The Bilingual dilemma: Inhibiting Interference and its Effect on the Bilingual Advantage

El dilema bilingüe: Inhibir la interferencia y su efecto en la ventaja bilingüe

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Abstract

A debated topic in the bilingualism field is if there is an advantage for bilinguals in terms of executive functions (EF). EF are an assemblage of mental processes and self-regulation skills including both basic and higher-level cognitive processes such as inhibition, working memory, monitoring, task shifting, updating, working memory capacity, planning, flexibility, and reasoning. This study investigated whether there was an inhibition control advantage for highly proficient Spanish-English late bilingual adults, compared to Spanish-speaking monolingual adults in Bogotá, Colombia. The study utilized the Victoria version of the Stroop Task (Stroop, 1935) to measure the abilities of inhibitory control between the two groups, in addition to other measures to determine second language proficiency levels. A total of 21 monolingual and 20 bilingual participants between the ages of 20 to 38 took part in the study. Results showed that there was no significant difference in response times between the bilingual and monolingual participants when performing the Stroop task. The implications of these results, the limitations of the study and recommended changes for future studies, which could potentially demonstrate a bilingual advantage, are discussed.

Key Words: Age of acquisition, bilingualism, code-switching, executive functions, inhibition control.

Resumen

Un tema debatido en el campo del bilingüismo es si existe una ventaja para los bilingües en términos de funciones ejecutivas (FE). Las FE son un conjunto de procesos mentales y habilidades de autorregulación que incluyen procesos cognitivos básicos y de alto nivel como inhibición, memoria de trabajo, monitoreo, cambio de tareas,

actualización, capacidad de memoria de trabajo, planificación, flexibilidad y razonamiento. Este estudio investigó si existía una ventaja en el control de la inhibición para los adultos bilingües español-inglés altamente competentes, en comparación con los adultos monolingües hispanohablantes en Bogotá, Colombia. El estudio utilizó la versión Victoria de Stroop Task (Stroop, 1935) para medir las habilidades de control inhibitorio entre los dos grupos, además de otras medidas para determinar los niveles de competencia en un segundo idioma. Un total de 21 participantes monolingües y 20 bilingües de entre 20 y 38 años participaron en el estudio. Los resultados mostraron que no hubo diferencias significativas en los tiempos de respuesta entre los participantes bilingües y monolingües al realizar la tarea de Stroop. Se discuten las implicaciones de estos resultados, las limitaciones del estudio y los cambios recomendados para estudios futuros, que potencialmente podrían demostrar una ventaja bilingüe.

Palabras Clave: Edad de adquisición, bilingüismo, cambio de código, funciones ejecutivas, control de inhibición.

INTRODUCTION

The purpose of this study is to contribute to the existing literature in the bilingualism field by investigating a specific feature of the executive functions in a setting that has not had similar studies conducted in the past. Colombia, as a country with a growing Spanish-English bilingual population, has not been a common destination for bilingualism studies. Understanding the extent of differences between the cognitive processes of bilinguals and monolinguals is key for preparing future strategies and policies for this growing population. This study examines whether Spanish-English bilinguals have an inhibition control advantage compared to monolinguals, in an adult population of highly proficient late bilinguals as evidenced through the Victoria version of the Stroop task in Bogotá, Colombia.

1. Theoretical framework

1.1. Executive functions and inhibition control

Recently, there has been a growing interest in investigating whether bilinguals have an advantage in executive functions (EF) when compared to monolinguals. EF are a set of general purpose control mechanisms that regulate the dynamics of human cognition and action (Miyake & Friedman, 2012). More specifically, EF include both basic and higher-level cognitive processes such as inhibition, conflict resolution speed, working memory, monitoring, shifting, updating, working memory capacity, and reasoning (Von Bastian & Souza, 2016). EF also includes memory, supporting repetitive actions, adjusting to new situations, and inhibition control, which are all necessary for learning and maintaining a new language. (Paap, Johnson & Sawi, 2015). It has been proposed that bilinguals have EF advantages thanks to enhanced inhibition control, which results in greater mental flexibility while attempting to organize incoming conflicting information (García-Pentón, García, Costello, Duñabeitia & Carreiras, 2016).

Regardless of the linguistic environment in which a proficient bilingual speaker finds him/herself, both languages are activated during linguistic processing which creates conflict between the two languages and makes the entire process more cognitively demanding (Kroll, Dussias, Bogulski & Valdes-Kroff, 2012). The prevalence of parallel cross-language activation has been demonstrated for highly proficient bilinguals in both spoken production and visual recognition (Kroll & Bialystok, 2013). Two ways that bilinguals combat language conflict is through language selection and inhibition control. Bilinguals are skilled at selecting wanted stimuli from their working memory while inhibiting the unwanted ones (Bialystok, Craik & Luk, 2012). An inhibitory control system aids bilingual speakers in avoiding intrusions from the undesired language (Green, 1998). Code-switching occurs when speakers mix their known languages and adapt words from one language for the purpose of using them in the context of another language. Bilingual speakers who use both languages consistently in their daily lives have shown a propensity to perform tasks that involve code-switching more accurately and quickly (Beatty-Martínez & Dussias, 2017). Because bilingual speakers are accustomed to frequently utilizing different languages and preventing interference between the two, bilinguals may experience enhanced mental flexibility, which could give them an advantage over monolinguals who are not as accustomed to managing this kind of conflicting linguistic information in their daily lives. (García-Pentón et al., 2016).

