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A Study Of Possible Pre-Cognitive Advantages Of Bilingualism

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A STUDY OF POSSIBLE PRE-COGNITIVE ADVANTAGES

OF BILINGUALISM

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A STUDY OF POSSIBLE PRE-COGNITIVE ADVANTAGES OF BILINGUALISM

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Abstract

Past research has suggested that second language acquisition has a beneficial effect on the development of inhibitory control processes in children and adults. This has been referred to as the “bilingual advantage” and is most commonly quantified using the Simon task. Whether the bilingual advantage extends to precognitive mechanisms has not yet been examined. The goals of this study were to examine the bilingual advantage in university students; and to examine whether the bilingual advantage extends to the precognitive filtering mechanism of sensorimotor gating. It was predicted that, as compared to monolinguals, bilingual university students would have greater inhibitory control, as exhibited by lower error rate and smaller RT difference between congruent and incongruent trials, and a smaller “Simon effect.” With regard to sensorimotor gating, it was predicted that as compared to monolinguals, bilinguals would have greater eye blink startle inhibition. The study included 145 undergraduate participants (mean age 20.1 years), all of whom completed a language background questionnaire, the Simon task and a standard startle inhibition paradigm. Planned analyses that grouped participants by self-report of bilingual ability showed no support for the hypotheses. In exploratory analyses participants were categorized by mean age of second language acquisition and a trend effect was found. Among female participants who acquired a second language during the years of rapid prefrontal pathway development (ages 5 – 8) startle inhibition was greater (p = .06). Future studies should focus on investigating whether the bilingual advantage extends to brain pathways that contribute to attention, orientation, and conflict resolution; or other behavioral functions that are guided by inhibitory control pathways.

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Introduction

The effects of bilingualism on intellectual functioning have been studied since the 1920's. During these early years, most of the bilingual research was done in children. The conclusions obtained from the early investigation suggested that bilingual children, when evaluated using measures of intelligence, were found to be at a disadvantage when compared to monolingual children (Saer, 1923; Graham, 1925). Peal and Lambert (1962) however believed that earlier studies had not taken into account variables that underlie intelligence, and which therefore should be examined when studying the effects of bilingualism on intelligence. In contrast to earlier studies, Peal and Lambert controlled and studied such factors as gender, age, and the socioeconomic status of the participants. When they did so, they found that 110 ten-year-old French-English bilingual children outperformed their monolingual counterparts in both verbal and non-verbal cognitive tests. It was found that the bilingual group scored higher than monolinguals on the Raven Progressive Matrices, Lavoire-Laurendeau Nonverbal IQ, and most of the nonverbal tasks. This study represented a turning point in bilingual research because for the first time, it suggested that bilingual children may have a measurable advantage in cognitive functioning as compared to monolingual children. This is considered to be one of the most important studies to date due to the reversal of unpredicted findings at that time. The authors explained the differences found among the two groups as an advantage developed by the exposure of two languages. They suggested that this exposure developed mental flexibility, advantage in concept formation, and consequently, enhancement of other mental abilities. On the other hand, they suggested that monolinguals may have a more "unitary" intellectual structure that carried over into a wide range of mental tasks. For the first time, this study suggested that the experience of being bilingual had a measurably favorable influence in the development of cognitive processes.

Since Peal and Lambert's study in 1962, the effects that bilingualism exerts over bilinguals' cognitive development have been analyzed in both verbal and non-verbal tasks. Ellen Bialystok has been a major contributor to this literature. Her approach toward bilingualism has been based on how "control processing" exerts its effects in the development of the bilingual advantage. According to Bialystok (1997), cognitive processes that govern control and analysis are the basic mechanisms for language acquisition. They are required for the development of mental representations and the controlled access to those representations. "Analysis processes" involve the construction of mental representations, by which both concrete and abstract information are stored in categories; on the other hand "control of processing" directs attention to specific aspects of a representation, and is particularly important when ambiguous, competing, or distracting information is presented. When a child develops control processes in linguistics, it is reflective of the child's ability to pay attention to the key informative aspects of language for problem solving (Bialystok, 1986).

Contemporary research has shown that bilingual children do better than their monolingual counterparts in verbal tasks that require analysis or control processes. For instance, Bialystok (1986) evaluated the performance of 119 children between the ages of 7 and 9 on grammatical judgment tasks. All the children were fluent English speakers, and half of them were fluent speakers in another language. For this task, children had to judge and correct different kinds of sentences. There were four kinds of sentences: grammatically and semantically correct (GM), grammatically incorrect-semantically incorrect (gs), grammatically correct-semantically incorrect (Gm), and grammatically incorrect- semantically correct (gM). When performing grammatically judgments, the grammatically incorrect but meaningful phrases represented a "manipulation of analysis" in which the child had to reject the sentence by relying on his knowledge of language structure. The type of grammatical errors were lack of subject-verb agreement ("That dog don't come…"), incorrect comparative ("Tommy is more old than Sarah…"), particle/pronoun placement ("Mommy wakes up me…"), among others. On the other hand, when performing semantic judgments, grammatically correct-semantically incorrect phrases represented "manipulation of control" tasks. An example for this kind of judgment was: "If I am sick again tomorrow, I will have to see my fireman". In this case, the child had to override the semantic anomaly in order to judge as correct the grammaticality. For these kinds of sentences, a high level of cognitive control was required to answer correctly. Results showed a difference between monolingual and bilingual children only on the "control process" items (gM, Gm), particularly in the Gm items bilingual children were more accurate than monolinguals. Also, it should be noted that monolingual children judged gM items better than bilingual children, which reflects an advantage in analysis process for this group. The same study was replicated in 41 first-graders who were English- Italian bilinguals (Bialystok, 1988). Consistent with previous findings, the results showed that bilingual children were more accurate in judging sentences that were grammatically correct- semantically incorrect (requiring a high level of cognitive control) as compared to monolingual children.

It is also important to consider to what extent the bilingual advantage may extend to non-verbal tasks. Doing so may reveal cognitive mechanisms that underlie the bilingual advantage found in studies using verbal tasks. To understand the underpinnings of the bilingual advantage, it is useful to refer again to the analysis of representations and the control of attention processes, the two cognitive processes that are believed to underlie the bilingual advantage. Similar to what has been already defined with regard to verbal tasks, “analysis” is the process by which concrete and abstract information is integrated and formed into mental representations that are then organized in abstract categories. On the other hand, “control of attention” is the process by which attention is focused on detailed features of a representation, and is particularly important in ambiguous or misleading situations. Control of attention processes are essential for problem solving during which information has to be selectively processed or ignored. Here is where selective attention and inhibition come into play. An automatic response has to be inhibited when it contradicts the correct solution to the problem (Bialystok & Martin, 2004). In addition, control of attention is required to inhibit attention when ambiguous information is presented, and to switch between competing cues (Bialystok, Craik, Klein, & Viswanathan, 2004).

