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Strengthening Cognitive Development in Minority Populations: A Study of the Beneficial Effects of Bilingualism

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STRENGTHENING COGNITIVE DEVELOPMENT IN MINORITY POPULATIONS: A STUDY OF THE BENEFICIAL EFFECTS OF BILINGUALISM

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Dedication

For my God, my lovely husband Francisco, my father Francisco Javier, my mother Maricela, my sister Marisol, my brother Jesus - who have given me the light and strength throughout this journey.

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by

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Abstract

The long-term goal of this research is to better understand and characterize the "bilingual advantage" so that educational and child care institutions begin to recognize and encourage the active use of two languages to strengthen cognitive development in minority populations. The present study is one of the first one to include a very large sample of well-defined "active bilinguals" who, by objective measures, were determined to be bilingual and determined to engage in language switching on a daily basis. Another goal was to manipulate and activate in the laboratory what might be referred to as the "switching benefit." One hundred and twenty English-Spanish active bilinguals (mean age 21.9, SD = 7.0) and 120 English monolinguals (mean age 22.6, SD = 6.4) were evaluated on the Simon Task, Task Switching Task and ANT, alternating with a language switching activation manipulation. There was no bilingual advantage on the Simon Task and the ANT; however the Task Switching Task was able to detect the bilingual advantage. These results supported the idea that switching between stimuli features may closely resemble the type of switching that active bilinguals must do when switching between languages.

The administration of the Language Switching Activation manipulation condition immediately prior to the Task Switching Task promoted the ability to shift between mental sets as evidenced by higher accuracy, in monolinguals and active bilinguals. The results from the ANT suggested that the Language Switching Activation manipulation produced an immediate benefit for attention but interestingly, only among active bilinguals. The findings may suggest that the brain pathways that are exercised through years of language switching are altered in such a way that stimulation of these pathways improves alerting and orienting forms of attention. Additional studies are needed to replicate these findings and refine the Language Switching Activation manipulation condition, and to explore ways to further enhance attentional performance of active bilinguals

Also, in the exploratory analyses, variables that are known to have an effect on visual perceptual and motor reaction processes in young adults, such as video game playing and non-verbal intelligence, were included. It was found that video game playing may have influenced performance on the Simon Task, suggesting that bilinguals who have video game playing experience responded to the Simon Task significantly faster. Video game playing experience and non-verbal intelligence are factors that appear to have an effect on visual perceptual and motor reaction processes. The exploratory analyses suggested that video game playing experience and non-verbal intelligence are variables that must be included in analyses of the bilingual advantage.

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Chapter 1: Introduction

Data from the U.S. Census Bureau reported that in 2010 there were 50.5 million Hispanics in the United States (Humes, Jones, & Ramirez, 2011). By 2009, Hispanics constituted 16% of the total population in the U.S., making the Hispanic population one of the largest ethnic or race minority populations in the United States (Census Bureau, 2010). The Hispanic population in the U.S. consisted of the following proportions of Hispanic subgroups: 66% of Mexican, 9% Puerto Rican, 3.4% Cuban, 3.4 Salvadoran, and 2.8% Dominican (Census Bureau, 2010). In 2007 the Census Bureau reported that the total number of people speaking a language other than English at home exceeded 55 million. For 62% (34 million) Spanish was the first language of choice (Shin & Kominski, 2010). In El Paso, Texas approximately 68% of the population spoke Spanish at home in 2000 (Shin & Kominski, 2010). Thus, in the United States there are a large number of people who speak Spanish and have the potential to learn English as a second language and eventually become bilingual.

Minority children and adolescents, particularly those who have recently immigrated, may suffer academically for a variety of reasons (Heckmann, 2008). In turn, that may increase the likelihood of lower academic achievement, school-dropout; and perhaps in adulthood, poorer utilization of health care information and health care options. Identifying factors that strengthen cognitive development in minority populations could help to offset these effects.

Some people have proposed that learning a second language at a young age adversely affects children and may lead to speech or language problems (American Speech-Language-Hearing Association, 2011), confusion (Cuda-Kroen, 2011), deficiency in the native language and loss of proficiency as evidenced by slowed object naming (Cook, 1997). For these and other reasons, sometimes bilingualism has been discouraged rather than promoted in the educational setting. Others see bilingualism as providing many diverse advantages, including broadening of career and job opportunities, access to different cultures, appreciation of the literature, and importantly cognitive benefits.

In fact, a growing body of evidence has suggested that bilingualism is associated with specific cognitive advantages, particularly in the executive functioning domain (Bialystok, Craik, & Luk, 2008; Bialystok et al., 2005; Bialystok, Martin, & Viswanathan, 2005). This effect has been referred to as the "bilingual advantage." Executive functions are supported by the prefrontal cortex regions and are consciously invoked processes that are needed for planning, rule acquisition, abstract reasoning, cognitive flexibility, suppression of automatic responses, and selection of relevant information (Brocki & Bohlin, 2004). These cognitive processes have been shown to be enhanced by bilingualism.

Evidence from psycholinguistic studies on adult language processing suggests that bilinguals experience constant activation of their two languages, even when only one of the languages is being used (De Groot, Delmaar, & Lupker, 2000; W. Francis, 1999; Schwartz, Yeh, & Shaw, 2008; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008). For example, in one study Dutch-English bilinguals and English monolinguals were evaluated on a lexical decision task (van Heuven, et al., 2008). It was found that bilinguals had longer response times when shown with homograph words existing in the two languages than to English control words. These results support the idea that bilinguals experience the activation of both languages even when they read words in one specific language.

Bilinguals are believed to be highly skilled in inhibitory control because of their constant need to inhibit lexical competition from the non-intended language, and requiring their attention to be selectively and continuously directed towards relevant representations in the intended language (Abutalebi & Green, 2007; Bialystok, Craik, & Ryan, 2006). In fact, Green's (1998) inhibitory control (IC) model proposed that when bilinguals use one of their languages, their non-intended language is inhibited or controlled by the same cognitive functions involved in control of attention and inhibition (Bonifacci, Giombini, Bellocchi, & Contento, 2011).

Research has supported the idea that the need to constantly suppress one language in favor of another, and prevent intrusions of the non-intended language, provides an advantage in the development of “executive control”, which facilitates the control of two languages while speaking (Green, 1998; Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007). Thus, the function that is central to this control of two languages appears to be “inhibitory control”, which includes a cluster of mental processes that inhibit responding while attention is selectively directed to relevant sensory stimuli for the purpose of response determination. For example, in conflict resolution tasks, inhibitory control is exhibited when a response to a misleading cue is inhibited while attention is directed to the cue that will override an automatic response to a salient cue in favor of a correct response (Bialystok, et al., 2006).

Nigg (2000) provided a theoretical framework for different classes of cognitive inhibition. He proposed two categories of inhibitory processes, including “effortful” and “automatic” inhibition. Effortful inhibition included four types that require conscious control, while automatic inhibition referred to two types that were more reflexive.

Effortful inhibitory control processes included four types of inhibitory processes that are distinguished by their conscious and effortful nature. *Interference control* is the type of inhibition required to suppress distracting information that may compete with the primary response. Experimental tasks that involve interference control include “flanker” tasks, such as the Attentional Network Task (ANT), and possibly task-switching tasks. The brain structures that are related to these tasks are the dorsolateral prefrontal cortex (DLPFC), but they depend more heavily on the anterior cingulate gyrus, which is located in the anterior cingulate cortex (ACC). *Cognitive inhibition* is a second type of effortful inhibitory process that involves suppression of information to eliminate it from working memory. Experimental tasks that evoke cognitive inhibition are tasks that require the suppression of items from a to-be-forgotten list, and the interference suffered from these items during recall. The brain areas associated in this type of inhibition include the prefrontal cortex and the ACC. *Behavioral inhibition* refers to the suppression of an automatic motor response; for example, the suppression of a key press. Other experimental tasks such as stop tasks, and the Simon Task could be classified under this type of inhibition. The brain areas involved in behavioral inhibition are lateral and prefrontal cortex, and premotor cortex. The last type of effortful inhibition suggested by Nigg was *oculomotor inhibition*, which is measured with oculomotor and saccade tasks and provides quantification of the suppression of reflexive saccade and antisaccade eye movements. The brain areas involved in oculomotor inhibition are frontal eye fields and the orbitofrontal cortex. Nigg also accounted for a category of inhibition that relies on automatic inhibition of attention. These refer to tasks that require suppression of responding to a previously attended stimuli (inhibition of return), and attentional and oculomotor saccade. These tasks depend upon midbrain or oculomotor pathways and the posterior association cortex.

Therefore, Nigg's theoretical framework usefully characterized types of inhibitory control processes. For the purpose of investigating bilingualism, *interference control* and *behavioral inhibition* may be the most relevant types of inhibitory control processes.

Many studies have investigated the bilingual advantage and its effects of inhibitory control by using a variety of cognitive tasks. Tasks that require the use of inhibitory control have been favored, including the Simon Task, the Task Switching Task, and flanker tasks such as the Attentional Network Task (ANT). The extent to which each of these tasks involves the use of inhibitory control and other executive functions will be explained next.

1.1 The Simon Task

The Simon Task has been frequently used to study the efficiency of inhibitory control processes in bilingual children and adults. In the Simon Task a colored square appears on the left or right side of the computer screen, participants are instructed to respond based on the color of the square regardless of the position of the square on the screen. Congruent trials are those in which the colored square and the correct response key are in the same side, incongruent trials are those in which the colored square and the correct response key are the opposite side. In general, response times for congruent trials are faster than response times following incongruent trials (Simon & Craft, 1970). Thus, inhibitory control is involved when the most salient event (position of the square) has to be ignored and a response inhibited in order to respond correctly based on the less salient but correct event (color of the square). The Simon Task also involves the use of working memory, because the color rule and hand mapping has to be temporarily stored (e.g. If red, press right; if blue, press left). The brain areas that participate during the Simon Task have been studied. In one brain imaging study (Bialystok, Craik, et al., 2005) a significant association between faster response times and frontal activation was found in monolingual and bilingual participants. For bilingual participants, greater activation of the right temporal and left frontal and cingulate areas was associated with faster response times. Left frontal and cingulate areas are known to be involved in inhibitory control processes and resolving interference during the Simon Task (Bialystok, Craik, et al., 2005; Peterson et al., 2002). The motor response involved in the Simon Task is regulated by the supplementary motor area (SMA), which is in charge of performing correct movements based on memory from a specific temporal order (Shima & Tanji, 1998).

In one lifespan developmental comparison study (Bialystok, Martin, et al., 2005), four different age groups were evaluated on the Simon Task. The results showed that 5-year-old children, middle-aged adults (30-59 years) and older adults (60-80 years) had faster response times during both congruent and incongruent trials as compared to their monolingual counterparts. Later child studies (Martin-Rhee & Bialystok, 2008) supported these previous findings. Bilingual children responded faster to both congruent and incongruent trials, suggesting that bilingual children have enhanced inhibitory control that allows them to efficiently perform problem solving tasks. Although the only group that did not show the bilingual advantage in previous studies (Bialystok, Martin, et al., 2005) was the young adult group (20 years old), additional studies however suggested that this advantage could be intermittent. For example, in a study of young university students (Bialystok, Craik, et al., 2005), a group of 10

French-English bilinguals, 10 Cantonese-English bilinguals, and 10 English monolinguals (mean age 29 years, range 22-36 years) were evaluated on the Simon Task. Both groups of bilingual had learned both languages during childhood, and had continued to use both of their languages in a daily basis. The Cantonese-English bilinguals were faster than the other two groups in both congruent and incongruent trials. The authors mentioned that the results might be explained by sampling variability due to the small number of participants in each group.

In another study Bialystok (2006) examined the performance of 57 bilinguals (mean age 22.1 years) and 40 English monolinguals (mean age 21.8 years) on the Simon Task. Half of the participants in the groups had previous experience with video games. Participants were evaluated in two versions of the Simon Task: the standard Simon Task using squares (previously explained), and the Simon Task with arrows, in which the direction that the arrow was pointing to had to be recorded using a response key. Also, the number of response switches in each testing block was manipulated by varying the number of switches from congruent to incongruent trials and vice versa; as a result, there were two switch conditions (high and low). In general, participants had larger mean response times during the arrow Simon Task than in the squares Simon Task, suggesting that the arrow task was more demanding than the standard version. Another finding was that participants with video game experience performed faster in both the standard and arrows Simon Tasks, and in all conditions including the control trials. The bilingual advantage was present only in the arrow Simon Task in the high switch condition, which is the most difficult condition. The author proposed that there might be important differences between the two Simon Tasks. It is possible that the tasks involve different cognitive processes. Working memory may be primarily involved in the square Simon Task since the association between the color stimulus and hand mapping of the task need to be constantly remembered. Furthermore, the association between color and response is easy to associate. On the other hand, the arrows Simon Task taps more into inhibitory control processes: In this task, two spatial representations need to be resolved, the location of the arrow on the screen and the direction the arrow is pointing. This dual paradigm is believed to simulate the competition of the representation of two languages in bilinguals. Bilinguals showed better performance due to enhanced ability in solving visual perceptual conflict that is believed to derive from the constant practice of managing two languages.