One way that bilingual speakers manage language interference is through inhibitory control. Inhibitory control allows an individual the ability to perform a prolonged activity without succumbing to unwanted distractions (Diamond, 2006). Inhibition is necessary during language switching because bilingual speakers must select the target language and inhibit the unwanted language depending on the speaker's required social interaction. An extensive review of control processes and language switching in previous works naming experiments (Declerck & Philipp, 2015) supported the claim that if a bilingual speaker can successfully switch from one language to another, while avoiding undesired intrusions from the non-target language, then the speaker has a high level of inhibitory control. Bilinguals have demonstrated higher levels of inhibitory control when compared to their monolingual counterparts in experiments measuring inhibition control as evidenced by the Stroop and Simon task (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Poarch, Luo & Craik, 2014).

1.2. The bilingual advantage

The bilingual advantage hypothesis is the idea that bilinguals train the EF everyday through more multiple language interactions than their monolingual counterparts, and hence have advantages when performing non-linguistic tasks (Bialystok et al., 2012). This has been shown in several studies, some of which demonstrate a clear advantage for bilinguals in EF and cognitive control, but such advantages are not a foregone conclusion. Cognitive control is the ability to selectively focus on relevant goal

dimensions in our environment and is important for both our adaptive and flexible behavior (Kalanthroff, Davelaar, Henik, Goldfarb & Usher, 2017). While the capacity for cognitive control varies significantly across individuals (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000), cognitive control advantages have been shown via an individual's inhibition control across various age groups for bilinguals (Costa, Hernández & Sebastián-Gallés, 2008). Among bilinguals, two common indicators in measuring one's proficiency, which is a key factor when attempting to confirm the eligibility of bilingual participants, is the age of acquisition (AoA) and the amount of second language (L2) usage. AoA and L2 usage could be major components in the perceived bilingual advantage, leading to better performances in both speed and accuracy of bilinguals' cognitive responses (Green, 1998; Costa, La Heij & Navarrete, 2006).

1.3. Age of Acquisition (AoA)

One of the key components of the bilingual experience is the AoA of a L2. Once Lenneberg's (1967) Critical Period Hypothesis was introduced, the role that age plays in L2 acquisition gained an increasing interest. The hypothesis proposes that humans are predisposed to acquire language in the early years of life, and that this predisposition is diminished at the onset of puberty around the age of twelve (Lenneberg, 1967). Since then, the relationship between age and language has been shown as complex and variable for each individual. There are dynamic interactions for each L2 learner that exist among cognitive, oral, and contextual variables. In fact, Birdsong (2009) groups said variables together into a 'metavariable,' which encompasses both neural and cognitive development and is difficult to quantify when comparing adult L2 acquisition and child first language (L1) acquisition.

A benchmark study by Krashen, Scarcella and Long (1982) found that adults are superior to children in how fast they acquire their L2 regarding syntax and semantics. While the initial rate of acquisition may favor adults or older children, the ultimate level of language attainment, or the level at which a speaker reaches near native like proficiency, favors children rather than adults (Felix, 1985). Because adults and older children already have a solid knowledge base of their L1, their processes of learning a L2 will be inevitably different from the ones of younger children. Changes in brain organization could also affect both how the brain functions and how efficiently it operates. Neurological and cognitive changes in adult L2 learners have been hypothesized upon, including increases in neurofunctional specificity, varying degrees of synapse maintenance, shrinking brain volume, hemispheric organization, and declining dopamine levels, among other neurotransmitter interactions (Birdsong, 2009). More recently, the brain's 'plasticity' has been identified as another distinct possibility. As people age, the brain loses some of its ability to be molded. In terms of L2 AoA, neurochemical and hormonal fluctuations, neurological maturation, and

cognitive function all affect an adult's language learning ability. In simpler terms, a child's brain is more 'plastic' than an adult's one, allowing them to retain language function (Birdsong, 2018).

Age not only influences how a L2 is learned, but also the performance in cognitive tasks that measure inhibition, which can be seen in various empirical studies. For example, one study aimed to determine whether the inhibition control of 290 healthy adults between the ages of 25-80 and 32 adults with Alzheimer's disease were influenced by a variety of factors, with age being one of them. To measure inhibition control, the researchers applied the Stroop task and found that the healthy adults began to experience increased response times (RT) from 44 years old and onward because of a decline in attention and overall EF functionality (Soares, 2009). RT in tasks has been associated with measuring the decline of EF due to age. Older participants between the ages of 60-80 demonstrated a decline in their ability to complete the Stroop task regardless of whether the participants were bilingual or monolingual (Bialystok, 2009). Another study investigated if 88 experienced Japanese learners of English with a relatively high AoA (16-40) could be predictive of L2 oral proficiency (Saito, 2015). They found that both young and older adult English learners were equally subject to age effects both before and after puberty.

