols manipulated according to formal rules, at an earlier age than monolingual children.

In light of these mixed findings, it is difficult to generalize bilingualism's impact on linguistic skill. It may be possible to combine these mixed findings by studying solely the effect on bilingualism on linguistic ability but using linguistic variables as both dependent and independent would be difficult, due to the need of the study to appropriately control for degree of bilingualism. These mixed results may also suggest that bilingualism does not have a definite impact on linguistic ability, and the results may be due to different confounding factors.

Cognitive Reserve and Dementia in older adults

Despite many studies concluding that there is an effect of bilingualism on cognition in childhood, positive or otherwise, there is very little evidence of this impact in young adulthood. This may be due to young adulthood being the peak of cognition, when monolinguals have caught up to bilinguals who had an advantage in childhood. Bialystok, Craik and Luk (2012) state that the effect of bilingualism on young adults is restricted to very specific task conditions, such as the Simon task, but only in conditions requiring switching and monitoring, or the flanker task, only under high monitoring conditions, or a non-linguistic condition in a Stroop effect task. These situations are not enough to suggest a significant bilingual advantage in young adults, as there are many studies such as Von Bastian et al (2016) and Paap and Sawi (2014), which indicate no differences between bilinguals and monolinguals when comparing young adults.

However, some studies have shown that the knowledge of two or more languages can lead to cognitive benefits for older adults. Bialystok, Craik, and Freedman (2007) analyzed a group of 184 individuals diagnosed with dementia, 51% of whom are bilinguals, and concludes that the age of onset of dementia is delayed by approximately four years for the bilingual sample compared to the monolinguals. A similar study was conducted by Kavé et al (2008) on a large sample of 814 Israeli-Jewish individuals with a mean age of 83 years, who speak two, three or more than three languages. The subjects were first tested in 1989 and twice more within the following twelve years, to assess the decline of their cognitive state. The subjects were assessed using Katzman et al.'s (1983) *cognitive-screening test* and Folstein et al.'s (1975) *MMSE*. The results indicated that the number of languages spoken showed a negative correlation with the rate of cognitive decline. The results also indicated that those who reported being most fluent in a language other than their native language showed the lowest rate of cognitive decay.

Kavé et al (2008) attempts to explain these findings using the idea of cognitive reserve. Cognitive reserve refers to the theory that some people may be able to deal with damage to the brain better than others. Stern (2012) states that, the mind actively attempts to cope with the loss of neurons, using preexisting cognitive processes, or by findings compensatory mechanisms. People with high cognitive reserve are able to 'cope' for longer than people with low cognitive reserve. Research has indicated that factors such as education, occupation, leisure, and childhood cognition may affect an individual's cognitive reserve (e.g.: Stern, 2012; Liberati, Raffone & Olivetti, 2012; Murray et al., 2011). Of these, education and childhood cognition stand out as factors that may be related to bilingualism leading to a higher cognitive reserve in older bilingual or multilingual adults.

Other findings pertaining to benefits of Bilingualism

Some studies indicate that bilingual cognitive advantages may not be limited to the abstract domains of mental flexibility or concept formation but are linked to domain-general executive functioning. Miyake and Friedman (2012) define Executive Functioning (EF) as being a set of domain-general processes that control a person's goal-oriented thoughts and behavior, with the most general functions being *updating of working memory*, *inhibition of prepotent responses*, and *switching between tasks*. In line with this model, researchers have found significant advantages for bilinguals on updating working memory (e.g.: Bialystok, Craik & Luk, 2008; Luo et al., 2013), inhibition (e.g.: Ransdell, Arecco & Levy, 2001; Bialystok, 2005; Engel de Abreu, 2012), and task switching (e.g.: Prior & MacWhinney, 2010; Bialystok, 2005) as well as visuo-spatial representations in working memory (e.g.: Blom et al., 2014). These domain-general advantages that can be significantly identified has caused researchers to believe that the advantages of bilingualism may be more widespread than simply inhibitory control or concept formation but is more generalized into executive functioning as a whole. However, some researchers vehemently deny the existence of such a general advantage and claims that even if there was an impact of bilingualism on cognition, it may be domain-specific or task-specific (e.g.: Paap & Sawi, 2014; Von Bastian et al., 2016).

Many studies advocate the treatment of bilingualism as a continuum rather than consider individuals as being either bilingual or not. This distinction was possibly first made by Peal & Lambert (1962) when distinguishing bilinguals from pseudo-bilinguals, as they suggest that only genuine bilinguals may display advantages. Therefore, the degree of bilingualism is generally considered to be an important factor in bilingual studies (Kroll & Bialystok, 2013). Another example of a similar theory is that of the *Threshold of Competence* by Cummings (1976). In his

paper, he claims that bilinguals may need to achieve a certain level of competence in their weaker language, to avoid cognitive disadvantages, and possibly gain benefits. To this end, most recent studies assess the level of bilingualism, and attempt to use genuine, or competent, bilinguals in their studies.