The effects of bilingualism in inhibitory control have been studied across the lifespan by means of the Simon Task (Bialystok, Martin, et al., 2005). However, only a few studies (Bialystok, 2006; Bialystok, Craik, et al., 2005) reported the bilingual advantage among young bilinguals. One possible reason for this gap of bilingual advantage during late adolescence and early adulthood is that the executive control processes may be peaking during this age period producing a “ceiling effect” and obscuring possible beneficial effects of bilingualism (Bialystok, Martin, et al., 2005; Costa, Hernández, & Sebastián-Gallés, 2008).

1.2 Task Switching Task

Shifting of mental sets refers to the ability to shift between multiple tasks, activities, operations, or mental sets (Miyake et al., 2000). For instance, the ability to hold two sets of instructions and shift efficiently between them in order to execute the one that is relevant to a particular stimulus (Bialystok, et al., 2006). This is often called “attention switching” or “task switching” (Miyake, et al., 2000). In bilinguals this may simulate holding two language representations in mind and responding to the context by using the appropriate language; then switching between languages back and forth, if necessary (Bialystok, et al., 2006). Inhibitory control is involved when inhibiting or ignoring the feature that is irrelevant and focusing attention to the relevant rule according to the context information. Other cognitive processes involved when moving from one task to another are goal shifting and focus of attention on relevant perceptual stimulus features (Rubinstein, Meyer, & Evans, 2001). The brain structure that is activated during task switching is the dorsolateral prefrontal cortex (DLPFC) (Savine & Braver, 2010), which is involved in monitoring and inhibition (Owen, Evans, & Petrides, 1996).

Recent studies investigating bilinguals' ability to switch between tasks have employed a different experimental task for young adults: the task-switching paradigm (A Prior & MacWhinney, 2010; Rubin & Meiran, 2005). The stimulus used in this task is defined as "bivalent" meaning it has two features, color and shape. Participants are asked to switch between two main tasks: color discrimination and shape discrimination; thus the stimuli can activate two competing responses. This competing activation parallels language selection in bilinguals, in which the appropriate language is selected through control mechanisms (Green, 1998). There are two types of experimental blocks in the task-switching paradigm, single-task blocks and mixed-task blocks. In single-task blocks, only one task is performed at a time, either Task A or Task B. In mixed-task blocks, both tasks are alternately performed. This experimental design allows calculating two measures of executive control: switching costs and mixing costs. Switching costs, also called local switching costs, represent the challenge of switching from one task to another; it is calculated by subtracting the RT of non-switch trials from the RT of switch trials within the mixed-task blocks (Rogers & Monsell, 1995). Mixing costs, also called global switching costs, involve the global control mechanisms necessary for sustaining two competing response sets. Mixing costs are calculated as the difference between mean RT of non-switch trials in mixed blocks and the mean RT of single-task blocks (Rubin & Meiran, 2005). The order of the blocks follows a "sandwich- like" design: single-task → mixed-tasks → single-task.

Prior and MacWhinney (2010) investigated whether bilinguals have enhanced set-shifting ability. Forty- five monolinguals (mean age 18.7 years) and 47 bilingual (mean age 19.5 years) college-aged students were assessed on a task-switching paradigm. The task consisted of two main tasks, color decision and shape decision; thus, bivalent stimuli were presented (red and green circles and triangles). The task switching was made evident by a cue rather than alternating runs. Each task was mapped to one hand; the "red" response was assigned to the index finger and the "green" response to the middle finger. Equally, the "circle" and "triangle" response were assigned to the index and middle finger respectively.

Switching and mixing costs were calculated; it was found that, as compared to monolinguals, bilinguals had a significantly reduced switching cost. Therefore, bilinguals were significantly faster during switching trials; meaning they were more efficient when switching and overcoming the activation of the previously performed task. The competition that arises from the two competing tasks may be comparable to the continuous activation of two language systems. The reduced switching costs represent the enhanced bilingual executive advantage for selecting the appropriate language and avoiding interference from the non-selected language. This evidence supported the idea that the constant inhibition of one language in favor of the contextually required language produces benefits in the executive function of shifting.

The previous findings were replicated in a recent study by Prior and Gollan (2011). The authors studied how the bilingual advantage was related to language switching, given that it is a frequent cognitive skill that bilinguals tend to develop. Forty-seven English monolinguals (mean age 20.2 years), 41 Spanish-English bilinguals (mean age 20 years), and 43 Mandarin-English bilinguals (mean age 19.4 years) were evaluated on the task switching paradigm (previously described), language switching task (bilinguals named numbers from 1 to 9 switching between their two languages), vocabulary test, verbal fluency test, and a matrices test (Kaufman brief intelligence test). Results showed that, after controlling for between-group differences in parental education level and response latencies (by dividing switching cots by the mean RT on repeat trials), Spanish-English bilinguals had a significantly smaller switch costs than monolinguals. It was also reported that Spanish-English bilinguals and Mandarin-English bilinguals differed in their experience of language switching, Spanish-English bilinguals most frequently engaged in the mixing of two languages. Moreover, the Mandarin-English group had lower Mandarin fluency scores than the Spanish-English group, thus the Mandarin-English bilinguals were less balanced bilinguals. The association between non-dominant language fluency and switching ability for the Mandarin-English groups was negatively correlated with task-switching costs. These results reflect some limitations on bilingual advantages. However, it also provided support for the important association between language switching and bilingual advantage.

1.3 Attentional Network Task (ANT)

The ANT has also been used to explore the benefits of bilingualism in inhibitory control and attention. The ANT is a comprehensive neurocognitive task that assesses the ability to resolve interference between congruent and incongruent trials, and the ability to switch between different types of trials (Costa, et al., 2008).

Attentional networks have been studied by Posner and Petersen (1990). They proposed that the neural networks of attention can be divided into three networks of attention: alerting, orienting, and executive control. According to Fan, McCandliss, Sommer, Raz, and Posner (2002) the alerting network maintains alertness and vigilance; the brain areas associated are the frontal and parietal regions of the right hemisphere. The orienting network allocates the required cognitive resources for detecting possible relevant information from the visual input; the brain regions associated with the activation of the orienting network involves the superior parietal and frontal lobes (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000). The executive control network of attention involves conflict resolution, processing of discrepant information, planning goals, and developing strategies (Fan, et al., 2002; Hernández, Costa, Fuentes, Vivas, & Sebastián-Gallés, 2010). The brain areas involved include midline frontal areas, such as the lateral prefrontal cortex, and the ACC (Bush, Luu, & Posner, 2000). As previously stated, the areas of the prefrontal cortex are involved in the control or inhibition of an inappropriate response, and the use of verbal and non-verbal information (Smith & Jonides, 1997). The ACC is especially active during tasks that require the selection of the appropriate response such as in divided attention tasks, error detection, and conflict (Badgaiyan & Posner, 1998; Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999).

The Attentional Network Task (ANT) was developed by Posner and colleagues (Fan, et al., 2002)in order to qualitatively assess the efficiency, independence, and the cognitive abilities involved in each of the three networks. In this task, participants were asked to fixate in a central point (+) on the computer screen and to respond whether the central arrow points right or left. Response times were recorded when participants pressed one of two keys from a keyboard. Participants' response times were influenced by alerting cues, spatial cues, and flankers. The computer screen displayed the target arrow along with four flanker arrows pointing to the same direction as the target arrow (congruent trials→→→→→), to the opposite direction (incongruent trials←←→←←), or flanked by lines (neutral condition -- -- → -- --). The row of arrows could be presented in two different locations, either above or below the fixation point. The alerting and orienting network were triggered by presenting a cue (an asterisk) before the target stimulus. There were four cue conditions: no cue, center cue, double cue, and spatial cue. In the no- cue trials, the participant saw only the fixation point; no alerting or spatial cues were presented. The central-cue trial involved the presentation of a cue at the site of the fixation point. In the double-cue trial, two cues were presented simultaneously at the two possible target positions; above and below the fixation point. In the spatial- cue trial, the cue was presented at the same location where the target stimulus was presented; spatial cues signaled the right location of the stimulus. Incongruent trials require more cognitive resources in order to solve the interference produced by the flankers; therefore responses tend to be slower for incongruent trials. The time needed to resolve the interference is often called "conflict effect" (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, et al., 2008). The alerting Network is manipulated by showing an alerting cue that prepares the participant to respond. The orienting network is manipulated by presenting a spatial cue at the same location of the target stimulus (spatially correct cue). And the executive control network involves resolving the discrepancy between congruent and incongruent stimuli. Similar to the Simon Task, the ANT involves the use of inhibitory control when a response is inhibited when the flanker arrows are pointing in different direction to the target stimulus, such as in an incongruent trial. On the other hand, the ANT relies more on non-verbal and less working memory skills as compared to the Simon Task (Bonifacci, et al., 2011), because there is no need to keep a color rule in mind.

Past research on attentional networks has examined the effects of enhanced inhibitory control in bilinguals on the three attentional networks. Costa and colleagues (2008) evaluated 100 Catalan-Spanish high-proficient bilinguals (mean age 22 years) and 100 Spanish monolinguals (mean age 22 years) using the ANT. Participants were instructed to fixate at the center of the computer screen and to record their responses by pressing a key from the key board. They were asked to use the left hand when the central arrow pointed to the left and the right hand when the arrow pointed to the right. The results showed that, overall, bilinguals were faster than monolinguals in the three types of trials (congruent, incongruent, and neutral). For the executive control attentional network, bilinguals were faster than monolinguals. An interaction between language groups and conflict effect revealed that the difference between incongruent and congruent trials was larger for the monolingual group. With regard to alerting, bilinguals were faster than monolinguals. An interaction between alerting effect and language group revealed that bilinguals were faster when a cue was presented than when it was not presented. In terms of orienting, bilinguals were overall faster than monolinguals in trials where the cue signaled the location of the target stimulus than when it did not. The interaction between language groups and orienting effect was not significant. In summary, these results suggest that bilingualism benefits inhibition of inappropriate responses, attention networks of executive control, and alerting by showing that bilinguals were overall faster than monolinguals in the three types of trials. Also, bilinguals solved the incongruent-trial- interference faster than monolinguals, and they were faster in the alerting-cue trials.

Costa et al. (2009) further explored the bilingual advantage in conflict resolution tasks and created different versions of the ANT by manipulating the number of congruent and incongruent trials. Two hundred and forty-four undergraduate students were evaluated (mean age 20 years) in one of two monitoring conditions. The low-monitoring condition consisted of two conditions in which the ANT was mainly composed of trials involving one type of stimuli. For instance, one condition consisted of 92% of congruent trials, and the other condition consisted of 8% of congruent trials. The high-monitoring condition consisted of two ANT versions in which the number of congruent and incongruent trials was evenly distributed, consisting of 50% congruent; the other condition consisted of 75% congruent trials. Contrary to previous findings (Costa et al., 2008), bilinguals did not exhibit the alerting network index. However, it was found that bilinguals were faster than monolinguals in both congruent and incongruent trials during the two versions of high-monitoring. The authors interpreted the results in the following way. The high-monitor ANT versions required continuous examination of the stimuli due to the constant shift of responses. On the other hand, the low-monitoring ANT versions did not require much monitoring processes because the responses to the stimuli were, most of the times, the same. It is worth mentioning that the ANT version used in Costa et al.'s study (2008) consisted of 33% incongruent trials, which resembled the high-monitoring condition of the ANT with 75% congruent trials allowing for the reliability of the previous results.

1.4 Neural Bases of Language/Task Switching

Findings from the previously cited behavioral studies are supported by the following brain imaging studies examining the regions that participate during language selection and language/task switching. Hernandez and colleagues (2000) investigated the brain activity patterns when bilinguals name pictures in English and Spanish. Six Spanish-English bilinguals (mean age 23.5 years) were asked to name pictures during an fMRI session. During the single language condition participants named pictures only in one of the two languages, and during the mixed language condition participants alternated between English and Spanish according to the visual cue presented (word "say" in English and "diga" in Spanish). It was observed that the brain activity in the left and right hemispheres did not differ during the single language condition. On the other hand during the mixed language condition there was higher activation (higher signal intensity and spatial extent) in the DLPFC.