1.4. Bilingualism and conflicting results

It remains unclear to what extent bilingual advantages can be detected in individuals who acquire their L2 in late childhood or adulthood (Vega-Mendoza, West, Sorace & Bak, 2014). Early bilinguals may develop different language networks from those of late bilinguals or monolinguals, specifically by connecting more areas of the executive control network (Hernández, 2009). The supposed assimilation of such network areas could theoretically provide early bilinguals with better cognitive abilities than late bilinguals due to increased interconnectivity. This has not been completely proven nor disproven from previous bilingualism studies, although, varying AoA have produced conflicting results. Some have only found advantages in early-acquisition bilinguals who performed a flanker task (e.g., Luk, De Sa & Bialystock, 2011), while others have shown advantages in late-acquisition bilinguals in a picture naming (lexical access) task (e.g., Pelham & Abrams, 2014). Depending on the author, AoA could refer to the onset of active bilingualism (Luk et al., 2011), the age of L2 production (Kapa & Colombo, 2013), the age of first exposure to L2 (Kalia, Wilbourn & Ghio, 2014), or the age of L2 fluency (Pelham & Abrams, 2014). Because studies in bilingual advantages have been conducted under the assumption of specific bilingual experiences, categorizing terminology differently has led to conflicting results due to methodological inconsistencies in classifying the AoA of the studies' participants.

In some cases, these conflicting results lacked a purely monolingual group for comparison, used a variety of languages across tasks, or did not fully delve into the

frequency of language use in the participants' daily lives (Von Bastian & Souza, 2016). In addition to recorded negative results, it is possible that if there is a bilingual advantage in the EF, it is minimal or has been overrepresented by previous studies. Paap et al. (2015) clarifies that previous psychological surveys have shown a high number of case studies that did not confirm the proposed hypothesis and, as a result, were not published. They found that only 52 out of 104 abstracts presented at conferences regarding the topic of bilingual advantages were later published. Of these 52 published articles regarding bilingual advantages, 68% favored the bilingual advantages while 29% clearly challenged the hypothesis, with the remaining percentages representing mixed results (De Bruin, Treccani & Della Sala, 2015). Similarly, a 2019 systematic review of bilingual advantage studies found that 53.3% favored the advantage, 28.3% reported mixed results, and 17.4% challenged the existence of an advantage (van den Noort, Struys, Bosch, Jaswetz, Perriard, Yeo, Barisch, Vermeire, Lee & Lim, 2019). Paap et al. (2015) attributed the phenomenon to small sample sizes or manipulated data to demonstrate favorable results. Van den Noort et. al. (2019), on the other hand, attributed the mixed results to methodological differences including the implementation of non-standardized tests, ignored participant variables, and a lack of longitudinal designs.

Evidence of such bilingual advantages have been demonstrated in some cases. Pelham and Abrams (2014) conducted an experiment with ninety (n = 90) participants who were divided into groups according to their proficiency and AoA (30 monolinguals, 30 early Spanish-English bilinguals, and 30 late English-Spanish bilinguals), and found that EF advantages were present in the bilingual groups regardless of AoA. Differences were identified based on L2 proficiency levels and usage rates of both languages, indicating that these measures could be more significant when searching for the bilingual advantage instead of only investigating the relationship between AoA and the bilingual advantage.

1.5. The stroop task

With the potential factors contributing to previous mixed results in established bilingualism studies, the next step was to select a suitable task for measuring inhibition control in the bilingual and monolingual participants. Stroop's task has been utilized for inhibition and interference, among other neurophysiological functions (Stroop, 1935). The original task consisted of three stimuli: naming words of colors in blank ink, naming words of colors in a contrasting/incongruent ink color and naming the colors of filled in squares. Stroop noticed that participants had slower RT with the contrasting words of colors in different color tints compared to the other stimuli. He explained that this phenomenon exists due to the interference created from the automation of reading semantically, therefore one must employ inhibition to combat the process.

Since the original task's first implementations, many variations have been developed. For the purposes of this study, a classic color-word version was employed, named The Victoria Stroop Task (VST). The VST consists of three stimuli conditions: the dot (control), the congruent, and the incongruent. The task instructs participants to identify the ink color in which words are printed. In the dot condition, there are filled in circles and the participant must identify the color. In the congruent condition, words of colors are written, and the color tinting matches the words. Finally, in the incongruent condition, the word and the color tinting do not match.