Bialystok (1999) analyzed the ability for solving cognitive problems in bilingual and monolingual children by means of the dimensional change card sort task (similar to the Wisconsin Card Sort task). Sixty preschool children participated in the study, half of them were monolinguals and half of them were English-Chinese bilinguals. The task consisted of two phases, in which a set of cards showed a circle or a square that was red or blue. In the first phase, also called “preswitch”, children had to sort a set of cards by one feature, color. And in the second phase, or “postswitch”, the cards had to be sorted by the other dimension, shape. So, in the postswitch phase the rule given for the preswitch phase had to be ignored, or inhibited. In this kind of task, the analysis of representation is measured when the child understands the application of the sorting rule; control processes are measured when the child must ignore the previous rule and resort the cards to match the new rule. The findings suggested that bilingual children could resist distracting information better than monolinguals; bilinguals had more correct trials during the “postswitch” phase than their counterparts. This study suggested that the bilingual advantage extended to areas unrelated to linguistics since the card sort task is considered non-verbal. It should be noted, however, that children encode visual stimuli verbally, bringing into question whether these types of tasks are in fact "non-verbal". Nonetheless, bilingual children may be considered "privileged" in their ability to manage cognitive conflict and employ selective attention.

The Simon task could be defined as a non-verbal task because it is unlikely to be influenced by verbal strategies, compared to the tasks described above. In order to provide a clearer distinction of non-verbal inhibitory processes in bilingual and monolingual children, the Simon task has been used as an important indicator of the bilingual advantage. In the Simon task a stimulus is presented on the right or left side of the screen and the correct key press response is determined by the color of the stimulus, for example if blue press left key, if red press right key. Using these parameters, congruent trials are those in which blue stimuli are presented on the left side of the screen, and red stimuli are presented on the right side of the screen. For incongruent trials, blue stimuli are presented on the right side of the screen and red stimuli are presented on the left side of the screen. In this task the color of the stimulus is the important aspect for a correct response and not the position of the stimulus. Half of the trials are congruent and the other half are incongruent. In typical controls, congruent trials are solved faster and more accurately compared to incongruent trials; this is known as the Simon effect (Simon & Craft, 1970). Thus, in the Simon task two features are displayed (color and position of the stimulus) and the most salient (position) has to be ignored in order to respond to the less salient but correct feature (color). Martin-Rhee and Bialystok (2008) used the Simon task to examine inhibitory control processes in bilingual children. A total of 34 children were tested, half were English monolinguals, and the other half were fluent in both French and English. The bilinguals responded faster and more accurately than their monolingual counterparts and the difference was consistent in both congruent and incongruent trials. This study suggested that bilingual children performed better on a task that required inhibitory control processes and also faster on the task that relied on speed of processing. Bialystok et al. (2005) proposed the idea that bilinguals benefit more from the constant shifting between congruent and incongruent trials which enhance performance in both congruent and incongruent trials; this may explain bilinguals' advantage in both types of trials.

So far, the presented evidence strongly supports the idea that bilingualism has a positive impact on the development of inhibitory control cognitive processes in children. Whether such advantages extend into adulthood is also important to consider. Most of the research done in bilingual adults has been based exclusively on what has been examined in bilingual children. Bialystok, Craik, Klein, and Viswanathan (2004) addressed whether the bilingual advantage found in children remains throughout the life span. In this study, a group of 40 bilingual adults ranging in age from 30 to 54 years performed the Simon task. Half of them were Tamil – English bilinguals and the other half were monolingual. It was found that bilinguals were consistently faster in both congruent and incongruent trials, and they also showed a smaller Simon effect, which is indicative of less distraction by interference on incongruent trials. Based on these findings, it was suggested that the bilingual advantage was sustained into adulthood. Previous studies have found similar results using the Simon task in adults (Bialystok et al., 2005); Bialystok, Martin, & Viswanathan, 2005). Taken together child and adult studies suggest that inhibition, attention, and selection of information for problem solving are enhanced by the development of second language ability. A possible explanation is that inhibitory processes are exercised by bilingual ability because of a constant demand to inhibit task irrelevant information (the non-used language).

However, there seems to be a gap across the lifespan where bilingualism does not seem to benefit inhibitory processes that come from bilingualism. Bialystok, Martin, and Viswanathan (2005) assessed the following groups on the Simon task: children between the ages of 5 and 6 years, young adults (university students) between the ages of 20 and 30, middle-age adults between the ages of 30 to 59, and older adults between the ages of 60 and 80 years. It was found that children, middle-age adults, and older adults were significantly faster in both congruent and incongruent trials as compared to their monolingual counterparts. The young adults group was the only one that showed no difference between bilinguals and monolinguals with respect to response time for congruent and incongruent trials. Given that only one study has been completed to suggest that university age bilingual students do not have increased inhibitory control, it seems important to assess this age group and see if the lack of difference can be replicated

Beyond its use in bilingual studies, the Simon task has been considered an important tool for exploring attentional processes and executive functions (Lu & Proctor, 1995). The Simon effect results from the time it takes to resolve the conflict between location of the target and location of the response key. The solution of such conflict requires that an intentional process overrides an automatic one. To do so efficiently and effectively requires selective attention, inhibition, and response switching. These processes may suggest the neural pathways involved in this task (Bialystok, 2006).

Studies are needed to explore more fully the inhibitory mechanisms involved in the bilingual advantage. One approach is to examine performance on psychophysiologic measures of primary inhibitory processes. For example, sensorimotor gating is believed to represent a mechanism that is fundamental to attention and inhibition. Sensorimotor gating is measured by manipulation of the startle reflex. The startle reflex is the response to a sudden unexpected stimulus. The stimuli may be acoustic, tactile, light, or airpuff. In the case of acoustic stimulus, the startle reflex is measured by the eye blink reaction via electromyographic (EMG). The eye blink startle response is reduced by the presentation of a weak stimulus (prepulse) presented 30-500ms before the startle eliciting pulse (pulse); this is known as prepulse inhibition (PPI). PPI is a brainstem based response that is consistent across species. It reflects the ability of the nervous system to act as a preattentive filtering mechanism. In this preattentive filtering mechanism, the prepulse functions to inhibit the startle response and perhaps to warn the organism of the startle eliciting stimulus. In this way, PPI acts as a "sensorimotor gating" mechanism by which extraneous information is filtered or "gated out". This allows the organism to direct its attention to important aspects as it is being protected from saturation or information overloading (Jovanovic, et al., 2004). The inhibitory influence exerted by the prepulse is regulated by specific and relatively well-mapped neural pathways, including the limbic cortico-striato-pallidopontine (CSPP), cortico-striato-pallido-thalamic (CSPT) circuitry, and the pons (Braff & Geyer, 1990; Lee et al. 1996). Because PPI is modulated by prefrontal and frontal cortex it is believed to represent a primary inhibitory mechanism (Lee, Lopez, Meloni, & Davis, 1996).

The present investigation explored further possible cognitive advantages among bilinguals. One goal was to replicate past findings of the bilingual advantage in university students as assessed with the Simon task. In the absence of more studies assessing young adults, and consistent with a large number of studies of other age groups, we predicted that bilingual university students would perform more accurately, faster, and would have a smaller Simon effect than monolinguals. We then assessed the same participants for sensorimotor gating. Taking into consideration the inhibitory processes bilinguals must exert while suppressing the undesired language (control attention and inhibition), we predicted that bilinguals would have a greater amount of suppression of startle eye blink in response to the presentation of a prepulse. If the hypotheses followed the predicted pattern, this study would be one of the first to show how second language acquisition could influence pre-cognitive mechanisms, such as sensorimotor gating.

