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Bialystok's Bilingual Advantage Hypothesis: the Case of Spanish-English Bilinguals

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Abstract

Recent studies examining effects of bilingualism on executive function in children and adults have found evidence supporting (a) advantages in executive control and (b) disadvantages in linguistic processing. There is evidence suggesting that bilinguals have better controlled processing and are more efficient at certain cognitive functions. Such findings have led to the hypothesis that there is a bilingual advantage (BA) for various cognitive tasks[6, 4]. Studies examining the BA hypothesis typically time participants as they perform tasks thought to involve executive function. Commonly used tasks include the Stroop, Simon, Anti-saccade, and Flanker. Some researchers hold however that bilingual advantages in executive function either do not exist[16] or are restricted to very specific tasks or experiences[14]. Although existing studies on both sides have made strong claims, there remain gaps in the data and analyses. The present study explored the hypothesis that if bilinguals possess certain cognitive advantages compared to their monolinguals counterparts, then Spanish-English bilinguals would produce faster Reaction Times (RT) than monolinguals in both the Simon and the Flanker tasks. Results showed that, overall, the Spanish-English bilinguals were significantly faster to respond in both the Simon and Flanker tasks than were the monolinguals. However, bilinguals were not significantly faster than monolinguals in the incongruent condition. Thus, the present study's findings are broadly in line with those reported in studies by Bialystok and her colleagues[7,6,8]. Moreover, the monolinguals committed fewer errors compared to the bilinguals. Therefore, a strong version of the bilingual advantage hypothesis was not supported by the results of the present study.

Keywords: bilingual advantage (BA), executive function, inhibitory control

1. Introduction

In the early 20th Century, people believed that if children grew up speaking two or more languages, they would become so confused that their intellectual growth would be cut in half. However, since the 1960s, evidence has been mounting that rather than stunting intellectual growth, bilinguals may actually exhibit several cognitive advantages[21,1,11,18]. Researchers have attempted to demonstrate how bilingualism affects our brains. Over the years, studies have produced several different hypotheses on how the brain is affected when a person uses more than one language. For instance, Ellen Bialystok, a psychologist from York University and one of the leading researchers in this field, says that the bilingual mind is in constant conflict because it has to make quick decisions in order to focus on the targeted language, resulting in a constant need to parse information. This continuous process leaves marks on the brain which, according to her, strengthens the regions of the brain involved in executive function and inhibitory control. According to Bialystok and her colleagues, being bilingual leads to brain changes which can confer advantages in executive function relative to monolinguals. Evidence supporting this "bilingual advantage hypothesis" is now supported by a large community of researchers. However, a growing number of other researchers believe that this hypothesis is built on

weak evidence. According to Kenneth Paap, a psychologist at San Francisco State University, bilingual advantages in executive function "either do not exist or are restricted to very specific and undetermined circumstances[2]."

2. Background

It has been theorized that bilinguals are in continuous mental conflict because they have to make quick decisions in order to center their attention on the targeted language. Recent studies examining the effects of bilingualism on cognition have found evidence that supports the emergence of two propositions: advantages in executive control, a set of cognitive processes which includes problem solving or attentional control, and disadvantages in linguistic processing, including rapid verbal production or picture naming[4, 13].

Bilingualism has often been defined as the ability to express oneself in two languages. However, the degree of someone's bilingualism is extremely hard to determine, because each bilingual is different in terms of their ability to speak, understand, and (if they are literate) read and write their second language, and each is different with respect to their ultimate attainment in the second language both in absolute terms, and in terms of their first language.

Moreover, executive function, also known as cognitive processing or cognitive control, is a term used to refer to several cognitive processes including problem solving, task switching, working memory, and cognitive flexibility, among others. These processes are essential for managing thoughts and behaviors. Consequently, these control processes are partly responsible for achieving daily goals[14]. It has been said that executive function controls and commands all cognitive skills. Furthermore, inhibitory control has been defined as the capacity to inhibit or regulate attentional or behavioral responses[19]. Inhibitory control allows us to focus on relevant stimuli when irrelevant stimuli are present.