The contrasting written word and printed color creates interference, also known as the Stroop Effect. The Stroop Effect occurs when the relevant dimension of color naming interacts with the irrelevant one of word reading, which produces overlapping and intrusive responses (Khng & Lee, 2014). This effect was identified by Costa et al. (2006) as possibly the most often cited evidence of coactivation of the two lexicons and the resulting interference between the two as a cross-language Stroop Effect in bilingual contexts. This effect demonstrates that people often have difficulty ignoring the temptation to read instead of focusing on color identification (Eidels, Algom & Williams, 2014). When comparing this to the congruent condition of the task, the incongruent condition typically takes participants longer to respond. The additional time that is taken in the incongruent condition compared to the congruent condition is referred to as Stroop Interference (Bugg, Jacoby & Toth, 2008). Participants also typically commit more intrusions in the incongruent condition of the task than the congruent. Intrusions occur when participants incorrectly indicate the written word instead of the printed ink color.

Despite the instructions stating that the participants must focus solely on the colors, task-irrelevant information is also processed which creates an interference conflict (Kalanthroff et al., 2017). Inhibition control and the Stroop effect are measured by examining the interference conflict via the differences in the speed of responses, and the accuracy of responses between the congruent and incongruent conditions of the task. Bialystok makes the distinction that the Stroop task is a difficult one, to explain that simpler tasks used to measure EF do not always produce favorable results that demonstrate an EF advantage for bilinguals. In the study (Bialystok et al., 2014), participants performed the Stroop task and bilinguals in both age groups showed less interference than monolinguals. The authors justified their task selection, stating that tasks involving slower and more effortful processing are more likely to show group differences and bilingual advantages (Bialystok et al., 2014).

The distinction of using complex tasks to demonstrate the proposed advantage for bilinguals is important because better performance of the EF should facilitate better execution of more complex tasks and demonstrate how bilinguals process conflicting information compared to monolinguals. It has been hypothesized that the Stroop task involves a high demand on executive control through inhibition and switching

between languages which is a common occurrence associated with bilingualism (Green, 1998). On the other hand, Paap et al. (2015) identified that in nonverbal tasks the interference score, or measure of inhibitory control, was only shown as having a significant bilingual advantage in 13 of 64 tests (20.3%).

Another relevant example of a Stroop task implementation comes from Bialystok, Craik and Luk (2008), who used the Stroop task in trials with both younger and older bilinguals and monolinguals. Switching costs between congruent and incongruent conditions were lower in both bilingual groups compared to the monolingual group. Similarly, another VST implementation found that the task is a reliable measure for bilingual participants and that age is a key indicator of performance, concluding that the 16-17 year old group outperformed the younger groups (Malek, Hekmati & Amiri, 2013). Contrarily, the VST was implemented with Chinese-English bilinguals and English monolinguals, but the results were non-conclusive (Lee & Chan, 2010). Because differing language interactions, participants ages, Stroop task versions, L2 proficiencies, among other factors vary greatly between bilingual populations, it is a reasonable assumption that different combinations of language profiles could produce different results in the task.

The current study implemented the VST that has been utilized in many settings, age groups, and language combinations thanks to its duplication in numerous languages and its availability in an electronic format. The VST (Regard, 1981) has been implemented in various experiments over the last several decades and is used for measuring selective attention, inhibition control, and most commonly, for analyzing executive brain functions (Malek et al., 2013).

2. Research question and hypothesis

Arguments have now been made for and against the bilingual EF advantage, and more specifically, a bilingual advantage in inhibition control. The following research question is therefore proposed: What is the difference in inhibition control between highly proficient late bilingual adults and monolingual adults as evidenced through the Victoria Stroop task in Bogotá, Colombia?

It was hypothesized that on one hand, highly proficient late bilinguals could have a faster response time than monolinguals when performing the Stroop task due to their heightened ability of inhibition control thanks to using this mechanism more often than monolinguals (Bialystok et al., 2014). On the other hand, monolinguals may have experienced less interference due to being proficient in only one language when performing the Stroop task, which may result in them responding more quickly (de Bruin et al., 2015; Paap et al., 2015).

3. Method

3.1. Participants

The total number of participants (n = 41) was deemed appropriate based on the previous critique of studies provided by Paap et al. (2015), in which the authors noted that bilingual advantages principally occurred when the sample size was less than 30 total participants. The first group of participants consisted of Spanish-English bilingual teachers of English who were between the ages of 21-37 (n = 21; 12 males and 9 females; mean (M) age of 29.33 and standard deviation (SD) of 4.82). Participants in this study were all native Spanish speakers, who acquired English as their L2 after the age of 15, were actively teaching English at the time of the study and were considered highly proficient based on their scores from international certifications of English proficiency (e.g., TOEFL, IELTS, etc.). That is not to say that the bilingual participants were wholly homogeneous in nature. Variance in L1 and L2 dominance scores.