Methods

Participants

Participants included 145 UTEP undergraduate students recruited through Experimetrix, the online Psychology undergraduate study participant pool. Participants were self-selected and bilingual or monolingual status was determined by self-report on a language background questionnaire. Each student completing the protocol received course credit for their participation in the study.

Tasks and procedure

At the beginning of the testing session, participants signed a consent form, and completed a language background questionnaire. Next, participants were assessed on an auditory test in order to determine the range of sound frequency for each participant. Then, participants were prepared for the prepulse inhibition session. After the prepulse inhibition session, participants were translated to a different room for the Simon task. Finally participants were debriefed. The same procedure was followed for each of the participants.

Language Background Questionnaire

Each of the participants completed a language background questionnaire in order to determine whether they were bilinguals or not. Participants reported which language they considered their stronger language, the percentage of time they use each language and the degree of proficiency for writing, speaking, listening comprehension, reading, and pronunciation skills for each language. The criterion for determining to what extent a participant is bilingual was assessed on a self-rating scale for spoken proficiency in English and Spanish. The scale contained 9 items. The extremes of the scale represented items for English and Spanish monolinguals, for example a) I speak only English, i) I speak only Spanish; whereas the middle point of the scale was reflective of someone who is fluent bilingual, e) I speak English and Spanish with equal fluency. This criterion has been previously used at UTEP as a screening question for bilingual studies by Francis, Corral, Jones, & Sáenz, (2008) (see item 1- Appendix). For the purpose of the present study, a participant was considered to be "bilingual" when the participant rated their language proficiency as being one of the middle criteria (choice d, e, or f) ; when a participant rated their language proficiency on the extremes of the scale (a, b, h, or i), the participant was considered to be "monolingual." Participants marking "g" were considered bilinguals because they attend classes in English on a weekly basis at UTEP, where they are required to speak, comprehend, and write in English, even when they were Spanish dominant. Participants marking letter "c" were considered monolinguals because they were less likely to be asked to speak or comprehend Spanish on a weekly basis.

Based on these criteria, a total of 84 participants were classified as monolinguals, and 61 as bilinguals. English was the stronger language for 81 (56%) participants, Spanish for 32 (22.3%) participants, and a mixture of both languages for 32 (21.7%) of the participants. The average age for English acquisition was 5.1 years old (SD= 4.3), and 3.7 years old (SD= 4.3) for Spanish. The average age of second language acquisition was 8.2 years old. The average percentage of time that participants reported speaking English was 66%, for Spanish 33%, and for mixing both languages it was 9 %. Also, bilingual participants reported that they speak 60% of the time in their dominant language, while 40% of the time in their non dominant language.

Simon task

The Simon task was presented on a Mac laptop with a 14.5-in monitor. The stimuli were programmed and presented with the software PsycScope (reference) and a response button box was used to collect response time data. Participants were seated in front of the computer and instructed to fixate on the center of the screen. Each trial started with a fixation point (+) in the center of the screen, which remained on the screen for 800 ms. The fixation point was followed by a 250-ms blank interval, then a red or blue square appeared on the left or right side of the screen. Participants were instructed to press a specific response key based on the color of the stimulus, regardless of its position in the screen. Participants were randomly assigned to "red" or "blue" conditions. Half of the participants were instructed to press the right button when a blue square appeared, the other half were instructed to press the right button when a red square appeared. Congruent trials were those in which the color of the square was consistent with the side of the correct response key, and incongruent trials were those in which the stimulus was presented in the opposite side of the correct response key. The experiment started with 8 practice trials, all of which had to be answered correctly in order to proceed with the experimental trials. One hundred experimental trials were presented, half of which were congruent trials and the other half were incongruent. The trials were shown in a randomized order. The variables analyzed included proportion of correct responses for congruent and incongruent trials, RT for congruent and incongruent trials, and RT difference between congruent and incongruent trials ("Simon effect").

PPI

The acoustic startle response was measured with San Diego Instruments Startle Reflex system (SDI, Serial N, Model N). The participants were tested in a sound-proofed area. Participants were asked to sit in a chair and keep their eyes open looking at a fixed point. Three small electrodes were used to collect electromyography data and were centered below the right eye, approximately 30 degrees towards the corner of the eye, and behind the right ear (ground). Before placing the electrodes, the surface of the skin was cleaned with an alcohol pad and then lightly abraded with electrode prep paper (3M). The acoustic stimuli for the PPI paradigm were presented through headphones (Sony MDR-V6). Background noise of 50dB was presented during the entire session. The PPI session was programmed to last 12 minutes and included a 60 second white noise acclimation period, and 36 stimulus trials, of which 18 were pulse-alone trials, and 18 were prepulse-pulse trials. The eye blink response was produced with a white noise sound burst at 104dB of 50ms duration. The prepulse trials were presented with a 70dB white noise pre-stimulus of 50ms duration, followed by a lead interval fixed at 100ms, then followed by 50ms of 104 dB white noise pulse. The pulse and prepulse trials were randomly distributed through the session.

The outcome variables analyzed were millivolt (mV) level at the start of pulse and prepulse trials, maximum amplitude of the peak in mV, time of the peak in milliseconds, number of trials eliciting blink response, number of trials eliciting noise response, and number of trials eliciting no response. Only noise trials were excluded from the PPI analyses. Inhibition effects were calculated by subtracting the maximum amplitude of the peak for pulse trials from the maximum amplitude of the peak for prepulse trials. Percentage of the amplitude reduction, or prepulse inhibition, was calculated as [100 – (max prepulse/max pulse) * 100].

Results

Data from 145 participants were analyzed, including 71 males, and 74 females. The age range of the participants was 17 to 46 years old (M= 20. 18, SD= 4.03). Approximately 63% of the participants identified themselves as Hispanic, 14% as Mexican-American, 13% as Mexican National, 6% as White, and 4% as Black, Hawaiian, Irish, or Asian Pacific Islander.

Prior to analysis, all data were examined for outliers and for distribution properties. Descriptive statistics for all variables analyzed are provided in Table 1. The primary analyses compared monolinguals and bilinguals speakers and the variances for all variables were compared by group (F- test for equality of variances). Visual inspection revealed approximately normal distributions, and variance between groups did not differ for any of the variables to be analyzed. The language grouping criteria (previously explained on the Language Background Questionnaire section above) yielded 84 monolinguals, including 41 males and 43 females, and 61 bilinguals, including 30 males and 31 females.

Simon task

Before primary analyses comparing monolingual and bilingual participants on Simon task variables were conducted, males and females were compared on all variables to determine whether sex accounted for significant group differences. No significant differences were identified and sex was not included as a factor in the Simon task analyses. Table 2 summarizes the results for each Simon task variable by sex, and Table 3 presents the same variables for monolinguals and bilinguals.