Recently, numerous researchers have associated bilinguals with superior performance on tasks which measure executive function[9, 7]. Evidence for this belief has been deduced from tasks including the Simon Task[8] and the Flanker Task[6]. These tasks, among others, are preferred because they require participants to control and resolve conflict to maintain accuracy. Although there is no one task capable of isolating all and only one aspect of executive function, there are tasks which are thought to be useful indicators of certain aspects of it[12]. For example, the Simon task is thought to index inhibitory control without the involvement of a linguistic component[5, 8].

2.1 Previous Research

2.1.1 support for the bilingual cognitive advantage hypothesis

Several studies conducted by Ellen Bialystok and her colleagues point to benefits of bilingualism on executive function. In one such study[6], reaction times from the Simon Task, Peabody Picture Vocabulary Test, Raven's standard progressive matrices, Alpha span Task and Sequence Span Task were used to determine whether the bilingual advantage persists for adults and whether bilingualism attenuates some of the negative effects of aging on cognitive control. Three studies were conducted with groups of younger adults ranging from 38-43 years and older adults ranging from 70-72 years. Participants were English monolinguals and bilinguals who spoke diverse second languages. The results revealed that even though all participants were comparable on measures of verbal and spatial intelligence, bilinguals were consistently faster in the Simon Task on both congruent and incongruent trials. Most importantly, the older bilingual adults' measurements showed a reduction in the age-related reaction-time increase in the Simon effect, which implies that the lifelong experience of using two or more languages attenuates the age-related decline in the efficiency of certain cognitive functions.

2.1.2 counter arguments to the bilingual cognitive advantage hypothesis

Kenneth Paap, the most prominent critic of the Bilingual Advantage Hypothesis, has conducted studies seeking evidence of bilingual advantages in executive function. In one such study[15],three studies compared bilinguals and monolinguals on 15 indicators of executive processing. Each of the three studies includes a series of seven to eight activities, which included the Simon Task, Flanker Task, Eriksen Flanker Test and Color-Shape switching. Between 90 and 110 psychology students participated in each test. Results revealed that there was no evidence for a bilingual

advantage in any of the measures that this study used. Therefore, this study's findings failed to support the bilingual advantage hypothesis.

Paap has suggested that individual studies tend to use only one task and one indicator for each executive process component, and as a result, there is no possibility of getting converging evidence. He has also claimed that many studies have small numbers of participants and few items used in their experiments. Additionally, many studies compare monolinguals and bilinguals who vary in many ways besides the number of languages they speak, for example, they may vary in nationality, education level, socioeconomic background, immigrant status, and cultural traits. After a careful review of the issues raised by researchers who do not support the BCA, and after failing to find a study which specifically considered Spanish speakers, the present study was designed to control for several of these factors by testing monolingual and bilingual participants who are native Spanish speakers, who have lived in México and who have similar socioeconomic backgrounds and levels of education.

2.2. Hypothesis

If bilinguals indeed possess certain cognitive advantages compared to monolinguals, then Spanish-English bilinguals should produce faster reaction times (RT) than monolinguals in two tasks, the Simon and Flanker Tasks, both of which are frequently used in published studies as proxy measures of executive function.

3. Methodology

In order to obtain evidence of beneficial cognitive effects in bilinguals, Spanish monolinguals and Spanish-English bilinguals were recruited and asked to complete a Language Proficiency Questionnaire followed by two non-verbal tasks that involve executive function. The present study opted to use the Simon and Flanker tasks with Reaction Time (RT) as the dependent variable, and language status (with two levels (monolingual, and bilingual) as the independent variable. Previous studies have tested participants, both bilingual and monolingual, in English. To avoid any possible unwanted effects due to testing participants in their non-native language, this study tested all participants in their native language, which in this case was Spanish.

3.1 Language Proficiency Questionnaire (LPQ)

The Language Proficiency Questionnaire was based on the Language Experience and Proficiency Questionnaire (LEAP-Q)[22]. The questionnaire was adapted to a web-based version using Qualtrics. This questionnaire incorporates various demographic questions including age, location, language acquisition information, self-rated proficiency, occupation, instrument and video game use, among others.