The participants were classified as 'late learners'. Late learners of a L2 are often considered to be between the ages of 12 to 20 and beyond at the time of acquisition (Abrahamsson, 2012). Among studies comparing bilinguals and monolinguals, few have examined older age groups who are physically, mentally, and emotionally healthy, and even fewer have examined the difference between a monolingual group and a bilingual group who acquired their L2 after the age of 15.

The second group of participants (n = 21; 9 males and 12 females; were between the ages of 20-38; M age of 27.29 and SD of 15.49) consisted of monolingual adults who had a shared native language of Spanish. Further demographic information can be seen below in Tables 1 and 2. One monolingual participant was classified as an outlier after a Z-score analysis of all participants yielded a result of z = 3.65 from a raw RT of 1,145ms in the incongruent condition of the task and was subsequently removed. The remaining Z-score analysis did not generate any other scores either below -3.0 or above 3.0. Therefore, the final number of monolingual participants in the following data analysis is twenty (n = 20) without any change to the number of bilingual participants (n = 21). The instruments described below were used to gather more demographic information on the participants.

3.2. Instruments

3.2.1. Questionnaire

The questionnaire included questions regarding the participants' physical, psychological, and mental health in addition to questions regarding their parents' education. These data were used to determine how these factors contributed to the participants' performance of the Stroop task and were used to attempt to draw further

correlations between the participants' demographic information and their ability to perform the task.

3.2.2. Bilingual Language Profile

The Bilingual Language Profile (BLP) is a questionnaire that has a built-in formula for calculating language dominance in various language combinations (Birdsong, Gertken & Amengual, 2012). The BLP was used to ensure that the bilingual participants acquired English as a L2 after the age of 15 and that the monolingual participants did not have any self-perceived knowledge of English as a L2. The BLP has four modules focused on: general demographic information, linguistic history, language use, competencies, and attitudes towards both languages. Larger numbers in each category indicated more language exposure, greater language use, higher language proficiency, and a more positive attitude towards the languages in question. All categories were then aggregated to produce one mean score for each language. From the two mean scores, dominance scores are generated to provide an idea of the self-perceived difference in language proficiency between the native language and the L2. A high dominance score demonstrated that the participants' perception of their own proficiency in their native language was significant over their L2.

3.2.3. Victoria Stroop Task (VST)

The VST, as an adapted version of the original Stroop task, consisted of the three conditions previously described. For this version on the computer, the first two screens were instructions, followed by a screen in which the participant could take a moment to familiarize themselves to which numbers (1-4) on the keyboard corresponded to each color (red, green, blue, and yellow). The fourth screen was the dot condition and intended for the participants to practice pushing the correct buttons. The final two screens contained the congruent and incongruent conditions, respectively. Each condition consisted of 24 trials. The VST was administered via the software Psychology Experiment Building Language (PEBL), which is an open-access software used for running psychological experiments (Mueller & Piper, 2014).

3.3. Experimental procedures

This study was approved by the Ethics Committee in the Education Department at *Universidad de Los Andes*. The experiment was conducted with one participant at a time in a room without any visual or auditory distractions. Each participant was instructed to read and sign a consent form followed by a general questionnaire and BLP.

The computer version of the VST was then administered with the Spanish monolingual group only completing the VST in Spanish, while the bilingual group completed the VST in both Spanish and English. The Spanish and English VSTs for the bilingual group were separate and not mixed between individual conditions of

each task. The order of the language used in the VST for the bilingual group was counterbalanced.

4. Results

4.1. Full scale experiment – demographic & Stroop task results

The bilingual group's dominance score from the BLP (M = 58.13, SD = 26.74), was closer to 0, indicating a more balanced bilingual language profile than the dominance score of the monolingual group (M = 154.47, SD = 15.49), as demonstrated in Tables 1 and 2. Of the 21 bilingual participants, 2 participants identified themselves as being balanced bilingually with dominance scores near zero (≤ 20 and ≥ -20). The remaining participants all identified themselves as being Spanish dominant with a score greater than 20. The proficiency levels of the bilingual participants were crosschecked from their BLP English mean scores and their English international proficiency certificates, to ensure that all participants were at least equal to level B2 (upper intermediate) in English proficiency based on the definition provided by the Common European Framework of Reference for Languages (Council of Europe, 2011). The monolingual participants, on the other hand, all identified themselves as being Spanish dominant. Monolingual participants were also required to complete the English proficiency section of the BLP to ensure that their English proficiency levels would classify them as true monolinguals.

The bilingual participants' various standardized English exams confirmed that all participants were proficient, with 12 participants being classified as C1 and the remaining 9 being classified as B2. A cross analysis of the BLP along with the bilingual's English exams validated that all participants were proficient in the L2 both in their perception of their own abilities as well as in a standardized language assessment. That is not to say that the bilingual participants were wholly homogeneous in nature. L1 and L2 dominance scores, education, type of language test, and subsequent scores demonstrate that the bilingual participants, while all meeting the required parameters, also showed signs of variance commonly found in bilingual advantage studies.