Unpaired t-test was used to examine possible differences between monolinguals and bilinguals on the Simon task variables. RT differences between congruent and incongruent trials

("Simon effect") for monolinguals and bilinguals did not differ significantly (mean difference = -17.51; t (143) = -1.46, p = .14). Proportion of correct responses in congruent trials in the Simon task was examined for the language groups. Monolinguals and bilinguals did not differ significantly in proportion of correct responses for congruent trials (mean difference = -.006; t (143) = -1.17, p = .24) nor for incongruent trials (mean difference = .004; t (143) = .43, p = .66). The response times (RTs) of monolinguals and bilinguals were also compared. RTs of monolinguals and bilinguals did not differ significantly on congruent trials (mean difference = -44.53; t (143) = -1.29, p = .19); similarly, there were no RT differences for incongruent trials (mean difference = -62.04; t (143) = -1.80, p = .07). Because no differences were found between bilinguals and monolinguals in the Simon effect, the mean Simon effect and standard deviation for subjects answering each of the language background questionnaire items were reported in Table 4 for archival purposes.

PPI

Prior to conducting the primary analyses, males and females were compared. It was found that males and females differed significantly with regard to all PPI variables. Table 5 presents the results for each variable. The average time in which the peak was reached in pulse trials was significantly shorter for females than for males (mean difference = 9.54; t (143) = 2.81, $p < .01$). The opposite pattern was present for prepulse trials, in which peak amplitudes for males occurred significantly earlier than for females (mean difference = -9.71; t (143) = -2.58, p = .01). For peak amplitude ("strength" of the blink), females as compared with males blinked significantly harder on pulse trials as indicated by higher peak amplitudes (mean difference = -92.59; t (143) = -3.31, $p < .01$). For pre-pulse trials, the same pattern was repeated; peak amplitude for females as compared with males was significantly larger (mean difference =

-35.27; t (143) = -2.03, $p < .05$). Females as compared with males produced significantly more blinks on pulse trials (mean difference = -.74; t (143) = -2.26, $p = .02$); and similarly, for prepulse trials, females as compared with males produced a greater number of peaks (mean difference = -2.07; t (143) = -3.22, $p < .01$). Males and females did not differ in noise trials on pulse trials (mean difference = .04; t (143) = .25, $p = .79$), nor prepulse trials (mean difference = -.01; t (143) = -.07, $p = .94$). The number of pulse trials eliciting no response was higher for males than for females (mean difference = .69; t (143) = 2.70, $p < .01$). For pre-pulse trials, the same pattern was repeated; no blink response for males as compared with females was significantly larger (mean difference = 1.94; t (143) = 3.00, $p < .01$).Given these results, sex was included as a factor in all subsequent PPI analyses. Males and females differed significantly on the amount of inhibition exhibited on prepulse as compared to pulse trials (PPI), (mean difference = -7.91; t (143) = -2.13, $p = .03$).

ANOVA was used to examine differences between monolingual and bilinguals on PPI, with sex included as a factor. There were no differences between monolinguals and bilinguals for PPI, F (1, 141) = .66, p = .41; sex differences were at the border of reaching statistical significance, F (1, 141) = 3.59, $p = .059$; and no interaction was found, F (1, 141) = 1.96, $p = .16$.

Exploratory analyses I

Given the absence of monolingual and bilingual differences in the planned analysis, we decided to explore this further. Primary analyses were repeated using three groups instead of two, comparing English monolinguals, Spanish monolinguals and bilinguals (the rationale for these analyses will be considered in Discussion below). There was total of 82 English monolinguals (39 males, 43 females), 26 Spanish monolinguals (13 males, 13 females), and 37 bilinguals (19 males, 18 females).

Simon task

As previously stated, no significant differences were identified between males and females on Simon task variables. Table 6 presents the results for each variable for English monolinguals, Spanish monolinguals, and bilinguals. An ANOVA was used to evaluate the effect these groups in the Simon task variables.

The Simon effect was examined for the three groups, and groups did not differ significantly (F (2, 142) = .80, p = .44). For proportion of correct responses in congruent trials, and there were no differences among the groups (F (2, 142) = .84, p = .43). For proportion of correct responses on incongruent trials, there was no difference among the groups (F (2, 142) = .84, p = .43). The RT's for congruent trials were examined, and there was no difference among the groups (F (2, 142) = 1.57, p = .20); similarly, no differences in speed response for incongruent trials (F (2, 142) = 2.08, p = .12).

PPI

As previously stated, significant differences were identified between males and females, therefore a two way ANOVA examined the effects of sex and the three groups on the component PPI variables. For PPI, differences among the groups were not significant (F (2, 139) = .74, p = .47); males and females did not differ significantly in PPI, F (1, 139) = 1.41, p = .23; and there was no interaction, F (2, 139) = 1.45, p = .23. The average time in which the peak was reached in pulse trials did not differ among the groups, F (2,139) = 1.36, p = .25; there was a main effect for sex, F (1,139) = 4.06, p = .04; and there was no interaction, F (2,139) = .71, p = .49. There were no differences between the groups for average time in which the peak was reached in prepulse trials, F (2,139) = .08, p = .91; there was no difference for sex, F (1,139) = 2.44, p =.12; and no interaction was present, F (2,139) = 1.38, p = .25. The peak amplitude or strength of the eye blink for pulse trials did not differ among the groups, F (2,139) = 1.23, p = .29; there was no main effect for sex, F (1,139) = 3.26, p = .07; and there was an interaction, F (2,139) = 4.08, p = .01. There were no differences among the groups for peak amplitude in prepulse trials, F (2,139) = .45, p = .63; there was no difference for sex, F (1,139) = 1.05, p =.30; and no interaction was present, F (2,139) = 2.07, p = .12. The number of pulse trials in which a peak was produced did not differ among the groups, F (2,139) = 1.16, p = .31; there were no sex differences, F (1,139) = 2.13, p = .14; and there was no interaction, F (2,139) = .98, p = .37. There were no differences among groups for number of peaks produced in a prepulse trial, F (2,139) = .72, p = .48; there was a main effect for sex, F (1,139) = 4.31, p = .03; and there was no interaction, F (2,139) = 2.10, p = .12. The number of pulse trials eliciting noise response did not differ among groups, F (2,139) = .40, p = .66; there was no main effect for sex, F (1,139) = .08, p = .77; and there was no interaction, F (2,139) = .21, p = .80. The number of prepulse trials eliciting noise response did not differ among groups, F (2,139) = .54, p = .58; there was no main effect for sex, F (1,139) = .00, p = .94; and there was no interaction, F (2,139) = .34, p = .71. The number of pulse trials in which a peak was presented and there was not a response did not differ among the groups, F (2,139) = .82, p = .44; there was no difference for sex, F (1,139) = 2.72, p = .10; and there was no interaction, F (2,139) = 1.60, p = .20. There were no differences among groups for number of prepulse trials in which a peak was presented and there was not a response, F (2,139) = .67, p = .51; there was no difference for sex, F (1,139) = 3.26, p = .07; and no interaction was present, F (2,139) = 2.16, p = .11.