In a similar study (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001) six bilingual college-age bilingual students (mean age 21.7 years) were evaluated on two types of language switching tasks. In the between-language switching condition, participants named pictures in either English, Spanish or alternated between these two languages. The blocked-language condition consisted of blocks of trials in either English or Spanish and the mixed-language condition consisted of trials alternating both languages. In the within language switching condition, participants named either actions or the object receiving the action, or alternated between these two tasks all in English. This task was cued by the words “to” or “the” shown before the picture. In the between-language switching it was found greater activation in the right DLPFC for the mixed-language condition than in the blocked-language condition. In the within-language switching the mixed and rest comparison were compared, there was some activation in the frontal cortex, including the DLPFC and the Broca’s area. However, this activation was not statistically significant. These results were later replicated by Hernandez (2009) in a group of twelve bilinguals (mean age 21.4 years) using the same picture naming paradigm. Thus, language switching is proposed to be not only a language process that involves articulation and phonological retrieval, but a general executive function (Hernandez, 2009; Hernandez, et al., 2001; Hernandez, et al., 2000). The previous studies showed that the DLPFC is involved during language switching in picture naming, which is also activated when performing executive control functions (Berman et al., 1995; Fujii et al., 2010; Osaka et al., 2004; Owen, et al., 1996) and nonlinguistic task switching (Meyer et al., 1997).

It has been proposed by other researchers (Price, Green, & von Studnitz, 1999) that translation, or language switching during translation should lead to activation in the DLPFC. Yet, none of the previously mentioned processes showed increased activation in the DLPFC in proficient German-English adult bilinguals (mean age 30.5), while either translating or reading words presented in one the two languages or an alternation of both languages (Price, et al., 1999). Hernandez and colleagues inferred that it might be that only some switching tasks produce the appropriate amount of executive function which in turn activates the prefrontal cortex (Hernandez, et al., 2001).

In a more recent study by Wang and colleagues (Wang, Xue, Chen, Xue, & Dong, 2007) the involvement of inhibitory control in language switching was further investigated. Twelve native Chinese speakers learning English named pictures in their first and second language according to randomly shown response cues. During the testing session, they were scanned using an event related (ER)-fMRI. It was found that language-switching trials elicited greater intensity of activation in the left superior frontal cortex as compared to non-switching trials. Contrary to past studies (Hernandez, et al., 2001; Hernandez, et al., 2000) activation in the DLPFC was not observed. Despite that, greater activation was found in the frontal regions and cingulate cortex; more specifically in the left superior frontal cortex and ACC. It was concluded that the brain mechanisms involved in language switching are the same involved for executive control processes that involve inhibitory control functions.

Those studies provide evidence that language control and language switching are subserved by overlapping brain structures and regions, including DLPFC, ACC, premotor cortex, and Broca's area; and depend upon the same prefrontal brain structures that are involved in the executive control function of inhibitory control (Festman, Rodriguez-Fornells, & Münte, 2010; Hervais-Adelman, Moser-Mercer, & Golestani, 2011).

1.5 The Issue of Active Bilingualism

There are many ways to be bilingual. Among the Hispanic immigrant population in the U.S., there may be Hispanics that have no knowledge of English. These individuals may start by learning a few words and forming very short sentences to communicate but never become proficient in the English language. Another type of bilinguals may include the children of immigrants ("first generation children") who were born in the U.S. and have at least one foreign-born parent (Fry & Passel, 2009).

They may speak Spanish at home and English at school. Since they receive their education in U.S. institutions these bilinguals may switch language dominance from Spanish to English when they stop practicing their native language. The same language-switching-dominance dynamic may occur for Hispanics who are "second generation" and beyond, those who were born in the U.S. from U.S.-born parents. Another type of bilingual is the bilingual who practices both languages continuously and develops equal proficiency in both. This type of bilingual has no problem using both languages on a daily basis; therefore switching languages becomes commonplace.

Logically, it may be expected that knowing a language early in life, while learning and using a second language during grade school, then completely switching to that second language, would not provide the same cognitive benefits as having to switch between the two languages on a daily basis over the course of many years. Assuming that inhibitory control is the function that benefits from the constant suppression of one language in favor of another, in order to study this benefit, a type of bilingualism that includes the daily use of two languages must be defined.

For the purpose of the present study, it will be necessary to define participants as "active bilinguals" in order to optimally test the research hypotheses. In fact, researchers have previously attempted to define active bilingualism. For example, Prior and colleagues (2011; 2010) defined active bilingualism as the continuous use of two languages since an early age (e.g. 6 years). Costa and colleagues(2008) defined "simultaneous bilinguals" as bilinguals who learned the two languages before schooling, used the two languages in a highly proficient way, and used them both in their daily life. It is important to note that to date, researchers have relied mostly on self-report measures. In moving forward, it may be important to improve the criteria for identifying "active bilinguals" by using objective measures of bilingual abilities. In the present study, "active bilingual" refers to bilinguals who have used two languages continuously since the age of 6 years. Given the geographical area in which the majority of the participants live, it was expected that language switching among bilinguals was going to be a commonly reported phenomenon.

1.6 Goals of the Study and Hypotheses

The proposed study aims to comprehensively measure the bilingual advantage by replicating and expanding on previous studies. Two of the proposed goals were expected to contribute to the knowledge on the possible beneficial effects that bilingualism may exert on inhibitory control. The first goal was to replicate and expand on previous studies by addressing two methodological issues that may influence results. A specific criterion for active bilingualism was defined by means of an objective measure of English and Spanish oral proficiency. Second, behavioral measures that specifically evoke "effortful and conscious" inhibitory control mechanisms as defined by Nigg (2000) were utilized.

The second goal of the present study was to manipulate; and thus, activate in the laboratory what might be referred to as the "switching benefit." This was done through the administration of a language switching activation task alternated between target neurocognitive tasks. Based on the previous findings, it was hypothesized that all the subjects who were going to be exposed to the language switching activation condition administered between the neurocognitive tasks were going to benefit from the activation of switching. Specifically, it was predicted that the active switching manipulation was going to improve performance on the Simon Task, Task Switching Task, and the ANT in bilinguals and in monolinguals.

Chapter 2: Methods

2.1 Participants

Approximately 300 participants were recruited from the UTEP Psychology Research Participation System (Sona System) and through flyers posted across campus. From the 300 participants, 57 were excluded from the analysis because they didn't meet the bilingual inclusion criteria, and 3 didn't meet the monolingual inclusion criteria. Participants recruited through flyers received monetary compensation which approximately was half of the total sample size, the other half received research credit participation through Sona System. The total sample size was 240 participants, from which 120 were active bilinguals and 120 were monolinguals. The sample comprised 110 males and 130 females between the ages of 17 and 66, the mean age was 22.3 years (SD = 7.09).

With regard to ethnicity, approximately 30% of the sample identified themselves as Mexican-American, 29.2% as Hispanic, 16.7% as Mexican National, 12.5% as Anglo-American, and the remaining 11.6% as African American, Asian American, or other. In regard to marital status, 88.3% were single, 7.5% were married, and 4.2% were divorced or separated. Participants reported their experience with video games, 50% of the sample reported playing a mean of 4.7 hours a week (SD = 4.7), during a period of 2 to 360 months.

Table 2.1 shows the descriptive statistics by groups. Groups did not differ with regard to gender (χ^2 (3) = 1.41, p =.70), age (F (3, 236) = 1.70, p = .16), English score (F (3, 236) = 1.28, p = .27), number of video game players (χ^2 (3) = 1.20, p =.75), hours of video game played (F (3,236) = 0.44, p = .71), months of video game played (F (3,236) = 1.57, p = .19), or TONI scores (F (3,236) = 2.09, p = .10).

Table 2.1: Descriptive Statistics by Groups, Mean (SD).

	Monolingual		Bilingual	
	Activated	Non Activated	Activated	Non Activated
Males	25%	24.2%	20%	22.5%
Females	25%	25.8%	30%	27.5%
Age	24 (9.0)	21.3 (3.8)	22.1 (8.2)	21.7 (5.8)
Age English Learned	2.1 (2.5)*	2.9 (4.2)*	7.3 (5.5)	5.9 (2.8)
Age Spanish Learned	10.7 (7.4)	10.1 (7.6)	1.3 (0.6)*	1.5 (2.8)*
TONI	97.9 (10.7)	93.9 (8.7)	97.6 (10.3)	96.6 (8.5)
English Score	78.6 (14.9)	76.13 (13.9)	77.2 (27.3)	82.8 (20.7)
Spanish Score	2.93 (15.2)	7.4 (22.2)	83.5 (14.8)*	79.1 (14.2)*
Video Game players	31	33	28	28
Video Game hours	2.4 (4.0)	2.5 (4.3)	1.8 (3.0)	2.7 (4.7)
Months played	77 (99.6)	54.2 (72.1)	49.2 (72)	50.8 (72.1)

* $p < .01$

Bilinguals and monolinguals differed with regard to some variables. Monolinguals learned English significantly earlier in life as compared to bilinguals (F (1, 236) = 64.48, $p < .01$); and bilinguals learned Spanish significantly earlier in life as compared to their monolingual counterparts (F (1, 181) = 165.29, $p < .01$). As expected, bilinguals obtained a higher score in Spanish as compared to monolinguals (F (1, 236) = 1209.14, $p < .01$). Participants answered questions related to their parents' level of education; this was an indicator of socioeconomic status (SES) (Prior & Gollan, 2011). The median value of highest level of education for both bilinguals and monolinguals was high school level.

Bilinguals and monolinguals differed with regard to ethnicity (χ^2 (7) = 100.87, $p < .01$). See Table 2.2. There were no Anglo-Americans, African-American, or Asian Americans as compared to the bilingual sample which was mostly composed of Mexican-Americans, Mexicans, and Hispanics.

Table 2.2: Ethnicity by Language Groups

	Monolingual	Bilingual
Anglo-American	25.0%	0.0%
African-American	9.2%	0.0%
Asian-American	2.5%	0.0%
American-Indian	0.8%	0.0%
Mexican-American	20.8%	39.2%
Mexican	0.8%	32.5%
Hispanic	30.0%	28.3%
Native Hawaiian	0.0%	0.0%
Pacific Islander	0.0%	0.0%
Other	10.8%	0.0%

χ^2 (7) = 100.87, $p < .01$

The 120 bilinguals who met the inclusion criteria scored 50 and above on the objective language measures in English and Spanish, that is reflective of fluent language proficiency in both languages (Mather & Woodcock, 2001). From those 120 bilinguals, 116 reported switching between English and Spanish every day or most days, and 67 bilinguals reported doing it since they were 6 years old.

From the monolingual sample, 8 participants were Spanish monolinguals; the remaining 112 were English monolinguals. The inclusion criteria for this group were a score lower than or equal to 10 in Spanish (in the case of the English monolinguals which was the vast majority of the sample), and 50 and above for the English score. From the monolingual sample, 12 participants (2 of them Spanish monolinguals) reported switching between English and Spanish every day or most days, and 4 of them (1 Spanish monolingual) reported doing it since they were 6 years old.

2.2 Procedures

At the time of arrival, participants read and signed the informed consent form. Once they decided to participate, the first test was the objective measure of verbal abilities in English and Spanish. After administration of the verbal abilities and after answering the language background questionnaire, the researcher scored and determined through the scoring computer program whether the participant met the inclusion criteria for either the “active bilingual” or monolingual group (read below for details of inclusion criteria). Once participants met inclusion criteria, half of the participants were randomly assigned to the “activation condition” and half to the “no-activation condition.” Participants in the activation condition performed each of the neurocognitive tasks alternating with a language switching activation task if bilingual, or a within language switching task if monolingual. Participants in the non-activation condition performed the neurocognitive tasks alternating with a control task. At the end of the session participants answered a demographics questionnaire, and were debriefed about the study. The entire session lasted 1 hour and 40 minutes.

2.2.1. Simon Task

The Simon Task with arrows from Bialystok (2006) was implemented in the present study. The Simon Task was presented on a Mac Book Pro laptop with a 14.5-in monitor. The stimuli were programmed and presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants recorded their responses by pressing a response button box that collected response time data. Participants sat in front of the computer and were instructed to fixate on the center of the screen. Each trial started with a fixation point (+) in the center of the screen, which remained for 800 ms. The fixation point was followed by a 250-ms blank interval, then an arrow pointing either to the left or right appeared on the left or right side of the screen. Participants were instructed to press a specific response key from a button box according to the direction that the arrow was pointing to. There were 8 practice trials and 100 experimental trials presented in random order, half of which were congruent and half incongruent trials. In a congruent trial, the location of the arrow on the screen and the direction the arrow was pointing to were the same (e.g. an arrow showed in the left side of the screen pointing to the left).In an incongruent trial, the location of the arrow on the screen and the direction the arrow was pointing to were opposite (e.g. an arrow showed in the left side of the screen pointing to the right).