Table 1. Bilingual participants' demographic information, BLP scores & English international exam proficiency scores.

ID	Age	Sex	Born	Home Language	AoA	Education	English Proficiency	Spanish Proficiency	Dominance	Education - Mother	Education - Father	Language Proficiency Test	Language Proficiency Test Score
b1	35	m	Colombia	Spanish	20+	Masters	97	195	98	Some University	University	TOEIC	985 = C1
b2	29	m	Colombia	Spanish	28	University	104,97	176,53	71,56	Some University	Some University	MET	104 = B2
b3	35	f	Colombia	Spanish	17	University	124,49	181,07	56,58	High School	High School	IELTS	7.5 = C1
b4	25	f	Colombia	Spanish	23	Masters	78,27	175,53	97,26	University	Masters	TOEFL	110 = B2
b5	31	f	Colombia	Spanish	20+	University	97,61	181,62	84,01	High School	High School	IELTS	6.5 = B2
b6	34	m	Colombia	Spanish	17	Masters	119,14	168,63	49,49	Some University	NA	IELTS	7.5 = C1
b7	37	m	Colombia	Spanish	20+	University	110,69	166,27	55,58	High School	High School	EFSET	93% = C1
b8	35	m	Colombia	Spanish	17	Masters	105,88	189,24	83,37	High School	High School	EFSET	94% = C1
b9	30	f	Colombia	Spanish	20+	University	127,04	163,54	36,5	Primary School	Primary School	MET	125 = B2
b10	31	m	Colombia	Spanish	20+	Masters	132,94	126,31	6,12	Masters	Masters	IELTS	7.5 = C1
b11	24	m	Colombia	Spanish	16	University	116,78	152,01	35,23	High School	Primary School	IELTS	6.5 = B2
b12	25	f	Colombia	Spanish	16	University	115,78	165,63	49,85	University	Some University	MET	115 = B2
b13	21	m	Colombia	Spanish	16	University	106,06	171,44	65,38	High School	NA	EFSET	93% = C1
b14	23	f	Colombia	Spanish	19	University	100,98	152,1	51,12	Some University	Some University	IELTS	6.5 = B2
b15	25	m	Colombia	Spanish	20+	University	116,5	159,55	43,04	Some University	University	MET	146 = C1
b16	24	f	Colombia	Spanish	15	University	141,66	141,11	0,55	Some University	Some University	TOEIC	935 = B2
b17	32	m	Colombia	Spanish	17	University	117,41	159,82	42,41	Some University	NA	IELTS	7.5 = C1
b18	36	m	Colombia	Spanish	20+	University	101,61	184,88	83,27	High School	Masters	TOEIC	950 = C1
b19	27	m	Colombia	Spanish	20+	University	99,34	181,61	82,27	High School	High School	TOEFL	105 = C1
b20	29	f	Colombia	Spanish	18	University	85,9	155,83	69,92	University	University	TOEFL	95 = B2
b21	28	f	Venezuela	Spanish	15	Masters	116,32	174,26	57,94	University	Some University	TOEFL	98 = B2
M:	29.33				16.5		110,3	167,7	58,07				
SD:	4.82						15,11	16,51	26,74				

Table 2. Monolingual participants' demographic information and BLP scores.

ID	Age	Sex	Born	Home Language	Education	E Proficiency	S Proficiency	Dominance	Education - Mother	Education - Father
m1	25	m	Colombia	Spanish	University	48,76	202,78	154,02	Some University	Some University
m2	20	f	Colombia	Spanish	University	39,14	194,24	155,1	High School	High School
m3	30	m	Colombia	Spanish	University	33,14	203,41	170,27	High School	Some University
m4	21	m	Colombia	Spanish	High School	17,25	186,61	169,36	High School	High School
m5	37	f	Colombia	Spanish	Some University	48,94	211,67	162,73	Primary School	Primary School
m6	26	f	Colombia	Spanish	University	44,13	194,24	150,11	High School	High School
m7	24	m	Colombia	Spanish	Some University	58,66	204,23	145,57	High School	High School
m8	32	m	Colombia	Spanish	University	25,42	187,98	162,55	High School	High School
m9	37	f	Colombia	Spanish	University	25,88	197,06	171,18	Primary School	Primary School
m10	20	f	Colombia	Spanish	Some University	49,03	204,32	155,29	High School	High School
m11	20	m	Colombia	Spanish	Some University	51,67	186,7	135,04	High School	Some University
m12	25	f	Colombia	Spanish	University	39,68	180,98	141,3	High School	High School
m13	28	f	Colombia	Spanish	Some University	19,25	185,52	166,27	Primary School	High School
m14	25	f	Colombia	Spanish	Some University	8,08	198,51	190,43	High School	High School
m15	31	f	Colombia	Spanish	University	32,23	189,79	157,56	High School	High School
m16	20	f	Colombia	Spanish	University	78	192,6	114,6	Some University	High School
m17	24	f	Colombia	Spanish	University	55,3	198,51	143,21	High School	High School
m18	38	m	Colombia	Spanish	University	53,57	202,05	148,48	Primary School	Primary School
m19	24	m	Colombia	Spanish	University	43,58	194,79	151,2	High School	High School
m20	34	m	Colombia	Spanish	University	52,66	199,78	147,12	High School	Some University
m21	32	f	Colombia	Spanish	University	54,93	207,5	152,56	High School	High School
M:	27.29					41,87	196,35	154,47		
SD:	5.99					16,45	8,09	15,49		