Assuming that the above theories are true, bilinguals of different calibers should indicate differences in cognition. Some research has found results showing this to be the case. Kharkhurin (2011) conducted a study where he examined the role of selective attention in bilinguals, when it comes to creative problem solving. Comparing highly-linguistically-proficient bilinguals with those of lower proficiency, the study indicated that high-proficient bilinguals employ the inhibition of irrelevant information as their preferred method of selective attention, while less proficient bilinguals were seen to use the facilitation of relevant information instead. Similarly, in a longitudinal study done by Barik & Swain (1976) comparing bilinguals and monolinguals, no significant difference was found between the two groups being analyzed, but a significant difference in performance was found between low and high achieving bilinguals. They hypothesize that this may be due to high performing bilinguals being over Cummings (1976) *threshold* of bilingualism.

An interesting phenomenon regarding bilingualism's impact on cognition was identified by Sterian & Mocanu (2014). According to their study, people who have been exposed to the basics of a language different from their primary language before the age of five, and resume learning that language later in life, can have unexpected cognitive advantages. They believe that children acquire basic concepts in the other language and retain them in their long-term memory, and regain access to them when language re-learning occurs, providing the benefits such as increasing the speed of linguistic acquisition as well as enhancing creativity in problem solving,

even when older. Although this study is highly specific and quite novel, this phenomenon is interesting enough that future studies may be considered to validate the truth or falsity of these claims.

Neuroimaging results

Due to the undeniable relationship between the mind and the brain, neuroimaging studies are also important in analyzing the impact of bilingualism on cognition. If bilinguals demonstrate different brain activation than monolinguals in performing the same task, it can conclude that bilingualism has some impact at a neural level. By determining the areas of the brain that differ in activation, assumptions can be made about what cognitive processes are being affected.

One of the domains of bilingualism that neuroimaging studies have examined is that of cognitive control, or inhibition. A study conducted by Ma et al. (2014) revealed that bilingual language control involves a network of regions including the precentral gyrus, the Supplementary Motor Area (SMA), the Supra Marginal Gyrus (SMG), and the fusiform gyrus, which are associated with high-level cognitive control. In a similar study conducted by Hsieh (2017), it was found that bilinguals show greater activation in the bilateral inferior frontal gyri, SMA, caudate nucleus and left fusiform gyrus, of which the frontal regions and the SMA are known to be correlated with domain-general inhibition. Baene et al. (2015) discovered that lateral and medial Pre-Frontal Cortex (PFC) as well as the inferior and superior parietal lobule were commonly active when switching is performed linguistically, or non-linguistically. These studies conclude that these activations indicate a domain-general inhibition used by bilinguals in language control, rather than a language module.

Multiple other studies support this hypothesis (e.g.: Luk et al., 2012; de Bruin et al., 2013; Weissberger et al., 2015; see Buchweitz & Prat, 2013 for a review). The plasticity of the brain allows it to develop parts that are used more, so, higher activations in certain brain areas may explain why bilinguals seem to demonstrate higher inhibitory skills than monolinguals.

Another interesting finding from neuroscience relevant to the topic is that bilinguals appear to share neural correlates for semantic concepts across languages. This means that similar brain areas would be activated for different words in different languages relating to the same concept. This has been most-clearly analyzed by using Multi Voxel Pattern Analysis (MVPA) to analyze functional Magnetic Resonance Imaging (fMRI) data. MVPA consists of training a machine-learning algorithm to identify pre-classified mental states or representations based only on neural activations. In these studies, MVPA was trained to identify the corresponding word in one language based solely on the neural activations of a word in a different language, while the two words were related solely on concept or meaning. This was successfully demonstrated in visual language comprehension, while reading nouns (Buchwietz et al., 2012), auditory language comprehension, or while hearing nouns (Correia et al., 2014), and language production, or speaking nouns (Van de Putte et al., 2017). In all cases, the analyzer was able to accurately predict which noun was being seen, heard, or read by participants based solely on training data from semantically similar nouns from another language. This lends support to the theory that bilinguals may separate word-meaning associations more than monolinguals, which may allow for better and more abstract representations of concepts.