Exploratory analyses II

We explored one more possibility for understanding the effect of second language acquisition on inhibitory control processes. Given that the initial results indicated no significant difference between monolinguals and bilinguals, and the trend of results was opposite from the predicted results, the criteria for monolingual and bilingual speakers were re-considered with regard to neurocognitive benefit for inhibitory control processes. It was reasoned that benefit in inhibitory control could vary based on the age, and consequently strongest brain development, at which the second language was encountered. Thus, for exploratory analyses the age of second language acquisition was used to determine group membership. Of the 19 participants who marked letter "a" ("I speak only English"), 12 had no previous exposure to learning a second language, while 7 had worked to acquire a second language earlier in their lives. Thus, participants exposed to a second language between the ages of 1 and 4 and participants never exposed to learning a second language comprised the "no benefit" group. Participants exposed to a second language between the ages of 5 and 8, when inhibitory control processes are rapidly developing, comprised the "maximum benefit" group. Participants who learned a second language after the age of 8 comprised the "moderate benefit" group. Regrouping participants according to exposure age yielded 52 participants in the "no benefit" group (22 males, 30 females); 41 participants in "maximum benefit" group (21 males, 20 females); and 52 participants in the "moderate benefit" group (28 males, 24 females).

Simon task

The mean proportion of correct responses and RT's for congruent and incongruent trials for "benefit" groups on the Simon task are shown in Table 7. As previously stated, no significant differences were identified between males and females on Simon task variables. ANOVA was used to evaluate the effect of benefit group on the Simon task variables.

The difference in RT's between congruent and incongruent trials, Simon effect, did not differ significantly among the groups, F (2, 142) = .83, p = .43. Proportion of correct responses in congruent trials was examined for the three groups, and there were no differences among the groups (F (2, 142) = .34, p = .34). For proportion of correct responses on incongruent trials, there was no difference among the groups, F (2, 142) = .64, p = .52. The RT's for congruent trials were examined, and there was no difference among the groups, F (2, 142) = .88, p = .41; similarly, no differences in speed response for incongruent trials, F (2, 142) = .41, p = .66.

PPI

As previously stated, significant differences were identified between males and females, therefore a two way ANOVA examined the effects of sex and the three groups on PPI and the component variables. Table 8 presents each of the PPI variables for males and females for each of the groups. For PPI, differences among the groups were not significant but a trend was suggested (F (2, 139) = 2.83, p = .06); males and females differed significantly in PPI, F (1, 139) = 4.70, p = .03; and there was no interaction, F (2, 139) = .40, p = .66. The average time in which the peak was reached in pulse trials did not differ among the groups, F (2,139) = .05, p = .95; there was a main effect for sex, F (1,139) = 8.30, p < .01; and there was no interaction, F (2,139) = 1.04, p = .35. There were no differences between the groups for average time in which the peak was reached in prepulse trials, F (2,139) = .65, p = .52; there was a main effect for sex, F (1,139) = 6.48, p < .01; and no interaction was present, F (2,139) = .51, p = .59. The peak amplitude or strength of the eye blink for pulse trials did not differ among the groups, F (2,139)

= .73, p = .48; there was a main effect for sex, F (1,139) = 11.79, p < .001; and there was an interaction, F (2,139) = 3.30, p = .03. There were no differences among the groups for peak amplitude in prepulse trials, F (2,139) = .44, p = .64; there was a main effect for sex, F (1,139) = 4.08, p =.04; and no interaction was present, F (2,139) = 1.04, p = .35. The number of pulse trials in which a peak was produced did not differ among the groups, F (2,139) = .65, p = .52; there was a main effect for sex, F (1,139) = 4.84, p = .02; and there was no interaction, F (2,139) = 1.60, p = .20. There were no differences among groups for number of peaks produced in a prepulse trial, F (2,139) = .42, p = .65; there was a main effect for sex, F (1,139) = 10.36, p < .001; and there was no interaction, F (2,139) = .75, p = .47. The number of pulse trials eliciting noise response did not differ among groups, F (2,139) = .02, p = .97; there was no main effect for sex, F (1,139) = .08, p = .76; and there was no interaction, F (2,139) = 1.13, p = .32. The number of prepulse trials eliciting noise response did not differ among groups, F (2,139) = .08, p = .91; there was no main effect for sex, F (1,139) = .00, p = .99; and there was no interaction, F (2,139) = 1.45, p = .23. The number of pulse trials in which a peak was presented and there was not a response did not differ among the groups, F (2,139) = .87, p = .41; there was a sex main effect, F (1,139) = 6.62, p < .01; and there was no interaction, F (2,139) = .67, p = .51. There were no differences among groups for number of prepulse trials in which a peak was presented and there was not a response, F (2,139) = .79, p = .45; there was a main effect for sex, F (1,139) = 8.84, p < .01; and no interaction was present, F (2,139) = .82, p = .43.

Discussion

Past research has suggested that exposure to a second language has a positive effect on the development of inhibitory control processes in children and adults; this has been called the “bilingual advantage”. Inhibitory control processes associated with the bilingual advantage have been measured with response choice tasks such as the Simon task. In the Simon task, responding to a salient feature -- the left or right location of the square on the screen -- has to be inhibited in order to respond to the less salient correct feature -- in this case the color of the square. In fact to override an automatic response requires not only inhibition but also precognitive functions such as sensorimotor gating. Whether being bilingual benefits precognitive functions has not yet been investigated. Sensorimotor gating may be especially interesting to study because sensorimotor gating is believed to represent a psychophysiologically-based mechanism that acts as a stimulus filter, sustains attention, and benefits inhibition (Braff, Geyer, & Swerdlow, 2001).

The present study had two goals. The first goal was to further investigate the bilingual advantage in university students. Only one study to date (Bialystok, Martin , & Viswanathan, 20005) had suggested that while all other age groups exhibit a bilingual advantage, 20 to 30 years old university students did not. Given the bulk of evidence in favor of the bilingual advantage, it was predicted that bilingual university students in this study would have greater inhibitory control, as measured by fewer errors and a smaller RT difference between congruent and incongruent trials (smaller Simon effect).

The second goal was to examine whether the bilingual advantage extended to a precognitive non-language based task measuring sensorimotor gating, operationalized as startle inhibition. Participants were assessed on a startle eye blink task. It was predicted that as compared to monolinguals, bilinguals would have greater sensorimotor gating and thus greater inhibition of the eye blink response following the presentation of a prepulse stimulus.

In the planned analyses, contrary to what was predicted, but consistent with one previous study, there were no differences in accuracy scores or RTs between bilingual and monolingual university students on the Simon task. However, a trend effect suggested that bilinguals were slower than monolinguals on incongruent trials, opposite to what we would have expected. Bilingual and monolingual university students did not differ on a measure of startle eye blink inhibition.

Because differences between bilinguals and monolinguals on the Simon task were not found and predictions regarding sensorimotor gating were not supported, exploratory analyses were conducted in order to further examine possible neurocognitive differences in participants exposed to a second language (Exploratory analysis I). The grouping criterion in the planned analyses was reconsidered. Language dominance was determined by Item 1 from the Language Background Questionnaire (Appendix). A participant was considered "English monolingual" when the participant rated their language proficiency as being on the upper extreme of the scale (a, b, or c); when a participant rated their language proficiency as being in the middle range of criteria (choice d, e, or f) the participant was considered to be bilingual, and when a participant rated their language proficiency as being on the lower extreme of the scale (g, h, or i) the participant was considered to be Spanish monolingual. It was reasoned however that the nature of monolingualism in Spanish and English speakers in this study may have been unique. At the time of participation, all participants in this study were attending an English-language based university. Thus, while English monolingual participants could function well with no knowledge of Spanish, Spanish monolinguals in this study were required to use English to some extent each week of the semester. Hence, for the first set of exploratory analyses the planned comparisons were repeated using three groups instead of two, English monolinguals, Spanish monolinguals, and bilinguals. Similar to the planned analyses, groups did not differ on either the Simon task or on measures of startle inhibition.