The experimental Stroop task measured the participants' ability to respond as quickly as possible to the inputs presented before them. The inputs were divided into three conditions: dot, congruent, and incongruent.

4.2. General performance measure
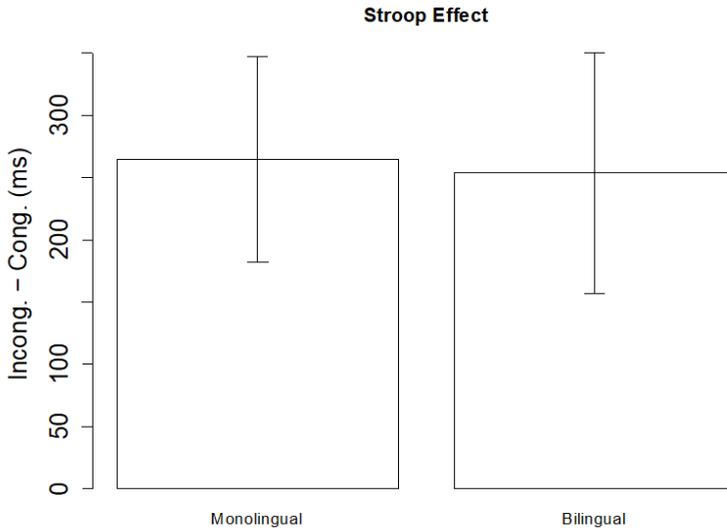
Stroop Effect

Figure 1. Stroop effect in monolinguals and bilinguals based on RT. Error bars are SEM.

The general Stroop task performance measure shows the RT in the congruent and incongruent experimental conditions of the Stroop task in Spanish for both groups (Figure 1; Monolingual M = 264.80 ms, SD = 385.01; Bilingual M = 253.53 ms, SD = 448.99). It demonstrated a Stroop effect: bilingual participants were faster in the congruent condition (M = 1520.76 ms, SD = 352.94) than the incongruent condition (M = 1774.30 ms, SD = 620.34). Similarly, the monolingual participants were faster in the congruent (M = 1340.39 ms, SD = 321.13) than the incongruent condition (M = 1605.20 ms, SD = 607.79).

An ANOVA on the RTs of the Stroop task in Spanish for both groups of participants tested the hypothesis that bilinguals would respond faster in both the congruent and incongruent conditions of the task. The ANOVA used experimental condition (congruent, incongruent) as a within-subject factor and group (monolingual, bilingual) as a between-subject factor. The analysis yielded a significant effect between the experimental conditions of the task ($F_{(1, 40)} = 16.12$, $p < 0.001$, $\eta^2_g = 0.067$; effect size is the generalized eta squared) indicating better performance on the congruent than the incongruent condition. However, the effects of group ($F_{(1, 40)} = 1.58$, $p = 0.21$, $\eta^2_g = 0.031$) and its interaction with the task were not significant ($F_{(1, 40)} = 0.007$, $p < 0.93$, $\eta^2_g < 0.001$), suggesting that the Stroop effect was similar regardless of being monolingual or bilingual. Also, no significant differences were found in bilinguals who did Spanish and English versions of the Stroop task (paired t-test: $t_{(20)} = -1.27$, $p = 0.21$) and none of the regressions controlling for demographics and level of English were significant.

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To further confirm that there were no Stroop effect differences between groups, a two one-sided equivalence test (TOST) was used which, contrary to the ANOVA, determines whether there is sufficient statistical evidence to conclude similarity. This test requires equivalence bounds; or RT differences that can be considered irrelevant. Cohen's d of 0.2 was utilized as it is considered a small effect and the bilingual advantage is typically not especially strong in the prevailing literature using Stroop tasks. Specifically, we compared the Stroop effects observed in Figure 1. The test is akin to a t-test but asks whether there is sufficient evidence to claim that both means are the same (an ANOVA or a traditional t-test only tests if they are different). The equivalence test was insignificant, $t(39.09) = 0.560$, $p = 0.289$, given equivalence bounds of - 82.619 ms and 82.619 ms (on a raw scale). What this means is that there is no statistical reason to conclude that the Stroop effects are identical based on this sample.