The variables analyzed were proportion of correct responses for congruent and incongruent trials, RT for congruent and incongruent trials.

2.2.2. Attentional Network Task (ANT)

The ANT (Fan, McCandliss, Sommer, Raz, & Posner, 2002) assessed the alerting, orienting, and executive networks of visual attention. The stimuli were presented using E-Prime (Version 1) Software in a Gateway Solo laptop computer running Microsoft Windows 95, using a 14'' Dell monitor. The central arrow (target arrow) was presented along with four flanker arrows pointing to the same (congruent trial), opposite direction (incongruent trial), or horizontal lines (neutral trial). A single arrow consisted of 0.55˚ of visual angle and the contours of adjacent rows were separated by 0.06˚. The target arrow plus four flanker arrows consisted of a total 3.08˚ of visual angle. Each trial lasted 4000 ms: a fixation period was presented for 400 ms, a cue or no cue condition for 100 ms, fixation period for 400 ms, the target and flankers presented for no longer than 1700 ms, and final fixation period for 3500 ms minus the duration of the first fixation. The fixation period consisted of the presentation of a fixation point (+) in the center of the screen which remained for the whole trial. The attentional orienting component consisted of the appearance of the five arrows either above or below the fixation point separated by 1.06˚. The alerting condition consisted of four warning conditions: no cue, center cue, double cue, and spatial cue. For the no-cue trials, there were no alerting or spatial cues; only a fixation period for 100 ms was presented. For the center-cue trials, an asterisk at the location of the fixation point was shown for 100 ms. For the double-cue trials, two warning cues were presented for 100 ms at the two possible target positions (above and below the fixation point). For the spatial-cue trials, the cue was presented for 100 ms at the same position where the target was presented. The task consisted of 4 blocks. The first block was a practice trial that lasted approximately 2min. There were 3 experimental blocks with 96 trials each, that was a total of 288 experimental trials. Each test block consisted of 32 congruent trials, 32 incongruent trials, and 32 neutral trials presented in a random order. The cue conditions were presented in random order, in each block there were 24 center cue trials, 24 double cue trials, 24 no cue trials, and 24 spatial cue trials. The total administration time for this task was 15-20 min. Participants were seated approximately 60 cm away from the monitor and asked to determine whether the central arrow pointed left or right. Participants provided their answers by pressing the left mouse button from the integrated keyboard for the left direction and the right mouse button for the right direction.

The data file was automatically generated with the raw data from the type of trial (congruent, incongruent), cue type (no cue, center cue, double cue, spatial cue), and flanker type (neutral, congruent, incongruent). The individual files were later transformed into an Excel files so that a macro could extract and calculate the three networks of attention. The index for each attention network was calculated as follows. The alerting Network index was equal to the mean of the median response time of the no-cue condition minus the mean of median response time of the double cue condition. The Orienting Network index was equal to the mean of median response time of the center cue condition minus the mean of median response time of the spatially correct cue condition. The executive network index was equal to the mean of median response time of the incongruent trials minus mean of median response time of the congruent trials.

These indices are referred to as efficiency scores because, in a normal population, smaller index values indicate greater efficiency in alerting, orienting, or executive aspects of attention (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005).

2.2.3. Task switching paradigm

The following methodology was based on the work of Prior and MacWhinney (2010). Participants switched between two main tasks: color discrimination and shape discrimination. All target stimuli contained two dimensions (color and shape), each of which was relevant for only one of the tasks. For the shape task, participants were asked to identify the shape of the target stimulus; in the color task, participants identified the color of the target stimulus. Each trial started with a fixation point in the center of the screen presented for 350ms, followed by the presentation of a white background for 150ms. A task cue was presented on the screen for 250ms, 2.8˚ above the fixation point. Graphic cues were used as task cues in order to avoid using linguistic information that may interact with participants' language skills. For instance, a color gradient represented the cue for the color task, and a row of small black shapes (4.5˚ x 0.8˚) represented the cue for the shape task. The cue remained on the screen, and the target stimulus appeared in the center of the screen. The target stimuli were red or green circles (2.8˚ x 2.8˚) and triangles (2.3˚ x 2.3˚). The cue and the stimulus remained on the screen for a maximum of 4000ms, or until participant provided an answer. A white background was presented for 850ms before the onset of the next trial.

Participants started with one task, either shape or color task. The order of the task was counterbalanced across participants. Participants solved the first task using the right hand, and the second task using the left hand. For all participants the following mapping of task to hand was assigned throughout both the single-task and mixed-task blocks: the "red" response was assigned to the index finger, and the "green" response to the middle finger; the "circle" response was assigned to the index finger, and the "triangle" response to the middle finger. The response keys for the shape and color task were labeled with the appropriate corresponding colors and shapes. During the first part of the task, participants performed two single-task blocks. The order of the tasks was counterbalanced across participants. Each single-task block started with 8 practice trials followed by 36 experimental trials. In second part of the study, participants started with 16 mixed-task practice trials, followed by 3mixed-task blocks comprised of 48 trials each. Half of the mixed-task trials were switch trials and the other half were non-switch trials of both the color and shape tasks; all trials were presented in random order. In the third and last part of the task, participants again performed two single-task blocks presented in the opposite order from that used in the first part of the task. Based on this "sandwich" design, the total number of trials was: 72 switch trials, 72 non-switch trials, and 144 single-task trials, half of which will be color and shape task trials.

The outcome variables were mean response time and proportion of correct responses for single-task blocks, non-switch, and switch trials for mixed-task blocks. Switching costs were calculated by subtracting the response time of non-switch trials from the response time of switch trials within the mixed-task blocks. Mixing costs were calculated as the difference between mean response time of non-switch trials in mixed blocks and the mean response time of single-task blocks.

2.2.4. Language Switching Activation Task

Language switching activation tasks were used to mimic in the laboratory what happens on a daily basis in the brains of "active bilinguals", necessarily differed for monolinguals and bilinguals. For bilingual participants, the language switching activation task consisted of naming pictures in English and Spanish in an alternated order, in this task bilinguals switched between languages (Hernandez, et al., 2001). Participants were presented with simple line drawings from the Snodgrass and Vanderwart (1980), Pictures Please (Abbate, 1984), and Obler and Albert (1986). Sixty pictures were selected according to their high-frequency level. The task was designed using PsyScope. There were three activation blocks, each consisting of 20 pictures. First a language cue ("say" or "diga") was presented 500 ms before the picture. Then the cue and the picture remained on the screen until the participant provided an answer. The language cues appeared alternately in English and Spanish, meaning that participants named the pictures in English and Spanish alternately. The experimenter created a list with the names and exact order of the pictures that were presented to the participant. This allowed the experimenter to check for accuracy of the participant responses, while the program automatically collected response time of word production.

Following Hernandez's (2001) methodology, monolingual participants performed a "within language switching task" in which they were shown action figures. Monolinguals named either the action being performed, or the object receiving the action. The cues for each of the tasks were presented 500 ms before the picture was presented. The cue for naming the action was the word "To", participants completed it with the verb reflected in the action picture. The cue for naming the object receiving the action was "The", participants completed it with the name of the noun receiving the action in the picture. Both the picture and the cue remained on the screen until a response was provided. The pictures were presented in an alternated way (e.g. first action, then object receiving the action, again action, and so on).

2.2.5. Control task

Bilingual participants in this condition named the same pictures bilinguals in the activation task named, in the language that they felt more comfortable with. Participants were asked to name the pictures only in one language throughout the entire session. Language cues were not necessary for this condition. Response time was also recorded.

Monolingual participants were asked to name the same action pictures that monolinguals in the activation task named, except that they only named the actions and not the object receiving the action. The language cue ("To") was presented throughout the session. The experimenter checked accuracy of the participant responses. Response time was also recorded for this condition.

2.2.6. Language Background Questionnaire

Participants answered questions regarding their language skills, age of acquisition, proficiency, and daily use patterns. This measure has been previously used at UTEP for bilingual studies by Francis, Corral, Jones, & Sáenz, (2008). Special attention was paid to some questions in order to determine whether bilingual participants had learned English and Spanish before the age of 6, and whether they had used both languages constantly ever since. Monolingual participants were either native English or Spanish speakers who had not studied or been exposed to any other language before the age of 12.

2.2.7. Woodcock-Johnson® III Test of Cognitive Abilities (WJ III COG) in English

The WJ III COG was the most reliable a screening tool for verbal English proficiency. The WJ III COG provided a measure of verbal ability through The Verbal Ability- Standard Scale comprised of four subtests: Picture Vocabulary, Synonyms, Antonyms, and Verbal Analogies. This verbal ability cluster assessed different aspects of language development in spoken English language, such as knowledge of vocabulary and the ability to reason using it. This cluster was a measure of verbal comprehension, and has median reliabilities of .90 in the age of 5-19 range and .95 in the adult range (Mather & Woodcock, 2001).

In the Picture Vocabulary section the participant named pictures orally. The items were shown in order of difficulty starting with the easiest to the most difficult. The Synonyms section required the participant to hear a word and provide a synonym orally. Likewise, Antonyms required the participant to hear a word and provide an antonym orally. Verbal Analogies required listening to three words of an analogy and completing the analogy orally.

The number of correct responses was entered in the WJII COG Scoring and Reporting program (CD-ROM) which generated a score report based on age norms. The report included different types of scores such as the raw score, grade equivalent (GE), age equivalent (AE), relative proficiency index (RPI), and cognitive-academic language proficiency (CALP) levels. For the purpose of the present study the RPI was critical for developing an inclusion criterion. The RPI provided information on the subject's predicted quality of performance (Mather & Woodcock, 2001). The RPI is a comparative score composed of a numerator and denominator. The numerator reflects the subject's proficiency level, and the denominator represents the average proficiency (90) of the comparison group of the same age. English-Spanish bilingual and English monolingual participants with a RPI of 50/90 and above were considered for inclusion in the present study. This inclusion criterion was obtained from the administration manual of one of the Woodcock Family measures, the Woodcock-Muñoz Language Survey- Revised Normative Update (WMLS-R NU) which provides a table containing the levels of Cognitive-Academic Language Proficiency (CALP) and their equivalence values for RPI. The reason for selecting 50/90 as a cut point is because it is reflective of a fluent CALP, which means that a subject with that score will find the task demands manageable.

2.2.8. Woodcock-Muñoz® III Pruebas de Habilidades Cognitivas (Batería III COG)

Batería III COG was used as crucial screening tool for verbal Spanish proficiency. Likewise, Batería III COG provided a measure of verbal ability through The Verbal Ability- Standard Scale comprised of four subtests: Picture Vocabulary, Synonyms, Antonyms, and Verbal Analogies. The psychometric characteristics of Batería III COG were the same as WJ III COG, thus the reliability values were the same. The inclusion criteria based on RPI was be the same as in the WJ III COG. English-Spanish bilingual participants were expected to obtain a RPI of 50/90, and English monolingual participants were expected to obtain a RPI of 10/90 and below in order to be considered for inclusion in the present study. An RPI of 10/90 represents a very limited or negligible CALP, reflective of someone who does not know a language.

2.2.9. Test of Nonverbal Intelligence (TONI-3)

The TONI-3 is a language free measure of cognitive ability that was designed to test subjects ranging in age from 5 to 85 years. The participant was asked to look at a set of abstract figures in which one or more of the figures were missing. A second set of pictures with the possible solution was shown below the first set. The participant was asked to provide the correct response for each of the test items. The ceiling rule allowed continuing the testing until the last item of the test was administered, or until the participant responded incorrectly to 3 responses in 5 consecutive items. After the test administration, the experimenter calculated the total raw score, and then with the help of the Examiner's manual the deviation quotient was obtained from a table. Deviation quotients have a mean of 100 and a standard deviation of 15. The larger the quotient the better the performance it represented. Quotients falling within the 90 to 110 range were average. The test contained 45 items and took about 10 to 15 minutes to administer.

Chapter 3: Results

The dependent variables of interest were analyzed using IBM SPSS Statistics 19. Homogeneity of variance and normality of distribution were first examined. All variables were normally distributed. Homogeneity of variance was tested using the Levene Statistic, which revealed that all variables had homogeneous variances with the exception of one variable from the Simon Task. Levene's test indicated unequal variances for bilinguals and monolinguals, F (1, 238) = 7.12, p < .01, for response time for incongruent trials in the Simon Task. To accommodate the unequal variances for one variable, a more stringent significance alpha was lowered from α = .05 to α = .025 (Keppel & Wickens, 2004) only for analyses that included this variable.