3.2 Simon Task

The Simon Task measures response selection, response execution and response conflict, among other processes. An adapted version based on the original task by Simon and Wolf[2] was used in this project. In this study's version of the Simon Task, the participant is asked to press the right shift button when a red square appears on the screen, regardless of the position of the square, or the left shift button when a blue square appears on the screen, also regardless of the position of the square. A trial is congruent when the stimulus appears on the same side of the screen as the button corresponding to its color. A trial is incongruent when the stimulus appears on the opposite side of the screen as the button corresponding to its color. (See Figure 1). The Simon effect is an increase in reaction time (RT) on incongruent trials relative to congruent trials.

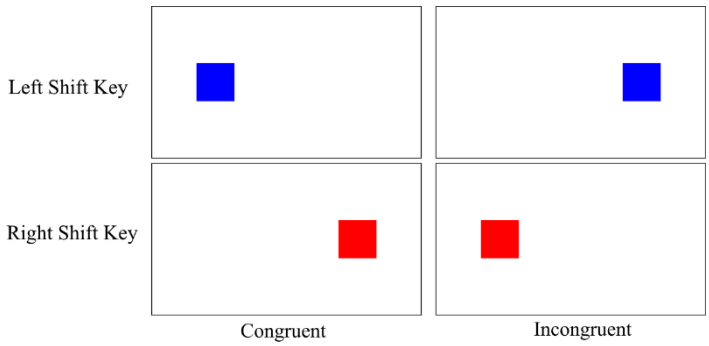

Figure 1. Illustration of Simon task (congruent and incongruent trials)

The Simon portion consisted of a practice test followed by one block of 28 congruent and incongruent trials presented in random order. Half of the trials presented the target on the left with the other half of the targets presented on the right. Thus, the RTs obtained for the two levels of congruency (congruent versus incongruent) were based on one block of 28 trials. For the Simon Task, the following measures were obtained: reaction times (RT) of correct trials (ms), correct congruent and incongruent trials, number of correct congruent and incongruent trials, mean RT of correct trials (ms), mean RT of congruent trials, mean RT of incongruent trials (ms), and Simon effect (ms).

3.3 Flanker Task

The Flanker Task measures resistance to distractor interference, response conflict and response execution, among other processes. An adapted version based on the original task by Eriksen and Eriksen[19] was used in this project. In this study's version of the Flanker Task, the participant had to indicate the direction of an arrow (the central arrow) surrounded by two arrows on each side. These other arrows were intended to either distract or facilitate the decision. A congruent trial occured when the central arrow was presented with four other arrows pointing in the same direction. An incongruent trial occured when the central arrow was pointing in a different direction than the other four arrows (See Figure 2). The Flanker portion consisted of a practice test followed by one block of 100 congruent and incongruent trials presented in random order. For the Flanker Task, the following measures were obtained: reaction times (RT) of correct trials (ms), correct congruent and incongruent trials, number of correct congruent and incongruent trials, mean RT of correct trials (ms), mean RT of congruent trials, and mean RT of incongruent trials (ms).

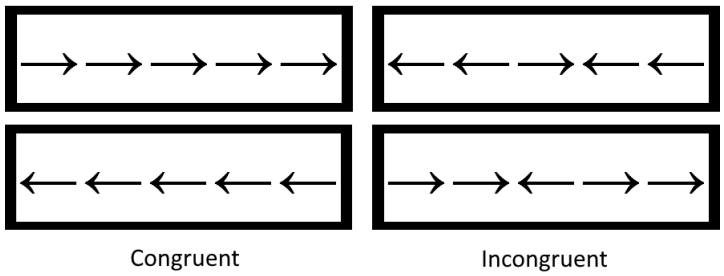

Figure 2. Illustration of Flanker Test (congruent and incongruent trials)

3.4 Participants

Participants consisted of 8 Spanish monolinguals and 44 Spanish-English bilinguals, who were between 23-63 years old and who lived in Mexico. Participants were native Spanish speakers whose second language was English. Several of them spoke other languages including: French, Italian, German, Portuguese and Japanese. However, in the present

study multi-linguals were grouped with bilinguals (see Figure 3 for a classification of participants). Participants completed the survey protocol independently and remotely via Inquisit software.