Thusly, the bilingual advantage may be weak for the ANOVA to detect, but the equivalence test suggests that it seems to exist. If the raw averages from Figure 1 are examined, bilinguals were roughly 10 ms faster. To detect such a small effect with a two-sample t-test, a power of 0.8, and standard error from the mean of 89 ms, a sample size of 1269 participants in each group would have been needed. The minimum detectable effect size with our sample size is 79 ms. These estimates should be taken with some reservations because they are based on post hoc results (10 ms) and highlight a larger issue: the bilingual advantage may be hard to detect or may not exist in this particular population.

In addition to measuring the RTs of the participants, the PEBL software also automatically calculated the number of intrusions that each participant experienced. They were generated from the incongruent condition of the task only when the participant indicated the response for the written word (for example BLUE) instead of the tinted color (for example RED). Other incorrect responses (such as indicating YELLOW when it is neither the written nor the tinted color) are not included.

Because intrusions are counts, a Poisson regression (Table 3) was implemented. The negative sign of the interaction could suggest a pattern of bilingual advantage: the incongruent task generated more intrusions for monolinguals. However, none of the regression estimates were significant, meaning that monolinguals and bilinguals had the same level of intrusions, although this could be a power issue; see the sample size comments above. Adding additional demographic information and language information did not change the significance nor the overall results.

Table 3. Poisson regression. DV: Intrusions.

	Estimate	Std. Error	z-value	p-value
Intercept	3.200	0.044	72.611	<2e-16
Incongruent Task	0.047	0.062	0.770	0.442
Bilingual (1)	0.027	0.062	0.433	0.665
Task: Bilingual	-0.032	0.087	-0.373	0.709
Akaike Information Criterion: 442.95				

5. Discussion

The results of the current study indicate that bilinguals' inhibitory abilities did not significantly differ compared to the monolinguals ones. However, all participants were faster in the congruent condition than the incongruent, confirming the validity of the experiment itself as a measure of inhibition control. One explanation for the results could be attributed to the bilingual group leaning on selectivity in the task instead of inhibition control to manage the parallel activation in the task. It is possible that the bilingual group do not have better inhibitory control compared to the monolingual group. An explanation for the findings could be infrequent use of code-switching in the bilingual group. Code-switching typically occurs when there is a demand revolving around social, linguistic, or social motivations (Auer, 2013). The bilingual participants in this study have no apparent social motivation for code-switching on a consistent basis because of their two distinct settings, inside and outside of the classroom. The participants are expected to speak and give instruction as much as possible in English in the classroom. Outside of the classroom, the societal norm would be to communicate in Spanish, with little crossover between languages. DeKeyser (2013) clarifies that it is best to find bilinguals who rarely have an opportunity to use their L1 which would promote further cross language transfer and to find participants who are isolated from other speakers of their L1, so that they are using their L2 more frequently. Neither of these suggestions were applied in the current study, and as such, the participants were perhaps not experiencing code-switching, language transfer, and interference to the point at which inhibition control would be needed on a consistent basis. Finally, the ever-elusive metavariable of the bilingual group's L2 AoA could also explain the lack of significant difference in the results, especially if the ease of neurological and cognitive variability between participants is considered.

CONCLUSIONS

There was little notable difference in the performance of the Stroop task between the bilingual and monolingual groups. Both groups responded faster in the congruent condition than the incongruent condition, as consistently shown in any valid Stroop experiment. The number of intrusions between the monolingual and bilingual group did not significantly differ. The bilingual group performed the Stroop task in both

Spanish and English but did not show any significant variation in their performance based on the language used.

Because of the varying results in previous studies and the results presented in the current study, it could also be argued that while learning a L2 does reorganize brain structures, it does not necessarily lead to more efficient performance across all (or any) of the EF. Indeed, the reorganizing could lead to comparable performance with monolinguals or even to inferior performance (Paap et al., 2015). The immense variation of language profiles makes finding a cohesively similar group of bilinguals a challenge. A possible solution for finding participants with similar bilingual experiences could be selecting participants who work as translators or interpreters because they would be code-switching at a high rate. Green (1998) identifies translation as an equivalent task to the experience in the Stroop task, and therefore could result in bilinguals performing better in future experiments.

Further research is needed to replicate the results in similar contexts. The debate of the bilingual advantage remains unresolved based on the data gathered in this study, which did not demonstrate an advantage for the bilingual participants. The growing population of bilingual/multilingual people warrants further investigation into the disputed phenomena of a cognitive bilingual advantage. Future research should consider the multitude of variables present in bilingualism to craft an appropriate research model. Because of the vastness of bilingual combinations present throughout the world as well as the wide array of cognitive experiments available, future research should focus on attempting to replicate experiments that resulted in a bilingual advantage or replicate experiments did not show an advantage. A similar study in the future could be improved upon by finding a group of bilingual participants who are more closely matched linguistically and demographically, using multiple experiments to measure inhibition control, and finding participants who code-switch more frequently. More research is required if we are to fully understand how being bilingual cognitively differs from being monolingual.

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