The results will be presented in three subsections. The first subsection describes the results of manipulation checks that were used to demonstrate the validity of the measures. The second subsection includes results from tests of the main hypotheses. The third subsection gives the results from exploratory analyses of factors that have not been previously examined in the context of the bilingual advantage, and examine the possible effects that non-verbal intelligence and video game playing experience may have had on neurocognitive performance.

3.1 Manipulation check

A manipulation check was carried out in order to determine whether the language switching activation task used for the "activation" condition in bilinguals and monolinguals produced effects that were consistent with increased cognitive challenge.

Response accuracy was analyzed using a 2 (bilingual, monolingual) x 2 (activated, non-activated) ANOVA. There was no difference between bilinguals and monolinguals, *F* (1, 236) = 1.60, *MSE* = .001, *p* = .20. There was a significant main effect of activation status, *F* (1, 236) = 4.57, *MSE* = .003, *p* = .03, and a significant interaction between language group and activation status, *F* (1, 236) =

9.06, *MSE* = .007, p < .01. The mean accuracy score for the activated and non-activated groups was .978, and .985, respectively.

Response time of voice production was also analyzed using the same 2 x 2 ANOVA design described above. A significant main effect was found for language group, F (1, 236) = 21.88, *MSE* = 4244676.70, p < .01, and for activation status, F (1, 236) = 51.94, *MSE* = 10072612.33, p < .01, as well as a significant interaction between language group and activation status, F (1, 236) = 4.10, *MSE* = 854928.66, p = .03. See Table 3.1.

Table 3.1: Mean Response Time and Standard Deviations by Groups for Language Switching Activation Task.

Monolingual		Bilingual	
Activated	Non Activated	Activated	Non Activated
1850.2 (595.1)	1559.84 (406.3)	1703.59 (436.8)	1174.49 (255.9)

Again the main effect of activation group is consistent with the difficulty and the time required for responding to these different tasks and thus suggests the validity of the task. The main effect of language group suggests that the difficulty of the two types of activation tasks for bilinguals and monolinguals was not equivalent. This issue is discussed in more detail in Discussion below.

3.2. Main Analyses

Data from each neurocognitive task were analyzed using a mixed-designed analysis of variance, with language group and activation status as between-subjects variables, and accuracy or response time for each neurocognitive task as within-subjects variable.

For the Simon Task, there were two dependent variables including accuracy and response time. For accuracy a 2 (language group) x 2 (activation status) x 2 (trial type) repeated measures ANOVA was used; the between-subjects variables were language groups (bilinguals, monolinguals), and activation status (activated, non-activated). The within-subjects variable was accuracy for two types of trials (congruent, incongruent). The between subjects effects revealed no significant main effect of language group, *F* (1, 236) = 1.81, *MSE* = .006, *p* = .17; or activation status, *F* (1, 236) = 0.83, *MSE* = .003, *p* = .36. The interaction between language group and activation status was not significant, *F* (1, 236) = 0.15, *MSE* = .001, *p* = .69. The within-subjects effect revealed a significant main effect of type of trial, *F* (1, 236) = 159.14, *MSE* = .426, *p* < .01. Participants responded more accurately to congruent trials (M = .98, SD = .02, SE= .002) than incongruent trials (M = .92, SD = .07, SE = .005). The interaction of group and activation status with trial type was not significant, *F* (1, 236) = .473, *MSE* = .001, *p* = .49.

For Simon Task response time, a 2 (bilingual, monolingual) x 2 (activated, non-activated) x 2 (congruent and incongruent trials) repeated measures ANOVA was used. The between subjects effect revealed no significant main effect of language group, *F* (1, 236) = 0.98, *MSE* = 21163.93, *p* = .32, or activation status, *F* (1, 236) = 0.28, *MSE* = 13250.41, *p* = .43. The interaction between language group and activation status was not significant, *F* (1, 236) = 0.27, *MSE* = 6106.47, *p* = .59. The within-subjects effect revealed a significant main effect of type of trial, *F* (1, 236) = 332.51, *MSE* = 438356.46, *p* < .01, participants responded faster to congruent trials (M = 496.13 ms, SD = 94.05, SE = 6.08) as compared to incongruent trials (M = 556.57 ms, SD = 118.02, SE = 7.63). The interaction of group and activation status with type of trial was not significant, *F* (1, 236) = .29, *MSE* = 382.13, *p* = .59.

For the Task Switching Task, the three dependent variables (accuracy, response time, and switching and mixing costs) were examined separately. For accuracy, it was used a 2 (bilinguals, monolinguals) x 2 (activated, non-activated) x 3 (single task trials, non-switch trials in the mixed task, and switch trials in the mixed task) repeated measures ANOVA. The within-subjects variable was accuracy for the three different types of trials.

The between groups tests indicated that there was a main effect of language group, *F* (1, 236) = 4.99, *MSE* = .02, *p* = .02. Bilinguals (M = .95, SD = .05, SE = .003) responded more accurately as compared to their monolingual counterparts (M = .94, SD =.06, SE = .003) in the Task Switching Task. Post hoc comparisons revealed that bilinguals responded more accurately in the single task trials, *F* (1,

238) = 4.48, *MSE* = .004, *p* = .030; and in the non-switch trials, *F* (1, 238) = 4.19, *MSE* = .004, *p* = .04. See Table 3.2 for more detail.

Table 3.2: Accuracy Means and Standard Deviations by Language Group for Task Switching Task

	Monolingual	Bilingual
Single task trials	.97 (.03)	.98 (.01)
Non-switch trials	.94 (.05)	.95 (.03)
Switch trials	.91 (.06)	.92 (.05)

Similarly, there was a significant difference for activation status, *F* (1, 236) = 11.91, *MSE* = .04, *p* < .01; the activated groups (M = .95, SD = .05, SE = .003) had a significantly higher accuracy as compared to the non-activated groups (M = .94, SD = .06, SE = .003). Post hoc tests revealed that participants in the activated condition responded more accurately than those in the non-activated condition in the single task trials, *F* (1, 238) = 7.97, *MSE* = .007, *p* < .01, in the non-switch trials, *F* (1, 238) = 6.36, *MSE = .01, p* = .012, and in the switching trials, *F* (1, 238) = 9.02, *MSE = .03, p* < .01. See Table 3.3 below. There was no interaction between language group and activation status, *F* (1, 236) = 2.32, *MSE* = .010, *p* = .12.

Table 3.3: Accuracy Means and Standard Deviations by Activation Groups for Task Switching Task

	Activated	Non Activated
Single task trials	.98 (.01)	.97 (.03)
Non-switch trials	.95 (.03)	.94 (.05)
Switch trials	.93 (.05)	.90 (.06)

For the within-subjects variable (type of trial), there was a significant main effect, *F* (2, 472) = 168.87, *MSE* = .10, *p* < .01. See Table 3.4 below. Participants made significantly fewer errors in the single task trials than in the non-switch and switch trials from the mixed blocks. Participants committed the greatest number of errors in the most challenging condition, that is, on trials from the mixed blocks in which participants were required to respond to changing switch and non-switch trials.

Table 3.4: Accuracy Means and Standard Deviations by Type of Trial for Task Switching Task.

	Mean	SD
Single task trials	0.97	0.03
Non-switch trials	0.94	0.04
Switch trials	0.92	0.06

A 2 (bilingual, monolingual) x 2 (activated, non-activated) x 3 (response time for the three different types of trials) repeated measures ANOVA was used to examine the second dependent variable response time for the Task Switching Task. The effect of language group was not significant (F (1, 236) = 3.42, MSE = 314250.00, p = .065), and the main effect of activation status was not significant (F (1, 236) = 2.81, MSE = 257908.86, p = .095). Also, the interaction between language group and activation status, F (1, 236) = 1.28, MSE = 117701.54, p = .25 was not significant.

For the within-subjects factor, there was a significant main effect of trial type, F (2, 472) = 931.20, MSE =12622716.64, p < .01. Participants solved the single task trial trials (M = 513.93 ms, SD = 91.86, SE = 5.86) significantly faster than the other two types of trials: non-switch (M = 814.36 ms, SD = 221.04, SE = 14.17) and switch trials (M = 964.29 ms, SD = 251.65, SE = 16.11) (from the mixed blocks). These results were consistent with the difficulty level of each trial type.

The third and fourth dependent variables for the Task Switching Task, switching cost and mixing cost, were computed. Switching cost was calculated by subtracting the response time of non-switch trials from the response time of switch trials within the mixed-task blocks. Mixing cost was calculated as the difference between mean response time of non-switch trials in mixed blocks and the mean response time of single-task blocks. These two outcome variables were analyzed in a 2 (bilingual, monolingual) x 2 (activated, non-activated) x 2 (switching cost, mixing cost) repeated measures ANOVA. There was no main effect of language group, F (1, 236) = 1.76, MSE =36622.12, p = .18; activation status, F (1, 236) = 1.70, MSE =35222.99, p = .19; or language group- activation status interaction, F (1, 236) = 0.52, *MSE* = 10878.60, *p* = .46. The within-subjects effect revealed a significant main effect of type of cost, *F* (1, 236) = 141.75, *MSE* = 2717961.27*, p* < .01; switching cost (M = 149.93 ms, SD = 113.54, SE = 7.34) was less than mixing cost (M = 300.43 ms, SD = 164.35, SE = 10.59).

For the ANT, the three networks of attention were computed. The alerting network index was calculated as the difference in response time between the no-cue trials and double cue trials. The orienting network index was calculated as the difference in response time between the center cue trials and correct spatial cue trials. The executive network index was calculated as the difference in response time between incongruent and congruent trials.

Following the same statistical approach used by other researchers (Costa, et al., 2008), which is consistent with the original conceptualization of alerting, orienting, and executive attention as segregated networks (Posner & Petersen, 1990), alerting, orienting, and executive response times were assessed in separate models using a 2 (bilingual, monolingual) x 2 (activated, non-activated) ANOVA.

For the alerting network index, there was no main effect of language group, *F* (1, 236) = 0.06, *MSE* = 4.00, *p* = .93, or activation status, *F* (1, 236) = 1.01, *MSE* = 627.26, *p* = .31. However, there was a significant interaction between language group and activation status, *F* (1, 236) = 8.00, *MSE* = 4941.33, *p* < .01. See Table 3.5. The activation status had opposite effects on monolinguals and bilinguals, meaning that monolinguals had an increase in the alerting index and bilinguals a decrease in the activation condition (language switching). In the non-activation condition (no language switching) monolinguals had a smaller alerting index, but bilinguals in the non-activated condition had a greater index.

Table 3.5: Means and Standard Deviations for Alerting by Language Group and Activation Status.

Monolingual		Bilingual	
Activated	Non-Activated	Activated	Non-Activated
37.25 (26.9)	31.40 (25.2)	28.43 (22.9)	40.74 (24.0)

For the orienting network index, the main effect of language group was not significant, *F* (1, 236) = 1.00, *MSE* = 1029.20, *p* = .31, as well as the main effect of activation status, *F* (1, 236) = 0.85, *MSE* = 870.20, *p* = .35. There was a significant interaction between language group and activation status, *F* (1, 236) = 7.30, *MSE* = 7466.78, *p* < .01.See Table 3.6. The activation status had opposite effects on monolinguals and bilinguals. Monolinguals in the activation condition (language switching) had an increase in the orienting index, and bilinguals experienced a decrease. In the non-activation condition (no language switching) monolinguals experienced a decrease in the orienting index and bilinguals experienced an increase.

Table 3.6: Means and Standard Deviations for Orienting by Language Group and Activation Status.

Monolingual		Bilingual	
Activated	Non-Activated	Activated	Non-Activated
63.51 (30.1)	48.55 (35.2)	48.22 (28.8)	55.56 (33.2)

For the executive network of attention, the main effect of language group, *F* (1, 236) = .12, *MSE* = 332.82, *p* = .72, and activation status, *F* (1, 236) = 0.35, *MSE* = 955.50, *p* = .55, were not significant. Also, the interaction between language group and activation status was not significant, *F* (1, 236) = 0.82, *MSE* = 219.69, *p* = .77.

In order to confirm that main effects for language group or activation status did not produce the alerting index score difference, the mean of median response time for the no cue and double cue were tested in a repeated measures ANOVA. Significant differences were found for cue type, *F* (1, 236) = 461.79, *p* < .01, which substantiated the validity of the cue benefit (double cue response times were significantly faster than no cue). However, no significant main effects were observed for language group, *F* (1, 236) = 0.97, *p* = .32, or activation status, *F* (1, 236) = 1.73, *p* = .18, suggesting that groups did not differ with regard to response time in no cue or in double cue trials, and that the response time differences in the unassisted condition (in this case, no cue trials) were random variation. See Table 3.7 below. This will be considered again in Discussion below.