In the second set of exploratory analyses we explored one more possibility for understanding the effect of second language acquisition on inhibitory control processes. The criteria for monolingual and bilingual speakers were re-considered in yet another way, that is, with regard to age of second language acquisition (see Items 2 and 3 from Appendix) and its possible neurocognitive benefit for inhibitory control processes. Inhibitory control processes (and other executive functions such as planning, goal-directed behavior, self-monitoring, and cognitive flexibility) are dependent on prefrontal pathways that develop most rapidly between the ages of 5 and 8 years of age (Schachar & Logan, 1990). The development of inhibitory control is directly related to the changes that occur in the brain at different stages of development. (Brocki & Bohlin, 2004; Dowsett & Livesey, 2000; Zelazo et al., 2003). Between the ages of 1 and 4 years, inhibitory control processes are barely beginning to develop. Research suggests that 3-year-old children may have the necessary cognitive resources to understand the rules of a task requiring response inhibition, but when it comes to performing the task they are unable to withhold or execute the correct response (Diamond, 2006; Dowsett & Livesey, 2000). This inability to withhold or produce a correct response is a consequence of the immaturity of the brain pathways responsible for response inhibition (Dowsett & Livesey, 2000). Furthermore, the ability to inhibit task irrelevant information increases throughout the middle childhood years and beyond, and when inhibitory processes are mature, the benefits expand to a range of behavioral domains. For example, children develop the ability to withhold responding until a correct solution to an abstract problem is recognized. Selective attention is another dimension that benefits from the development of inhibitory control, as children become more and more able to suppress an incorrect response in favor of a correct novel response (Harnishfeger and Bjorklund, 1994). This is the process required to perform successfully in the Simon task.

Taking the development of inhibitory control into consideration, it was reasoned that participants exposed to a second language between the ages of 1 and 4 before inhibitory control processes developed enough to be used in the service of resolving conflicting information, or participants who never learned a second language, were considered to be the group that would experience no benefit from learning a second language. Participants exposed to a second language between the ages of 5 and 8, when the brain pathways supporting inhibitory control processes were rapidly developing and first being used in the service of resolving conflicting information, were considered to be the group that would benefit the most. In other words, experiencing the extra demands of acquiring a second language at this time in development would exert a lasting "booster effect" on inhibitory control processes. Participants who encountered the second language after the age of 8, after which the development of inhibitory control processes had peaked but were nonetheless continuing, were considered to be the group that would benefit moderately from acquisition of a second language.

On the Simon task, the groups did not differ in their performance. With regard to startle inhibition however, a trend effect was found, with group differences at the border of reaching statistical significance. Participants who began learning the second language between the ages of 5 and 8 years, when inhibitory processes were most rapidly developing, had the largest amount of startle inhibition, particularly among females.

The negative findings for bilingual advantage on the Simon task in university students replicated those of Bialystok, Martin and Viswanathan, (2005). The language grouping criteria followed by Bialystok et al, and the RTs obtained were different from the ones of the present study. Nevertheless, the findings were the same, bilingual university students did not show the bilingual advantage. In Bialystok study, a participant was considered to be bilingual when the two languages were spoken between the ages of 1 and 2 years. This criterion was not strictly followed in our study. Also, bilingual and monolingual participants in Bialystok study were faster in both congruent and incongruent trials (RT congruent = 460 ms, RT incongruent = 475 ms for monolinguals; RT congruent = 465 ms, RT incongruent 475ms for bilinguals) than bilinguals and monolinguals from our study.

Regardless of how “bilingualism” was defined, university students did not exhibit the bilingual advantage on the Simon task. In Bialystok et al.’s studies, faster response times were found among children, middle age adults and older adults, but not for students attending university. It was found that middle age adult bilinguals (mean age= 43 years) and older adults bilinguals (mean age= 72 years) were significantly faster on congruent and incongruent trials, and showed a smaller Simon effect compared to their monolingual counterparts (Bialystok, Craik, Klein, & Viswanathan, 2004). Similarly, bilingual children (mean age= 5 years) performed more rapidly in the Simon task compared to monolinguals (Martin-Rhee & Bialystok, 2008). In their study from 2005 however, as compared with monolinguals, bilingual university students did not have an advantage with regard to errors or response time. Bialystok et al.’s explanation for the lack of difference among monolingual and bilingual university students on the Simon task was that the bilingual advantage may be evident only when inhibitory control processes are developing (mean age, 5 year olds) or when the bilingual advantage provides a protective effect for cognitive functions that are beginning to wane (participants 30 – 59 and 60 – 80 years old) (Bialystok, Martin, & Viswanathan, 2005). We would like to suggest another explanation. Given recent evidence regarding the remarkable plasticity of the brain throughout the lifespan (Willis & Schaie, 2009), it is possible that the large intellectual demands on university students are inducing a variety of developmental brain changes that, among other things, contribute to large individual differences in performance on the Simon task, and that these large individual differences obscure group performances. In fact, in the present study, standard deviations on the Simon effect variable were double that of the mean for all groups.

With regard to the current sample, another possible explanation for the lack of difference among university students on Simon task may be the lack of any "true" differentiation between bilinguals and monolinguals living in the El Paso border region. This region may be unique with regard to language exposure and acquisition. Many of the bilingual students who participated in this study came from Cd. Juarez, particularly freshmen, and they started to learn English as their second language while Spanish was still their dominant language. Therefore, their level of English proficiency was not fully developed, and perhaps the effect of second language acquisition had not had its full effect on their inhibitory control processes. At the same time, students who considered themselves as "monolinguals" may not be truly monolingual. For instance, even when participants in this study did not speak Spanish, it was likely that they were exposed to it on a daily basis, via social interactions, television, radio, music, and/or friends. As a consequence, this highly bilingual environment provides "monolinguals" frequent and consistent exposure to a second language. Hence, due to the nature of the bilingual setting in which they lived, bilinguals and monolinguals in this study may not have resembled the "pure" monolingual and bilingual participants in most of Bialystok's studies.

Earlier findings from Bialystok and Majumder (1998) suggested why characterizing the degree of bilingualism can be critical for studies of the bilingual advantage. Bialystok and Majumder examined the effects of different degrees of bilingualism among third graders on nonverbal problem solving tasks that tested either analysis of stimuli or inhibitory control. In their study there were three language groups: English monolinguals, French-English fully bilinguals, and Bengali-English partial bilinguals. It was found that the fully bilinguals outperformed the partial bilinguals and the monolinguals on non-linguistic task that required participants to exercise inhibitory control by focusing their attention on specific aspects of the problem, while ignoring distracting alternatives (as is required in the Simon task). On the other hand, no differences were found between groups on a task that required only the analysis of stimulus properties. It was concluded that only fully bilinguals had an advantage, and only with regard to inhibitory control. Similar results have been reported in other studies in which a high degree of bilingualism produced better cognitive performance as compared to partial bilingualism or monolingualism (Ricciardelli, 1992; Cummins, 1977). In future studies it may be critical to find ways to characterize these intermediary levels of bilingual language acquisition.