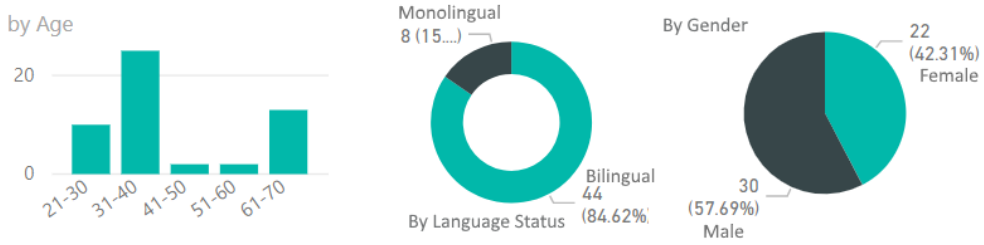

Figure 3. Classification of participants according to age, language status and gender.

According to the language proficiency questionnaire, the bilingual participants demonstrated a range of intermediate to high level of proficiency in their second language. The average self-rated second language proficiency in speaking, reading and listening was around 70% as compared to a native speaker. More than 50% of the participants had lived in other countries for an average of 3 years. Moreover, both monolingual and bilingual participants had similar socioeconomic backgrounds and levels of education.

4. Results and Analyses

4.1 Simon Task Analyses

An ANOVA with Reaction Time (RT) as the dependent variable and Language Status (again with two levels: Bilingual, and Monolingual) as the independent variable revealed a significant difference between RTs, F (1, 51) = 49.02, p < .0001, with bilinguals responding significantly faster than monolinguals (See Table 1, Figure 4). This finding suggests that overall, the bilinguals were significantly better able to cope with the Simon task than were the monolinguals.

Table 1. ANOVA analyses for Simon Task with Reaction Times (RT) as the dependent variable and language status as the independent variable

ANOVA Table

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	805693	805693	49.0168
Error	1360	22354428	16437	**Prob > F**
C. Total	1361	23160121		<.0001*

Means Table

Level	Std Error	Lower 95%	Upper 95%	Mean RT
Bilinguals	3.78	471	486	478
Monolinguals	8.76	528	562	545
Difference				67

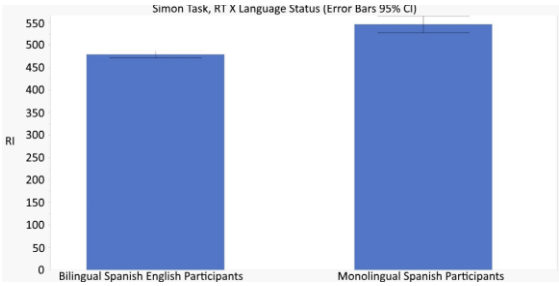

Figure 4. ANOVA analyses for Simon Task with Reaction Times (RT) as the dependent variable and language status as the independent variable

On average, the bilinguals responded faster on congruent trials (464 ms) than on incongruent trials (493 ms). This reaction time difference, or Simon effect, of 29 ms was significant, F (1, 43) = 14.7, p < .0001. On average, the monolinguals responded numerically faster on congruent trials (537 ms) than on incongruent trials (553 ms). However, this reaction time difference of 16 ms failed to reach significance (p > .3). On average, on congruent trials the bilinguals responded faster (464 ms) than the monolinguals (537 ms). This reaction time difference was significant, F (1, 51) = 25.3, p < .0001.Finally, and again on average, on incongruent trials the bilinguals responded faster (493 ms) than the monolinguals (553 ms). This reaction time difference was significant, F (1, 51) = 24.0, p = < .0001. (See Table 2, Figure 5)

These additional analyses indicate that the main initial finding of bilinguals being significantly faster overall was true for both congruent and incongruent trials in the Simon.

Table 2. Reaction Time (RT) average for the Simon Task

Reaction Times

	Congruent (average)	Incongruent (average)	Difference	Significant
Monolinguals	464 ms	493 ms	29 ms	Yes
Bilinguals	537 ms	553 ms	16 ms	No
Difference	73 ms	60 ms		
Significant	Yes	Yes		