Table 3.7: Mean of Median Response Time and Standard Deviation by Flanker Type and Language Group.

	Monolinguals		Bilinguals	
	Activated	Non-Activated	Activated	Non-Activated
No cue	593.80 (76.20)	568.55 (71.21)	591.72 (99.37)	592.05 (87.93)
Double cue	556.55 (76.35)	537.14 (72.82)	563.29 (99.46)	551.31 (81.24)
Center cue	572.46 (74.96)	546.02 (76.07)	574.57 (100.89)	563.90 (87.60)
Spatial cue	508.94 (71.44)	497.47 (75.68)	526.35 (104.69)	508.33 (88.33)

Similarly, the orienting index score components were tested in a repeated measures ANOVA. Significant differences were found for cue type, *F* (1, 236) = 683.91, *p* < .01, which again substantiated the validity of the cue benefit (spatially correct cue response times were significantly faster than center cue). As with the alerting condition response times there was no main effect for language group, *F* (1, 236) = 1.23, *p* = .26, or activation status, *F* (1, 236) = 2.34, *p* = .12, suggesting that differences in the unassisted condition (in this case the center cue trials) reflected only random variation.

3.3. Exploratory Analyses

In the following analyses two additional variables that may have important effects on neurocognitive performance were analyzed, including video game playing experience and non-verbal intelligence (TONI-3). In the past, these two variables have not been investigated in the context of bilingualism or the bilingual advantage. Video game playing experience (yes/no) was added to the above models as an additional factor; non-verbal intelligence scores were added as a covariate. Thus, the analyses described above were re-calculated, including video game playing experience as a between subjects factor and non-verbal intelligence scores as a covariate.

For the Simon Task accuracy, there was a significant main effect of TONI, *F* (1, 231) = 5.00, *MSE* = .01, *p* = .026, η^2 = .021. Simon Task accuracy scores and TONI scores were positively associated, *r* = .156, *p* = .016. For the within-subjects effect there was a significant main effect of type of trial, *F* (1, 231) = 5.05, *MSE* = .01, *p* = .026; participants solved congruent trials more accurately (M = .98, SD = .02, SE = .002) than incongruent trials (M = .92, SD = .07, SE = .005). For the Simon Task response time, there was a significant main effect of video game playing experience, *F* (1, 231) = 18.12, *MSE* = 351993.14, *p* < .01; video game players solved the Simon Task faster (M = 497.99 ms, SD = 112.34, SE = 9.10) than those who had no history of video game playing (M = 553.32 ms, SD = 90.37, SE = 9.10). There was a significant interaction between language group and video game playing experience, *F* (1, 231) = 5.14, *MSE* = 97378.33, *p* = .026. The response time decrease among video game players was larger among bilinguals, suggesting that bilinguals benefited more from video game playing experience than monolinguals. See Table 3.8 below. For the within-subjects effects there was a significant main effect of type of trial, *F* (1, 231) = 10.31, *MSE* = 13179.69, *p* < .01; participants responded faster to congruent trials (M = 496.13 ms, SD = 94.05, SE = 5.83) than incongruent trials (M = 556.57 ms, SD = 118.02, SE = 7.25).

Table 3.8: Response Time Means and Standard Deviations for the Simon Task by Language Group and Video Game Playing Experience.

	Monolingual		Bilingual	
Video game	No	Yes	No	Yes
	533.92 (95.74)	507.16 (83.26)	572.71 (123.34)	488.82 (95.63)

For Task Switching Task accuracy, there was a marginally significant main effect of TONI, *F* (1, 231) = 3.82, *p* = .052, *MSE* = .01, η^2 = .016. The same main effect of language group previously found in the main analyses section was also present, *F* (1, 231) = 4.36, *MSE* = .01, *p* = .03; bilinguals solved the task more accurately (M = .95, SD = .03) as compared to their monolingual counterparts (M = .94, SD = .05, SE = .003).Also the main effect of activation status was present, *F* (1, 231) = 9.93, MSE = .04, *p* < .01; the activated group responded more accurately (M = .95, SD = .03, SE = .003) than the non-activated group (M = .94, SD = .04, SE = .003). And for the within-subjects effects, there was a significant main effect of type of trial, *F* (2, 462) = 7.85, *MSE* = .01, *p* < .01, participant responded more accurately to single task trials (M = .97, SD = .03, SE = .002) than non-switch (M = .94, SD = .04, SE =.003) and switch trials (M = .91, SD = .06, SE = .004) from the mixed blocks task.

For response time, there was a significant main effect of video game experience, *F* (1, 231) = 4.40, *MSE* = 393841.90, *p* = .037, video game players responded faster (M = 739.33 ms, SD = 186.44, SE = 15.95) than those who had no history of video game playing (M = 787.11 ms, SD = 186.33, SE = 15.94). The interaction between language group and video game experience was not significant, *F* (1, 231) = 3.40, *MSE* = 304041.15, *p* = .066.

For the within-subjects effects, there was a main effect of type of trial, *F* (2, 462) = 7.67, *MSE* = 103137.66, *p* < .01; participants solved faster single task trials (M = 513.50 ms, SD = 91.68, SE = 5.80), as compared to non-switch (M = 814.36, SD = 221.04, SE = 14.12), and switch trials (M = 964.29 ms, SD = 251.65, SE = 15.92) from the mixed blocks. For switching and mixing costs, there was a significant main effect of video game experience, *F* (1, 231) = 4.64, *MSE* = 95049.30, *p* = .032; video game players had lower switching and mixing costs (M = 210.44 ms, SD = 131.27, SE = 9.34) than those who had no history of video game playing (M = 239.18 ms, SD = 144.71, SE = 9.34).

For the ANT alerting network of attention there was a significant interaction between language group and activation status, *F* (1, 231) = 8.11, *MSE* = 4988.00, *p* < .01. Controlling for video game playing and non-verbal intelligence did not change the interaction of language group and activation status. As previously described above, the activation status had opposite effects on monolinguals and bilinguals such that activation increased the alerting index in monolinguals but decreased in bilinguals. See Table 3.9 for means and standard deviations.

Table 3.9: Alerting Network Means and Standard Deviations by Language

Group and Activation Status.

Monolingual		Bilingual	
Activated	Non-Activated	Activated	Non-Activated
37.28 (26.90)	31.69 (25.28)	28.19 (22.91)	40.95 (24.09)

The interaction between activation status and video game playing experience was not significant, (F (1, 231) = 3.49, MSE = 2144.62, p = .063). See Table 3.10 for means and standard deviations.

Table 3.10: Alerting Network Means and Standard Deviations for Alerting by Video Game Experience and Activation Status.

	Activated		Non-Activated	
Video game	No	Yes	No	Yes
	36.76 (25.76)	28.71 (24.45)	34.34 (23.80)	38.29 (26.24)

For the orienting network index, there was a significant interaction between language group and activation status, F (1, 231) = 6.71, MSE = 6959.37, p < .01.See Table 3.11 for means and standard deviations. The activation status had opposite effects on monolinguals and bilinguals. Activation increased the orienting index in monolinguals and decreased in bilinguals.

Table 3.11: Means and Standard Deviations for Orienting by Language Group and Activation Status.

Monolingual		Bilingual	
Activated	Non-Activated	Activated	Non-Activated
63.33 (30.18)	49.11 (35.23)	48.91 (28.82)	55.35 (33.22)

For the executive attention index, there was a significant main effect of TONI, F (1, 231) = 9.69, p < .01, MSE = 24716.99, η^2 = .040. TONI scores and executive attention index were negatively associated, r = -.207, p < .01.

Chapter 4: Discussion

The long-term goal of this research is to better understand and characterize the “bilingual advantage” so that educational and child care institutions begin to recognize and encourage the active use of two languages to strengthen cognitive development in minority populations. This study aimed to explore the bilingual advantage by attempting to replicate and expand on previous studies. To ensure comparability to previous studies, methods used in previous studies were also used in this study. Moreover, two methodological refinements were incorporated. First, a comparatively large sample (determined by a power analysis) was used to ensure the validity of the findings. Second, using well-standardized measures of English and Spanish proficiency, specific criteria were developed to quantitatively define “active bilingualism”, and these criteria were used as the primary subject inclusion criteria. Following on the results of past studies, it was predicted that as compared with monolinguals, bilinguals would perform better on the Simon Task, ANT, and Task Switching Task.

This study also attempted to extend the field of study on the “bilingual advantage.” To do so, methodology was developed to attempt activation in the laboratory (experimental manipulation) of what might be referred to as the “switching benefit.” It was reasoned that if switching between languages over the long-term produced beneficial changes in cognitive ability, then a laboratory task mimicking everyday language switching administered immediately before a target cognitive task, might be expected to produce immediate and measurable performance benefits on the cognitive tasks that followed the language switching activation task. Thus, it was hypothesized that, as compared with subjects receiving a control condition, monolingual and bilingual subjects exposed to the language switching activation task administered between other neurocognitive tasks would realize performance benefits on subsequent neurocognitive tasks. It was predicted that the language switching activation task manipulation would improve performance on the Simon Task, the ANT, and Task Switching Task in bilinguals and in monolinguals.

4.1 Comparison of Results to Past Studies of the Bilingual Advantage

Before examining evidence for the bilingual advantage on the Simon Task, within-subjects effects for accuracy and response time for Simon Task were examined to determine the validity of the performance results. With regard to trial type, there was a significant within-subjects effect for accuracy and response time whereby participants responded faster and more accurately to congruent trials than incongruent trials suggesting that the trial type influenced performance in the expected directions, thus providing support for the validity of the task.

Following on past results, for the main analyses it was predicted that bilinguals would have higher accuracy and faster response time on the Simon Task as compared with monolinguals. No significant differences with regard to accuracy or response time were observed however.

Past studies of the bilingual advantage have frequently used the Simon Task to examine the possible benefits of bilingualism but have yielded mixed results for young adult bilinguals (Prior & MacWhinney, 2010). One study that suggested an advantage for bilinguals (Bialystok, Craik, et al., 2005), included a group of 10 young adult Cantonese-English bilinguals, 10 French-English bilinguals, and 10 English monolinguals (mean age 29 years, range 22-36). Participants were assessed in a magneto-encephalography (MEG) while solving the colored Simon Task. It was found that left and medial prefrontal areas were activated in the three groups, but bilinguals had greater middle temporal, cingulate, and superior and inferior frontal region activity in the left hemisphere as compared to monolinguals. At the same time, only Cantonese-English bilinguals showed an advantage in response time for both congruent and incongruent trials. The authors did not know how to explain the bilingual performance advantage present among only Cantonese-English bilinguals, and suggested that the results might be due to sampling variability.

Similar to the results of this study, there are also studies that have not found evidence of the bilingual advantage among young adults. For instance, in a lifespan developmental study (Bialystok, Martin, et al., 2005) in which children (5 years old), young adults (20-30 years), adults (30-59 years), and older adults (60-80 years) performed the colored Simon Task. It was found that the only group that did not show the bilingual advantage was the young adult group. A difference from the present study was that the number of trials in the Simon Task was smaller in Bialystok's study. In the present study there were 100 experimental trials, whereas Bialystok's study included 80 experimental trials. Thus, the Simon Task in this study consisting of greater number of experimental trials might reflect a more reliable estimate of the mean population, suggesting that a bilingual advantage in young adults is not detectable with the Simon Task. Besides, bilinguals in Bialystok's study were self-identified through a self-report measure without corroboration of an objective language measure. This study used an objective measure of language ability and also selected for "active bilingualism."

In another study by Prior and colleagues (2010), 45 English monolinguals (mean age 18.7 years) and 47 bilinguals (mainly Mandarin, Korean, Spanish, Russian, and Cantonese) (mean age 19.5 years) were evaluated in the color Simon Task and Task Switching Task. For the Simon Task there were no significant differences between the language groups. As compared with the present study which used similar numbers of males and females, most of the sample in Prior's study was females (in the monolingual group there were 32 females out of 45 participants, and in the bilingual group there were 27 females out of 47 participants.) Also, due to the vast diversity of bilinguals in Prior's study (Mandarin, Korean, Spanish, Russian, and Cantonese bilinguals); no objective measure was used to measure bilinguals' language skills.