Another factor that may have influenced the results of the study was the large standard deviations obtained, specifically on the Simon effect variable. In the present study, relatively large millisecond differences on RT and thus Simon effect were apparent between groups however the differences did not reach statistical significance due to very large standard deviations within groups that were often times twice as large as the group mean (see Table 1, Simon effect). The number of trials used in the Simon task program might be cited as the source of large standard deviations. In fact, it seems that there is no general rule for the optimal number of trials for this task. Previous studies have reported Simon task data from tasks consisting of 8 blocks with 52 trials each, 416 trials total, (23 to 37 year-olds) (Bialystok et al., 2005); 2 blocks with 20 trials (4 and 5 year-olds) (Martin-Rhee & Bialystok, 2008); 48 trials (30 to 58 year-olds) (Bialystok, Craik, Klein, & Viswanathan, 2004); and 80 trials (young adults, 20 to 30 years old) (Bialystok, Martin, & Viswanathan, 2005). Nonetheless, virtually all previous studies reported differences among language groups in Simon task performance. For the present study the number of trials for the Simon task program was increased from 28 (Bialystok, Craik, Klein, & Viswanathan, 2004) to 100 because 28 trials were considered to be very few. For future studies it may be important to consider how the Simon task could be improved to reduce standard deviations within groups.

Sensorimotor gating was examined in this study by measuring startle inhibition following the presentation of a prepulse stimulus. It was predicted that bilinguals would have greater inhibition of the eye blink response on trials in which the prepulse was presented prior to the pulse stimulus. No differences on startle inhibition were found between monolinguals and bilinguals, or between English monolinguals, Spanish monolinguals and bilinguals. However, a trend effect ($p = .06$) was found when age of second language acquisition was considered. With regard to precognitive processes, in this case sensorimotor gating, second language acquisition that occurred between the ages of 5 and 8 appeared to improve sensorimotor gating in female university students. For future studies of precognitive processes, the age of second language acquisition may be usefully considered as the primary grouping factor.

Sex differences in startle inhibition were apparent and opposite from previous studies comparing males and females. In this study of largely Hispanic participants, females had significantly larger startle inhibition than males. This has not been previously reported. Past studies of predominantly Anglo-American and western European participants have consistently reported that men exhibit more startle inhibition than women (Jovanovic et al., 2004; Swerdlow et al., 1993; Swerdlow et al., 1999; Swerdlow, Hartman, & Auerbach, 1997). The same phenomenon was observed between male and female rats (Koch, 1998). It is possible that this study has captured a unique characteristic of Hispanic university-age students that warrants further examination in studies designed to assess sensorimotor gating in bilingual university-age Hispanic students.

In conclusion, there was no support for the hypothesis that university-age bilinguals outperform monolinguals with regard to accuracy, speed or inhibitory control on the Simon task. These findings were consistent with one previous study (Bialystok, Martin, & Viswanathan, 2005) in which university bilinguals did not demonstrate a benefit from bilingualism as measured by the Simon task. Possible reasons for the lack of difference between the languages groups was the age range of the participants, the large standard deviations on the Simon task, the influence of the bilingual setting in which monolingual participants in this study live, and the degree of bilingualism.

With regard to startle inhibition, a trend effect suggested that in female university-age participants, acquisition of a second language during the years in which inhibitory control was developing most rapidly (ages 5 to 8) may benefit the precognitive process of sensorimotor gating into the university-age years (ages 17 to 46). Further studies are needed with larger numbers of participants in each “age of second language acquisition” group to confirm or disprove the observed trend.

For future studies, it would be optimal to recruit “true” monolinguals in other cities of the U.S. or even in Mexico. This would ensure that participants are not exposed to a second language. Similarly, recruitment of participants who are fully bilingual would require a more thorough oral test to ensure full development of bilingual skills. In addition, increasing the number of experimental trials in the Simon task might reduce the very large standard deviations within groups that were observed in this study. If the developmental perspective for advantages in inhibitory control processes is to be pursued, the age of second language acquisition should be considered as the primary criteria for participant recruitment.

The present study served as a gateway for dissertation ideas. Based on the present findings, future studies might pursue the bilingual advantage in young children between the ages of 5 and 8. It would be interesting to replicate Bialystok's studies for this age group and examine whether the bilingual advantage expands and benefits other pre-cognitive mechanisms that were not examined in this study. For instance, it could be interesting to investigate whether the bilingual advantage extends to brain pathways that contribute to various aspects of attention, including alerting, orientation, and conflict resolution as measured in Posner's flanker task. Another option could be to explore how bilingualism may benefit saccadic eye movements, another behavioral function that is largely guided by inhibitory control pathways.

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Table 1

Descriptive Statistics for Simon Task and PPI Variables

	Mean	SD	SE	Min	Max
PPI	37.13	22.55	1.87	0	92.84
Accuracy Congruent Trials	0.98	0.03	0	0.82	1
Accuracy Incongruent Trials	0.95	0.06	0.01	0.6	1
Response Time Congruent trials	878.05	205.38	17.06	390.66	1309.65
Response Time Incongruent trials	913.2	206.08	17.11	446.81	1304.17
Simon effect	35.15	71.79	5.96	-138.24	228.83
Time of Peak Pulse Trials	75.23	20.89	1.74	51.78	154.22
Time of Peak Prepulse Trials	130.68	23.08	1.92	61.67	175.61
Peak Amplitude Pulse Trials	288.49	173.98	14.45	72.17	900.83
Peak Amplitude Prepulse Trials	167.02	105.69	8.78	28	624.61
Number of pulse trials eliciting blink response	17.37	2	0.16	0	18
Number of prepulse trials eliciting blink response	12.26	3.98	0.33	0	18
Number of pulse trials eliciting noise response	0.18	1.13	0.09	0	9
Number of prepulse trials eliciting noise response	0.13	0.69	0.05	0	6
Number of pulse trials eliciting no response	0.43	1.58	0.13	0	17
Number of prepulse trials eliciting no response	5.53	4	0.33	0	18

Table 2

Means and Standard Deviations on the Simon Task Variables by Sex

	Males	Females
Simon effect	36.97 (72.45)	33.41 (71.67)
Accuracy Congruent Trials	.97 (.03)	.97 (.02)
Accuracy Incongruent Trials	.95 (.06)	.96 (.06)
Response Time Congruent trials	881.49 (211.05)	874.74 (201.19)
Response Time Incongruent trials	918.46 (208.55)	908.15 (204.96)

Table 3

Means and Standard Deviations on the Simon Task Variables for Monolinguals and Bilinguals

	Monolinguals	Bilinguals
Simon effect	27.78 (70.59)	45.30 (72.77)
Accuracy Congruent Trials	.97 (.03)	.98 (.02)
Accuracy Incongruent Trials	.95 (.05)	.95 (.07)
Response Time Congruent trials	859.31 (196.43)	903.84 (216.07)
Response Time Incongruent trials	887.10 (199.38)	949.14 (211.32)

Table 4

Mean Simon Effect, Standard Deviations, and Frequency for each of the Language Background Questionnaire Items