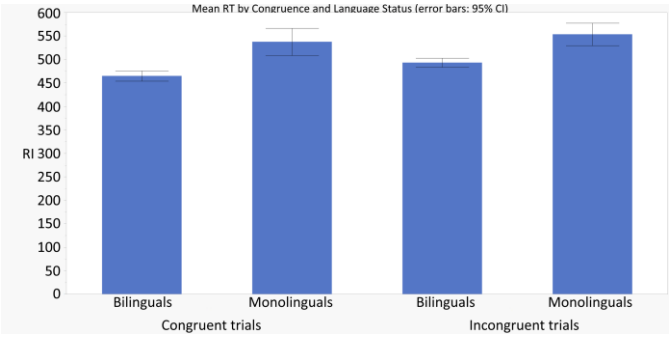

Figure 5. Reaction Time (RT) averages for the Simon Task

4.2 Flanker Task Analyses

An ANOVA with RT as the dependent variable and Language Status (with two levels: Bilingual, and Monolingual) as the independent variable revealed a significant difference between RTs, F (1, 51) = 9.68, p = .002, with bilinguals responding significantly faster than monolinguals. This finding suggests that overall, the bilinguals were significantly better able to cope with the Flanker task than were the monolinguals (See Table 3, Figure 6).

Table 3. ANOVA analyses for Flanker Task with Reaction Times (RT) as the dependent variable and language status as the independent variable

ANOVA Table				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	261134	261134	9.6766
Error	5119	138142025	26986	**Prob > F**
C. Total	5120	138403159		0.0019*
Means Table				
Language Status	Std Error	Lower 95%	Upper 95%	Mean RT
Bilinguals	2.49	520	530	525
Monolinguals	5.84	533	556	545
Difference				20

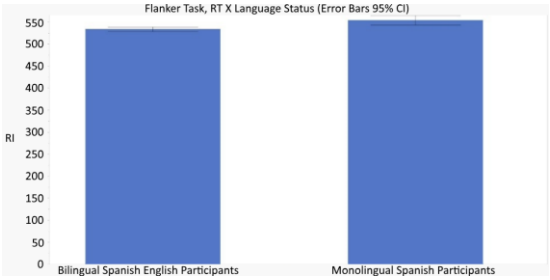

Figure 6. ANOVA analyses for Flanker Task with Reaction Time (RT) as dependent variable and language status as independent variable

Additional analyses revealed that on average, the bilinguals responded faster on congruent trials (496 ms) than on incongruent trials (555 ms). This reaction time difference of 59 ms was significant, F (1, 43) = 141.3, p < .0001. On average, the monolinguals responded faster on congruent trials (522 ms) than on incongruent trials (567 ms). This reaction time difference of 45 ms was significant, F (1, 7) = 17.3, p < .0001. On average, on congruent trials the bilinguals responded faster (496 ms) than the monolinguals (522 ms). This reaction time difference of 26 ms was significant, F (1, 51) = 10.5, p = .001. Finally, on average, on incongruent trials the bilinguals responded numerically faster (555 ms) than the monolinguals (567 ms). However, this reaction time difference of 12 ms failed to reach significance (p = .18) (see Table 4, Figure 7 below). These additional analyses indicate that while the bilinguals might have been significantly faster overall, their reaction time advantage did not extend to incongruent trials in the Flanker, where they were numerically faster on average but not significantly so.

Table 4. Reaction Time (RT) average for the Flanker Task

Reaction Times				
	Congruent (average)	Incongruent (average)	Difference	Significant
Monolinguals	522 ms	567 ms	45 ms	Yes
Bilinguals	496 ms	555 ms	59 ms	Yes
Difference	26 ms	12 ms		
Significant	Yes	No		