Recent contradicting research, objections, and answers

As in every scientific community, there are researchers in the field of bilingualism that oppose some of the ideas discussed above. A study conducted by Von Bastian et al (2016), assessed four domains linked to executive functioning; inhibitory control, conflict monitoring, shifting and general cognitive performance and concluded that bilinguals do not demonstrate significant advantages in any of the domains. Many studies conducted by researcher Kenneth R. Paap, indicate that bilinguals do not demonstrate benefits in domain-general executive functioning (e.g.: Paap, Johnson & Sawi, 2015; Paap & Sawi, 2014; Paap & Greenberg, 2013)

An attempt can be made to interpret the contradicting results of these studies. The first being that, the study by Von Bastian et al. (2016) did not consist of a strictly monolingual control group. They explain the reason for this stating that if bilingualism is a continuum, there should be a difference between bilinguals of different caliber, but a difference between bilinguals and monolinguals may have been noticed if the sample included a monolingual group. Another reason for the null findings of these studies may be due to the sample population consisting of university students, who are generally classified as young adults. As mentioned in a previous section, bilingual advantages are not highly observable in young adults, unless under very specific conditions, and this may lead to researchers generalizing this effect to all age groups, threatening the external validity of their studies. Another comment to be made about these studies is that even if their conclusions are accurate, and bilingualism does not impact executive functioning in general, it does not affect the claim of this paper, which is that bilingualism does have a positive impact on cognition. Widespread or not, it is difficult to deny that there is an impact on cognition, at least in specific domains. These studies are also considerably new,

therefore the researchers of the articles that speak for bilingualism have not yet had the chance to voice their opinions. The next wave of research will surely be of help in understanding this matter further.

Some may still argue that these advantages are not due to bilingualism, but stem from other factors such as Socio-Economic Status (SES). The idea that SES may be a factor in bilingual advantages or disadvantages stemmed from Saer's (1923) study which showed a significant difference in intelligence between rural bilinguals and monolinguals, but not urban bilinguals and monolinguals. However, current research explicitly controls for SES along with other possible confounding factors such as age, gender, and educational level (e.g.: Blom et al., 2014; Barik & Swain, 1976; Kavé et al., 2008; Ben-Zeev, 1977). Some studies have specifically used SES as an independent variable to see if bilingual advantages are due to high SES, but their results indicated that there was no interaction (Engel de Abreu et al., 2012). Therefore, it can be said with quite high certainty that SES is not a significant confounding factor in the relationship between bilingualism and cognition.

An argument can also be made that, while it appears that there are some beneficial consequences of bilingualism, what is important to discover is not what they are, but how exactly they impact cognition the way they do. While I agree that it would indeed be fascinating to answer that question, at this stage in scientific progression, bilingual research can only examine results of behavioral studies or of neuroimaging studies with low temporal resolution. Diaz (1983) states in his paper that since only psychometric tests have been used in his time to analyze bilingual children, it is impossible to model how bilingualism accelerates cognitive development. However, almost forty years later, it still has not been possible to completely understand how this cognitive development occurs, although more theories have been proposed, and understanding

has been gained of affected brain structures through neuroimaging results. As discussed earlier, language is a diverse and complicated phenomenon, and conceiving a mutually-agreed-upon model for its impact on cognition may still be some years away.

Conclusion

Taken as a whole, this research paper indicates that being bilingual or multilingual does have a positive impact on some domains of cognition. More specifically, the knowledge and use of two or more languages appears to increase mental flexibility and concept forming abilities in children and increase cognitive reserve and delay the onset of dementia in older adults.

These results imply that there may be some benefits of introducing a secondary language to young children in their education curriculum, especially in highly monolingual countries such as the US or China, where children have little to no use for languages other than their native tongue. Bilingual parents may also be encouraged to use both languages with the child on a day-to-day basis, as this will allow the child to develop as a balanced bilingual, possibly leading to increased cognitive development. Even if the second language would not be used later in life, it appears that attempting to learn more languages in early childhood may have positive effects on children's cognitive development. Sterian and Mocanu's (2014) study indicates that second language learning by children as less as five years old, may have a benefit in their overall cognition. Although these benefits may not be significant in young adults, it manifests again in older adults, further demonstrating the usefulness of possibly learning a second language and using it in everyday life.

Some of the limitations of the studies conducted in the field that could be investigated in future studies include yet more confounding factors, small sample sizes and the mixed results of bilingualism's impact on linguistic ability. Instead of controlling for confounding factors, future research could focus on each of the major confounds identified by Peal & Lambert (1962) including age, gender, and education in addition to SES, to see if any of these factors has anything to do with the beneficial influences discovered. Newer confounding factors should also be controlled for or considered, which were not quite relevant in Peal & Lambert's time, such as hours spent on the internet, time spent playing video games or social media exposure to different languages and culture. Having small sample sizes is an aspect of many studies regarding bilinguals, that have been criticized in literature. This mostly happens due to the difficulties in finding a large number of genuine bilinguals, who are equally proficient in both languages, and also as proficient in one language as comparable monolinguals. However, future studies could attempt to expand the sample size to see if results will replicate or not. As discussed in a previous section, bilingualism's impact on linguistic ability is also something future studies could focus on, as there have been no consensus on this topic in the research conducted thus far.

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