Item	Frequency	Simon effect	SD
a. I speak only English	19	24.87	18.25
b. I speak English, but I do not speak Spanish fluently	28	22.37	15.78
c. I speak both languages fluently, but my English is much better	36	35.01	8.75
d. I speak both languages fluently, but my English is a little better	7	95.72	43.59
e. I speak English and Spanish with equal fluency	20	33.96	16.75
f. I speak both languages fluently, but my Spanish is a little better	14	39.14	14.26
g. I speak both languages fluently, but my Spanish is much better	18	40.11	14.66
h. I speak Spanish, but I do not speak English fluently	3	39.34	59.21
i. I speak only Spanish	-	-	-

Table 5

Means and Standard Deviations on PPI Variables by Sex

	Males	Females
PPI	33.08 (23.22)	41.00 (21.33)*
Time of Peak Pulse Trials	80.09 (23.88)	70.55 (16.38)**
Time of Peak Prepulse Trials	125.71(23.96)	135.43 (21.28)**
Peak Amplitude Pulse Trials	241.23 (159.0)	333.82 (176.67)**
Peak Amplitude Prepulse Trials	149.02 (89.23)	184.29 (117.39)*
Number of pulse trials eliciting blink response	17.00 (2.58)	17.74 (1.09)*
Number of prepulse trials eliciting blink response	11.21 (4.09)	13.28 (3.62)**
Number of pulse trials eliciting noise response	.21 (1.21)	.16 (1.06)
Number of prepulse trials eliciting noise response	.13 (.65)	.14 (.73)
Number of pulse trials eliciting no response	0.78 (2.18)	0.09 (.33)**
Number of prepulse trials eliciting no response	6.52 (4.16)	4.58 (3.60)**

* $p < .05$

** $p < .01$

Table 6

Means and Standard Deviatiosn on Simon Task Variables by Groups for Exploratory Analyses I

	English monolinguals	Bilinguals	Spanish monolinguals
Simon effect	28.50 (70.40)	44.65 (79.69)	42.47 (64.40)
Accuracy Congruent Trials	.97 (.03)	.97 (.03)	.98 (.02)
Accuracy Incongruent Trials	.95 (.04)	.94 (.08)	.96 (.04)
Response Time Congruent trials	862.50 (197.20)	867.10 (222.05)	942.40 (201.70)
Response Time Incongruent trials	891.00 (200.13)	911.80 (219.33)	984.90 (196.44)

Table 7

Means and Standard Deviations on Simon Task Variables by Groups in Exploratory Analyses II

	Bilingual Exposure Ages 0 to 4	Bilingual Exposure Ages 5 to 8	Bilingual Exposure Ages 8 and above
Simon effect	43.50 (77.68)	36.69 (71.12)	25.50 (66.18)
Accuracy Congruent Trials	.97 (.03)	.97 (.04)	.97 (.02)
Accuracy Incongruent Trials	.94 (.07)	.95 (.04)	.95 (.04)
Response Time Congruent trials	860.80 (211.74)	861.40 (195.56)	908.30 (206.91)
Response Time Incongruent trials	904.40 (218.40)	898.10 (196.67)	933.80 (202.91)

Table 8

Means and Standard Deviations on PPI Variables by Groups in Exploratory Analyses II and by Sex

	Bilingual exposure Ages 0 to 4	Bilingual exposure Ages 5 to 8	Bilingual exposure Age 8 and above
Males			
PPI	34.43 (21.23)	36.56 (21.98)	29.42 (25.78)
Time of Peak Pulse Trials	79.83 (18.76)	84.21 (28.60)	77.23 (24.01)
Time of Peak Prepulse Trials	129.95 (24.12)	123.73 (20.0)	123.87 (26.81)
Peak Amplitude Pulse Trials	244.97 (157.28)	207.34 (91.72)	263.71 (196.57)
Peak Amplitude Prepulse Trials	141.50 (58.97)	129.57 (62.59)	169.51 (119.41)
Number of pulse trials eliciting blink response	17.63 (.72)	16.95 (1.74)	16.53 (3.75)
Number of prepulse trials eliciting blink response	11.95 (4.00)	10.71 (3.33)	11 (4.70)
Number of pulse trials eliciting noise response	0 (0)	0.23 (1.09)	0.35 (1.70)
Number of prepulse trials eliciting noise response	0 (0)	0.19 (.51)	0.17 (.94)
Number of pulse trials eliciting no response	0.36 (.72)	0.81 (1.12)	1.10 (3.28)
Number of prepulse trials eliciting no response	5.59 (4.10)	7.09 (3.31)	6.82 (4.76)
Females			
PPI	40.42 (21.15)	49.49 (20.06)	34.64 (21.02)
Time of Peak Pulse Trials	69.78 (10.35)	68.13 (14.62)	73.54 (22.92)
Time of Peak Prepulse Trials	135.87 (18.53)	139.01 (19.33)	131.88 (25.90)
Peak Amplitude Pulse Trials	358.10 (206.04)	381.05 (160.48)	264.11 (128.36)
Peak Amplitude Prepulse Trials	200.68 (140.20)	175.37 (83.64)	171.25 (112.16)
Number of pulse trials eliciting blink response	17.56 (1.65)	17.95 (.22)	17.79 (.50)
Number of prepulse trials eliciting blink response	13.23 (13.23)	13.95 (13.95)	12.79 (12.79)
Number of pulse trials eliciting noise response	0.33 (1.64)	0.05 (.22)	0.04 (.20)
Number of prepulse trials eliciting noise response	0.26 (1.11)	0.10 (.30)	0 (0)
Number of pulse trials eliciting no response	0.10 (.30)	0 (0)	0.16 (.48)
Number of prepulse trials eliciting no response	4.50 (3.54)	3.95 (3.22)	5.20 (4.02)

Appendix

1. Please indicate which statement best describes your spoken proficiency in Spanish and English.
    a. I speak only English.
    b. I speak English, but I do not speak Spanish fluently.
    c. I speak both languages fluently, but my English is much better.
    d. I speak both languages fluently, but my English is a little better.
    e. I speak English and Spanish with equal fluency.
    f. I speak both languages fluently, but my Spanish is a little better.
    g. I speak both languages fluently, but my Spanish is much better.
    h. I speak Spanish, but I do not speak English fluently.
    i. I speak only Spanish.

2. At what age did you begin to learn English?

3. At what age did you begin to learn Spanish?

CURRICULUM VITA

Marisela Gutierrez was born December 12, 1983 in Ciudad Chihuahua, México. First daughter of Francisco Javier Gutiérrez Torres and Maricela Vega Caro, she graduated from Tecnológico de Monterrey Campus Ciudad Juárez, in May 2001 and entered The University of Texas at El Paso in the fall of 2001. She graduated in the Fall of 2005 with a Bachelor of Science in Psychology with the honors of Magna cum Laude and outstanding academic achievement award. In the fall of 2006 she entered the Clinical masters program at The University of Texas at El Paso. In the fall of 2009 she received a Master's of Arts in Clinical Psychology. She entered the Health Psychology doctoral program in Fall 2008 and is working under the supervision of Dr. Christina Sobin in the Laboratory of Neurocognitive Genetics and Developmental Neurocognition.

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