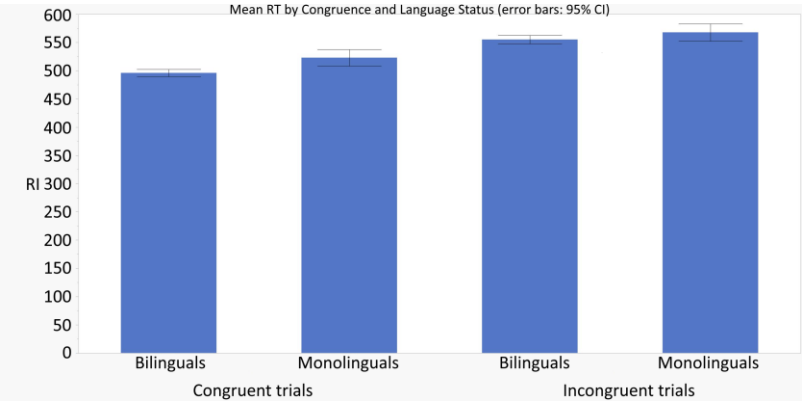

Figure 7. Reaction Time (RT) average for the Flanker Task

4.3 Errors

A strong version of a bilingual advantage hypothesis would hold that bilinguals would be both faster and more accurate than monolinguals. In this study, however, monolinguals committed fewer errors than bilinguals in total, on average, and when compared to a random sampling of bilinguals. Thus, findings do not support a strong version of the bilingual advantage hypothesis. (See Table 5)

Table 5. Number or errors and average errors for monolinguals and bilinguals in the Simon and Flanker Tasks

Errors		
	Number of Errors	Average
Simon Task		
Monolinguals	10	1.25
Bilinguals	84	1.9
Flanker Task		
Monolinguals	11	1.38
Bilinguals	68	1.54
Simon Task (Random sampling of participants)		
Monolinguals	10	1.25
Bilinguals	10	1.25
Flanker Task (Random sampling of participants)		
Monolinguals	11	1.38
Bilinguals	13	1.63

5. Discussion and Conclusion

The aim of this study was to seek evidence of a cognitive advantage in bilinguals based on previous research that had either supported, or failed to support this hypothesis. More importantly, one of the purposes of this research was to contribute data from Spanish-English bilinguals, which had not yet been collected. The present study explored the hypothesis that if bilinguals possess certain cognitive advantages compared to their monolinguals counterparts, then Spanish-English bilinguals would produce faster Reaction Times (RT) than monolinguals in both the Simon and the Flanker tasks. From the different analyses performed, the following findings were obtained:

1. Overall, the Spanish-English bilinguals were significantly faster to respond in both the Simon and Flanker tasks than were the monolinguals. However, bilinguals were not significantly faster than monolinguals in the incongruent condition. Thus, the present study's findings are broadly in line with those reported in studies by Bialystok and her colleagues[7,6,8] and which were interpreted as evidence supporting the existence of a bilingual advantage.

2. Overall, however, the monolinguals committed fewer errors compared to the bilinguals. Therefore, a strong version of the bilingual advantage hypothesis (according to which a bilingual would be both faster and less error-prone than a monolingual) was not supported by the results of the present study.

The present results notwithstanding, further research (and also meta-analyses) will be needed if the field is ever to understand why positive results are obtained in some studies but not in others. For instance, for the present study the bilinguals were not significantly faster than monolinguals in the incongruent condition of the Flanker Task,. However, previous studies have found that bilinguals were significantly faster in this condition. Additionally, contrary to predicted results, the monolinguals in the present study had a smaller Simon effect compared to their bilingual counterparts. Bilingualism itself is a complex phenomenon; it is perhaps no surprise, then, that research on the bilingual cognitive advantage continues to raise questions even as it seeks answers.

6. Future Research

Because research on the bilingual advantage is complicated by so many variables, it will be necessary for future research to incorporate additional tasks and better understand the ones being currently used, and control for more participant-related variables. To further explore the bilingual cognitive advantage, several participant-variables should be routinely incorporated in all analyses. For example, age of second language (L2) acquisition, age of fluency in the L2, years of L2 use, self-rated proficiency in listening, reading and speaking, education level, and use of video games and/or musical instruments have all been identified as important when exploring the BCA. Therefore all of the analyses of the data in light of the variables mentioned above would be promising for future research[13].

The relationship between bilingualism and cognitive advantage is complicated on so many levels that the possibilities for future research are likely infinite. Whichever directions that research takes, it will likely need to feature a better understanding of existing behavioral tasks, and possibly new tasks which measure executive function, inhibitory control and/or comparable behavioral and attentional processes.

If validated, the significance of the bilingual advantage could have serious implications for education and welfare. Some possible benefits of a bilingual cognitive advantage include improvement of quality of life in older age, reduction of negative effects of aging on cognitive functions, improvement of cognitive performance in certain tasks, and a protective effect against dementia[10]. Given these potentially high stakes, there is clearly a need for continued research on this topic.

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