The present study, which carefully defined active bilingualism and used a large sample size, did not find support for the hypothesis that the bilingual advantage would be found in the Simon Task. It has been previously suggested that one of the reasons why the bilingual advantage seems to be intermittent, or absent, during this age period is because young adults develop enhanced skills for visual information through the constant use of computers, reaching their highest potential and leaving little or no room for bilingualism to enhance cognitive function (Bialystok, Martin et al., 2005; Green & Bavalier, 2003; Prior & MacWhinney, 2010). Considering the several attributes of the present study (discussed in the Strengths and Limitation section in detail), it is possible that the bilingual advantage may be observable under specific task circumstances that the Simon Task does not detect. For example, Miyake and colleagues (2000) have previously proposed that executive control is composed of several executive functions such as updating of working memory, inhibition of distracters, and shifting between mental sets. The most commonly used tasks are the Simon, anti-saccade, and stop-signal tasks, which are representative of the inhibition component of executive function. However the main demand of active bilingualism is to actively switch between languages which may be better characterized by the executive function of shifting of mental abilities (Prior & MacWhinney, 2010). Thus, it is possible that the Simon Task may not be the most sensitive task for assessing the bilingual advantage.

For the Task Switching Task it was hypothesized that bilinguals would obtain smaller switching costs. There was no support for this hypothesis. There are only two studies that have used the Task Switching Task to investigate the benefits of bilingualism in a young adult population, such as college students (Prior & MacWhinney, 2010; Prior & Gollan, 2011). Prior and MacWhinney (2010) evaluated 45 English monolinguals (mean age 18.7 years) and 47 bilinguals (Mandarin, Korean, Spanish, Russian, Cantonese, among other languages) (mean age 19.5 years) in the Task Switching Task, and it was found that bilinguals had a significantly smaller switching cost as compared to monolinguals. Prior and Gollan (2011) evaluated 47 English monolinguals (mean age 20.2 years), 41 English-Spanish bilinguals (mean age 20 years), and 43 English-Mandarin bilinguals (mean age 19.4 years). It was found that the English-Spanish bilinguals, who reported switching languages more often than the English-Mandarin bilinguals, showed smaller task-switching costs.

One possible explanation of the lack of significant difference in switching costs between bilinguals and monolinguals in this study was that the bilingual participants from the study by Prior and colleagues (2010) were significantly older than their monolingual counterparts ($p < .05$, mean age of bilingual participants 19.5 years, SEM = .23; mean age of monolinguals 18.7 years, SEM = .14). Age is an important factor that may influence performance variability within groups. Another important factor to consider is the male and female ratio by language groups which may be a confounding variable. The sample of previous studies was composed mainly of females. In the Prior and MacWhinney (2010) study approximately 64% of the total sample size were females, and in the Prior and Gollan (2011) study 72% of the total sample were females. In the present study the male and female ratio by language group was more balanced; 54% of the total sample was composed of females.

Interestingly, one of the main findings of the present study was that bilinguals were more accurate on single task and non-switch trials than monolinguals, however did not differ with regard to accuracy on switching trials. No previous study has reported differences in accuracy in the Task Switching Task between bilinguals and monolinguals. While accuracy differences were not observed on switching trials, active bilingualism appeared to benefit subjects on single task and non-switch trials. Why this effect was not seen on switching trials requires further study. Higher accuracy rates on single task and non-switch trials supported the idea that active bilingualism may promote enhanced perceptual processes and further, that the lifelong use of two languages and switching on a daily basis between them, can lead to improvements in cognitive function and specifically perceptual processes (Prior & MacWhinney, 2010).

For the ANT it was hypothesized that bilinguals would have more efficient indices of attention, more specifically in alerting and executive control network (Costa, et al., 2009; Costa, et al., 2008). In this study there were no significant differences between bilinguals and monolinguals for the alerting, orienting and executive control network indices. Thus, the present study did not find support for this hypothesis.

There have been only two studies that have investigated the bilingual advantage using the ANT (Costa, et al., 2009; Costa, et al., 2008). Costa and colleagues (2008) found that100 Catalan-Spanish bilinguals (mean age 22 years) were more efficient in the alerting and executive network indices as compared to their Spanish monolingual counterparts (N = 100, mean age 22 years). Similarly, Costa and colleagues (2009) found that 31 bilinguals (mean age 20.3 years) outperformed monolinguals (N = 31, mean age 20.9 years) only in the executive control network index when there were 25% of incongruent trials and during the first block of the task. The authors could not provide an explanation for the lack of significant results in the alerting network index.

One difference between the past and present study was the way the data were analyzed. Costa and colleagues (2008, 2009) analyzed response time differences by task blocks. In the present study data from the 3 blocks were combined and analyzed as one mean value. Analyzing data by block could be something to consider for future data analyzes.

For the ANT, it is important to understand that the indices of each of the different networks were calculated as difference scores. Taking the alerting network index as an example, it was calculated as the difference in response time between no cue trials and double cue trials. The expectation was that when the double cue trial appears, participants would respond faster, because the double cue alerted the subject to respond to the stimulus, unlike the no cue trials which did not provide any information, and thus resulted in a longer response time. There were three possible outcomes for each of the indices of attention: high, low or negative. In this example, a high alerting network index could be obtained when the subject responded slowly to the no cue trials and responded much faster to the double cue trials. The second possible outcome was a low index score. In this situation the subjects could have responded slowly to the no cue trials and stayed slow in the double cue trials. Also, a low index could have been obtained when a subject responded fast to the no cue trials and also fast to the double cue trials. In both scenarios, the difference score would be low because the baseline response time for the no cue trials was very similar to the response time for the double cue trials. And third, a negative index score could have been obtained if the participant responded faster to the no cue trials than to the double cue trials.

It is important to define and understand how a low and high attention index may differ in terms of efficiency in attention indices. A high index score may suggest that there was a big discrepancy between the no cue and double cue trials, meaning that the way the participant processed both types of trials was very different. This may mean that while the participant responded slower to the no cue trials because the stimuli required a longer time to process, the participant experienced a big benefit from the double cue trials and responded to them much faster. Thus the efficiency index score would be large, reflecting the big discrepancy between these two conditions in attention processing. On the other hand, participants with a low attention index would suggest that the subject had good efficiency in the no cue condition and the double cue condition improved their performance only a small amount. In this case, the attention processes involved when solving the double cue trials did not differ much from the no cue trials because both were efficiently processed, thus resulting in a very low index score. It is also possible that a low score is produced when a subject is slow on the no cue condition and also slow on the cued condition. By testing whether "baseline" and cue condition response times differ one can determine whether groups are significantly slower or faster in either of the conditions used to calculate the index score (cued and no cued condition). As a reminder of a previous note, the attention indices are often referred to as efficiency scores because smaller scores are regarded as an indication of greater attention efficiency in alerting, orienting, or executive attention. In this study, monolinguals and bilinguals did not differ significantly with regard to their baseline scores, thus there was no evidence that either group was particularly slower or faster on the no-cue condition.

4.2. Effects of the Language Switching Activation Manipulation: Eliciting the "Bilingual Advantage" in the Laboratory

4.2.1. Manipulation Check of the Language Switching Activation Task

Overall, mean accuracy scores were high on the language switching activation task and ranged from .87 to 1. On most trials, participants correctly named the objects or action pictures during the activated and non-activated conditions. Thus the language switching activation task was not so difficult that participants were not able to complete it correctly. High accuracy scores also suggested that participants were well-engaged in the task.

Significant differences among the overall high accuracy scores were observed with regard to language group and activation status. The difference in mean accuracy scores for the activated and non-activated groups was consistent with the level of difficulty of the task, that is, higher accuracy was observed in the non-activation (no language switching) language task than in the activation language switching activation task. The bilingual non-activated group performed the easiest task (object naming in their preferred language) and scored the highest accuracy. On the other hand, bilinguals in the language switching activation condition (naming objects while alternately switching between languages) had the lowest mean accuracy scores of the four groups. Monolinguals did not differ with regard to accuracy in the activated (switching between naming action pictures and objects receiving the action) and non-activated (naming action pictures) conditions. Based on the mean accuracy scores that bilinguals obtained during the language switching activation condition, it might be inferred that switching between English and Spanish was more cognitively challenging than switching between naming an object and naming an action (the language switching activation task for the monolinguals).

With regard to response time of voice production, the difference in response time between the activation and non-activation conditions showed that participants in the activation condition took longer to produce a response. It might be suggested that participants in the activation condition required more time to access and produce concepts. This in turn may suggest that switching engaged more cognitive resources than naming objects in one language or naming action pictures only. The difference between bilinguals and monolinguals in time of voice production showed that bilinguals responded faster as compared to their monolingual counterparts. These results may suggest that the non-activation tasks for bilinguals and monolinguals may not be equivalent. It appeared that naming objects in one language did not require the same cognitive resources as naming action pictures. It may be that naming action pictures required more interpretation of the visual stimulus and therefore took longer to produce an accurate response. This will be discussed further in the Strengths and Limitation section.

4.2.2. The Effects of "Activation" on Neurocognitive Performance in Monolinguals and Bilinguals.

One of the goals of this study was to determine whether a "switching benefit" could be produced in the laboratory, and whether this might be observed in both monolinguals and bilinguals. The statistical models also allowed examining whether the language switching activation task improved performance on cognitive tasks immediately following the activation, regardless of whether a subject was bilingual or monolingual.

For the Simon Task it was hypothesized that participants in the activated switching condition would have better accuracy and response time performance as compared to those participants in the non-activated control condition. The activation switching task did not have a significant effect on the Simon Task performance.

In the Task Switching Task it was hypothesized that participants in the activation switching condition would perform more accurately and faster as compared to those in the non-activated condition. It was found that monolingual and bilingual participants in the activated condition responded more accurately in the Task Switching Task as compared to participants in the non-activated condition. The activation and manipulation of the "switching benefit" by means of the language switching activation task, consisting of switching between languages (for bilinguals) or within language (for monolinguals), improved accuracy when switching between mental sets. This finding suggested that the intended goal of the activation task, which was to enhance cognitive performance by increasing activation of "switching" pathways in the brain, was achieved.

The practice of switching between languages or within language has been previously studied using brain imaging studies (Hernandez, 2009, Hernandez, et al., 2001). Researchers have concluded that language switching in itself is an executive function. In other words, the practice of language switching activates the dorsolateral prefrontal cortex which is also involved during executive control functions. The present study provided evidence that the effects of a linguistic switching activation task could be observed in a non-linguistic switching task such as the Task Switching Task. It is noteworthy to mention that this "switching benefit" has not been previously studied, and it appears that language switching provides a cognitive benefit not only for bilinguals but for monolinguals as well.

Furthermore, while previous studies have examined the association between language switching and the bilingual advantage in Task Switching Tasks, no one had yet attempted to manipulate it in the laboratory. Prior and Gollan (2011) examined the relationship between language switching and bilingual advantage in two different bilingual groups, Mandarin-English (N = 43, mean age 19.4 years) and Spanish-English bilinguals (N = 41, mean age 20 years) and a group of English monolinguals (N = 47, mean age 20.2 years). Similar to the bilinguals in the present study, all bilinguals had been exposed to both languages before age 6 and had used them since then. They were evaluated on a Task Switching Task (the same used in this study) and in a language switching task. The language switching task was based on the task-switching paradigm containing two single language blocks, followed by three mixed language blocks, followed by two single language blocks. The stimuli were single digits (from 1 to 9), and participants had to name the numbers out loud as fast as possible. Response time and accuracy were assessed. It was found that, after matching for non-English fluency scores, the Spanish-English bilingual group was the only one that showed smaller task-switching costs. One reason that might explain the results was that the Spanish-English bilingual group reported significantly more language switching on a daily basis as compared to Mandarin-English bilinguals. These findings suggested that the bilingual advantage may have its foundations in language switching experience, and not degree of non-English language fluency.

In a similar study (Soveri, Rodriguez-Fornells, & Laine, 2011), 38 Finnish-Swedish older adult bilinguals (mean age 52.8 years, SD = 14.96) were evaluated in a Task Switching Task and a language switching questionnaire. It was concluded that the frequency with which bilinguals switched between languages in their everyday life predicted accuracy in mixing costs in a Task Switching Task. These findings suggested that constant language switching was associated with enhanced executive shifting.

In the ANT it was hypothesized that participants receiving the Language Switching Activation condition would show enhanced attention efficiency (smaller attention index scores) for alerting, orienting and executive attention. For the alerting index, an interaction between language group and activation status was found, and the results suggested that the activation condition had opposite effects in bilinguals and monolinguals. In active bilinguals, the activation condition resulted in greater alerting efficiency as suggested by their significantly lower alerting index score; among monolinguals, the activation condition resulted in lower processing efficiency as suggested by their larger alerting index. The same pattern was observed for the post-activation condition orienting index scores. Thus the activation condition increased attention efficiency in bilinguals, as evidenced by smaller alerting and orienting attention indices, and decreased attention efficiency for monolinguals.

The mean of median response time for the alerting and orienting indices components (double and no cue condition for alerting, and spatial and central cue condition for orienting) were also analyzed. The within group differences substantiated the validity of the cued trials, that is, cued trials (double and spatial cue trials) were solved significantly faster as compared to the baseline conditions (no cue and central cue trials) demonstrating the benefits that these conditions conferred. Moreover, bilinguals and monolinguals performed similarly, in other words, the baseline and cued condition response times did not differ significantly between bilinguals and monolinguals.

The alerting and orienting networks of attention have been mapped to specific brain pathways (Fan, et al., 2002). These findings may provide first evidence that additional studies of the brain pathways that account for these interesting attention differences in monolinguals and bilinguals may provide important new clues regarding the sources of the bilingual advantage.

The present study is the first attempt to manipulate in the laboratory what may be referred to as the "switching benefit." In the present study participants in the activation condition performed more efficiently in the Task Switching Task (accuracy), and had alerting and orienting indices of attention that suggested significantly greater efficiency. These findings, along with previous studies suggesting a significant association between bilingual advantage and language switching, may suggest that the activation manipulation had the intended effect. Also, the findings may reflect the fact that bilinguals experience greater cognitive demands on shifting abilities, as they have to pay attention to the correct cues in the environment (people and places) and decide when and how to switch between their two languages. Thus, the experience of lifelong active bilingualism may lead to enhanced ability to shift between mental sets. Additional studies are needed to further explore these findings.

4.3 Exploratory Analyses: The Influence of Video Game Playing and Non-Verbal Intelligence when Testing for the Bilingual Advantage

Video game playing is ubiquitous among young adults and is known to influence attention, visual perception, and motor response (Bialystok, 2006). Only one previous study has examined the effects of video game playing on the bilingual advantage. Also non-verbal intelligence is frequently used as a control factor in cognitive research however this factor has not been previously considered in studies of the bilingual advantage. In this study, it was attempted to expand the current literature by quantifying these variables and, in exploratory models, examining their effects on the performance of monolinguals and bilingual young adults.

4.3.1. Neurocognitive Tasks

In the Simon Task accuracy there was a main effect of non-verbal intelligence that explained a small amount (2.1%) of the variability. Although this finding is not related to the bilingual advantage, it may be interesting to pursue in future studies. For response time, a main effect for video game playing experience and an interaction between language group and video game playing experience were present. These results suggested that bilinguals who have video game playing experience responded to the Simon Task significantly faster.

These results are similar to those reported by Bialystok (2006). Fifty-seven young adult bilinguals (mean age was 22 years) and 40 monolinguals (mean age was 21.8 years) were evaluated on the arrow Simon Task. Approximately one third of the participants played video games (17 monolinguals, 19 bilinguals). It was found that video game players showed significantly faster response times and bilinguals showed enhanced performance in the arrow Simon Task. The task was manipulated by the number of switches between congruent and incongruent trials. It was found that bilinguals responded more rapidly in the high switch condition (28 switch trials out of 40) than in the low switch condition (15 switch trials out of 40).

Similarly, in the lifespan developmental study from Bialystok and colleagues (2005) approximately half of the participants had video-game playing experience. From the 56 bilingual (Portuguese, Cantonese, Italian, and Tamil) undergraduate students (age range 20-30 years), 22 had computer and video game experience; and from the 40 monolinguals, 18 had computer and video game playing experience. It was found that participants with computer and video game playing experience responded significantly faster to congruent and incongruent trials as compared to those with no computer and video game playing experience.

For Task Switching Task accuracy it was found that, independent of any other factor, non-verbal intelligence was positively associated with accuracy; however only a small amount of variance (1.6%) was explained by non-verbal intelligence. The same language group and activation status main effects that were previously found in the main analyses were also observed in these exploratory analyses. In addition, for response time, there was a main effect of video game experience, suggesting that participants with video game playing experience were faster overall when solving the task. For mixing and switching costs, the main effect of video game playing experience suggested that participants with video game playing experience had lower switching and mixing costs as compared to those who did not have video game playing experience. Others have previously suggested that this benefit comes from constant practice with video games in which young adults constantly practice and exercise interpretation and understanding of the stimuli, producing more efficient and rapid motor responses (Bialystok, 2006).

In the ANT, for the alerting and orienting indices, adding video game playing history and non-verbal intelligence did not make a difference in the results. For the executive index, no significant results were previously found but when adding these two factors in the model a non-verbal intelligence main effect suggested that independent of language group, activation status, and video game playing experience; non-verbal intelligence was negatively associated with executive index. In other words, as non-verbal intelligence scores increased, executive index scores became more efficient (decreased). It is interesting to note that this result substantiates the validity of the executive network index while suggesting links between efficiency of conflict resolution and a more general measure of intelligence.

Thus, when controlling for variables that are not usually included in studies of the bilingual advantage, especially video game playing, it is possible to observe the bilingual advantage in studies with young adults. Video game playing experience and non-verbal intelligence are factors that appear to have an effect on visual perceptual and motor reaction processes. The exploratory analyses suggested that video game playing experience and non-verbal intelligence are variables that must be included in analyses of the bilingual advantage. Video game playing experience is especially important to include in order to see the bilingual advantage.

4.4. Strengths and Limitations of the Study

4.4.1. Methodological Refinements

4.4.1.1. The Importance of Defining "Active Bilingual" Criteria

To date there is no single study that relied on an objective language measure to identify "active bilinguals." Some researchers have assessed verbal abilities in English only and relied on self-reported measures for the second language (Bialystok, 2006; Bialystok, et al., 2008). Others have relied solely on self-report measures (Bialystok, Craik, et al., 2005; Bialystok, Martin, et al., 2005; Costa, et al., 2009; Costa et al., 2008; Prior & MacWhinney, 2010; Prior & Gollan, 2011). The present study collected data only on "active bilinguals" meaning that the bilingual subjects in this study spoke both languages on a daily basis. Relying partially or solely on self-report measures will not ensure the inclusion of true "active bilinguals." Participants tend to be imprecise when answering questions about their language usage. Proof of that was that 57 participants of the potential subjects for this study (approximately 20% of the final sample size) were excluded from this study because they reported being bilingual, but the objective language measure revealed that they were not. In other words, there were many cases in which, by means of the self-reported measure, participants claimed to be "active bilinguals", however when language ability was measured objectively they turned out not to be. Thus relying solely on self-reported measures is not reliable for identifying "active bilinguals" and it is imperative to use an objective language measure.

Thus, the inclusion of "active bilinguals" determined by objective measures allowed us to observe the bilingual advantage that resulted from the daily use and constant switching between two languages.

One of the goals of the present study was to set specific criteria for active bilingualism, and improve the criteria by means of a standardized objective language measure. For this reason, the inclusion screening process for bilinguals was very strict. It was found that the vast majority of the bilinguals in this study (116 out of 124) reported switching between English and Spanish daily and 67 reported doing it since they were 6 years old. Besides relying on the self-report measure on whether or not they speak both languages on a daily basis, the objective measure of verbal ability was the most reliable screening tool for identifying “active bilinguals.” All bilinguals included in the present study scored a relative proficiency index (verbal ability) equal or greater than 50 in both English and Spanish. This score is known to reflect a competent level of fluency in both languages (Mather & Woodcock, 2001). It would have been optimal to recruit bilinguals who started switching between languages since age 6; however a self-report measure that requires the participant to recall age of language usage is likely to be unreliable. For this reason the self-reported measure was corroborated by the objective language measure.

4.4.1.2. Sample Size Considerations

To the best of our knowledge the sample size used in this study, which included 120 monolinguals and 120 bilingual, is one of the largest studies to date that has been conducted to examine the bilingual advantage in young adults. Very similar to this study, Costa and colleagues in 2009 studied a total sample size of 244 undergraduate psychology students (122 monolinguals, 122 bilinguals). This study is almost three times larger than Prior and MacWhinney (2010); and two times larger than Bialystok, Craik, and Luk (2008), and Bialystok (2006). Thus, as compared with other studies with smaller sample size, standard deviations and standard errors in this study were smaller than those reported in other studies (Prior & MacWhinney, 2010) suggesting that the reported findings have improved on the precision of the population estimates of these variables.

4.4.2. Limitations

One of the limitations of the study was that the Language Switching Activation Task for bilinguals and monolinguals may have not been comparable. It was noted that bilinguals named object stimuli faster as compared to their monolingual counterparts, because the activation task for bilinguals required them to name objects in English and Spanish alternately while monolinguals had to name actions or the object receiving the action, including the word “To” before naming the verb or “The” before naming the object. This task may not be comparable to switching between naming an object versus an action which was required of the monolinguals. One possibility is that the monolingual task required more cognitive processing including visual identification of the action, accessing the correct verb that depicted the action, and finally voice production of the correct verb. Nevertheless, this study is the first attempt to manipulate in the laboratory what may be called the switching benefit. The usefulness and validity of the Language Switching Activation task was well supported by previous studies (Hernandez, et al., 2001; Hernandez, et al., 2000) which provided the methodology for this task. Further studies are needed to replicate these findings and also refine these methods for future research.

4.5. Conclusions

The goal of this research was to better understand and characterize the “bilingual advantage”, and thus to identify cognitive factors that could strengthen development in minority populations. The present study is one of the first one to include a very large sample of well-defined “active bilinguals” who, by objective measures, were determined to be bilingual and determined to engage in language switching on a daily basis.

In this large sample of active bilinguals, there was no bilingual advantage on the Simon Task and the ANT. However, the Task Switching Task was able to detect the bilingual advantage in young adults only for the single task and non-switch trials. While no effect was seen for the switch trials, the findings suggested that active bilingualism improved perceptual processes that contributed to increased accuracy.

Future studies could attempt to manipulate features of the Task Switching Task with the goal of increasing its capacity to detect differences on the switching trials.

The Language Switching Activation manipulation condition administered immediately prior to the Task Switching Task promoted the ability to shift between mental sets as evidenced by higher accuracy, in monolinguals and active bilinguals. Additional studies are needed to replicate these findings and refine the Language Switching Activation manipulation condition.

Results from the ANT suggested that the Language Switching Activation manipulation produced an immediate benefit for attention but interestingly, only among active bilinguals. Because this is the first time that the Language Switching Activation manipulation has been attempted, the conclusions presented are purely speculative. The findings may suggest that the brain pathways that are exercised through years of language switching are altered in such a way that stimulation of these pathways improves alerting and orienting forms of attention. Additional studies are needed to explore ways to further enhance attentional performance of active bilinguals.

It was attempted to expand the current literature by quantifying variables, such as video game playing and non-verbal intelligence, which are known to have an effect on visual perceptual and motor reaction processes in young adults. Video game playing may have influenced performance on the Simon Task. The results suggested that bilinguals who have video game playing experience responded to the Simon Task significantly faster. Video game playing experience and non-verbal intelligence are factors that appear to have an effect on visual perceptual and motor reaction processes. The exploratory analyses suggested that video game playing experience and non-verbal intelligence are variables that must be included in analyses of the bilingual advantage.

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Vita

Marisela Gutierrez was born and raised in Ciudad Juarez, Mexico. In the fall of 2005, Dr. Gutierrez completed a Bachelor of Science degree in Psychology from The University of Texas at El Paso (UTEP) and received the Magna cum Laude honor and also the Outstanding Academic Achievement award from the Department of Psychology. In the fall of 2006, Dr. Gutierrez was accepted in the Clinical Master's program at UTEP and graduated in fall of 2009. In fall of 2008, she entered the Health Psychology doctoral program under the supervision of Dr. Christina Sobin in the Laboratory of Neurocognitive Genetics and Developmental Neurocognition.

For several years, Dr. Gutierrez was a critical member of the laboratory's research team that offered free blood lead level testing to children in El Paso Border Region and Juarez, while investigating the negative effects on neurocognitive development of early chronic low-level lead exposure. Findings from these studies helped to develop Dr. Gutierrez's dedication to understanding the cognitive advantages of active bilingualism in minority children. During her graduate studies, Dr. Gutierrez has collaborated with her mentor and other investigators on several peer-reviewed research publications. Dr. Gutierrez has presented her research at local, national, and international conference meetings and workshops including the HHDRC Summer Institutes in El Paso, the Association for Psychological Science, and the International Neurotoxicology Conference. Dr. Gutierrez has been the recipient of numerous research grants including a dissertation fellowship from The Hispanic Health Disparities Research Center (HHDRC). Dr. Gutierrez also served as an Assistant Instructor for the Department of Psychology for one year.

The title of Dr. Gutierrez's dissertation is *Strengthening Cognitive Development in Minority Populations: A study of the Beneficial Effects of Active Bilingualism*, supervised by Dr. Sobin.

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