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Degree of bilingualism modifies executive control in Hispanic children in the USA

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Abstract

Past studies examining the cognitive function of bilingual school-aged children have pointed to enhancements in areas of executive control relative to age-matched monolingual children. The majority of these studies has tested children from a middle-class background and compared performance of bilinguals as a discrete group against monolinguals. The objective of the present study was to determine if cognitive enhancement from bilingualism is sensitive to the child's degree of bilingualism in a sample of eight- and nine-year old Spanish–English bilingual children of low socioeconomic status. The results showed that the more balanced the children were in their language skills, the better they performed on non-verbal tasks of cognitive function. These results support an additive view of bilingualism, where more balanced proficiency in two languages is associated with more enhanced cognitive function, regardless of socioeconomic background.

Keywords

Bilingualism; executive control; bilingual education; socioeconomic status; Hispanic children

Research examining the relationship between language experience and cognition has pointed to selective advantages for bilingual children compared to their monolingual counterparts in tasks requiring the use of executive control (for review see Barac et al. 2014; for meta-analysis see Adesope et al. 2010). The reason for these enhancements is generally attributed to the need by bilinguals to constantly manage attention to two jointly activated languages (for review see Kroll et al. 2012), a process that requires high levels of selective attention (Bialystok 2015) and over time improves those processes broadly and enhances general executive control, even for nonverbal tasks (Bialystok, Craik, and Luk 2012). In turn, better executive control has been shown to be associated with enhanced academic performance, especially in the areas of math and reading (Best, Miller, and Naglieri 2011; Blair and Razza 2007). Nevertheless, cognitive function and academic performance are also sensitive to socioeconomic status (SES), with middle-class children typically outperforming lower class

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children on most measures (Noble, Norman, and Farah 2005, 2006). Because low SES and bilingualism often co-occur, especially in the USA, a more detailed measure of bilingualism is needed to investigate the role of that experience in children's development of executive control. The present study approached this issue by assessing degree of bilingualism in a sample of low SES Spanish–English children.

There has long been a concern that research showing effects of bilingualism on cognitive development has been confounded with the effects of SES (Morton and Harper 2007). The possibility is particularly salient in the USA (although ironically, Morton and Harper argued that bilinguals had *higher* SES than monolinguals and that the positive effects of bilingualism were in fact effects of SES). In the USA, Hispanics currently account for approximately 25% of school-aged children, and in some states such as California, more than 50% (U.S. Department of Education 2014, 2015). In the last US Census, Hispanics, or those who identify as coming from a Spanish-speaking background, exhibited the lowest academic performance of all racial and ethnic groups, including Blacks (Aud, Fox, and Ramani 2010; US Census 2012a). This at-risk status for educational performance is compounded by the fact that approximately 30% of Hispanic children in the USA under 18 years of age come from a low SES background, where SES is defined according to parental education and relative family income (Health, United States 2011). Overall, Hispanic children are one of the most at-risk educational groups in the USA.

Many Hispanic children live in families for which Spanish is the home language¹ but schooling is conducted in English, making them necessarily bilingual to some extent. However, the demographic background, particularly in terms of the at-risk factors operating for this group, may mitigate the reported effect of bilingualism on their cognitive development, particularly regarding executive control. The majority of the literature reporting cognitive differences between monolingual and bilingual children has focused on comparisons between groups of children in contexts more conducive to positive cognitive outcomes and high academic success (e.g. Bialystok 2010; Bialystok and Martin 2004; Filippi et al. 2015; Yang, Yang, and Lust 2011). Less is known about the effect of bilingualism for children who additionally face challenges from low SES, poverty, and non-stimulating home environments.

Some studies have compared monolingual children from middle-class backgrounds with bilingual children from low SES backgrounds by using statistical procedures to control for the variance attributed to those different contexts. Carlson and Meltzoff (2008), for example, administered a battery of executive control tasks to six-year-old children who were monolingual or bilingual. The bilingual children obtained large and significantly lower measures than monolingual children on levels of family income, parental education, and amount of time in which parents spent reading to children, all factors known to affect cognitive and academic outcomes. Therefore, the authors entered some (but notably not all) of these factors as covariates into the analysis of performance on the executive control tasks. These analyses revealed significantly better performance by the bilingual children in

¹An unknown percentage of children from Mexico and Central and Latin America come from communities speaking indigenous languages, but are still classified as 'Hispanic'.

performing executive control tasks that included conflict, but not for those in which no conflict was present, replicating the pattern found in research conducted with middle-class children (e.g. Martin-Rhee and Bialystok 2008). However, the statistical control of background variables may not be equivalent to a comparison between groups for which these background factors are controlled in the experimental design to preclude initial differences in experience.

A more direct way of evaluating the cognitive and executive control abilities of low SES bilingual children, therefore, is to compare them to monolingual children with similar backgrounds. Four studies have reported such data. The first study, by Engel de Abreu and colleagues (Engel de Abreu et al. 2012), compared eight-year-old monolingual children in Portugal and age-matched bilingual immigrants in Luxembourg whose families had come from the same region in Portugal where the monolinguals were tested. All the families were very low SES and were matched on many indices, with the primary difference being that the children in Luxembourg were attending local schools, and therefore, becoming bilingual. Consistent with this research, the monolingual children obtained higher scores on measures of language proficiency (cf. Bialystok et al. 2010), but the bilingual children performed better than monolinguals on those executive control tasks that included conflict, but not on those that did not include conflict, replicating again the previous pattern. Similarly, Mezzacappa (2004) reported better performance by Hispanic children performing a flanker task than was found for African-American children with similarly low SES. Although bilingualism was not formally measured in the study, Mezzacappa noted that about 70% of the Hispanic children spoke Spanish at home.

Using a factorial design, Calvo and Bialystok (2014) compared monolingual and bilingual six-year-old children who were either middle-class or working-class on a battery of executive control tasks, and again found that bilingual children outperformed the monolinguals in both SES levels. The important feature of this design was that none of the families was low SES, and none of the children was at-risk for academic failure from factors associated with poverty. The distinction between middle-and working-class was made on the basis of parental education to determine if there was an effect of a subtle manipulation of SES on children's performance, and whether this effect interacted with bilingualism. The results indicated two main effects, with bilingual children at both SES levels outperforming monolinguals on executive control tasks, and higher SES levels for both language groups leading to better performance as well. There was no interaction between these factors, indicating that both bilingualism and SES operate as independent influences on children's cognitive development.

Finally, a recent study by Krizman, Skoe, and Kraus (Forthcoming) used a similar design as that employed by Calvo and Bialystok but included measures of auditory sensory functioning and tested adolescents (14-year-olds) rather than young children. As in the previous studies, independent effects for both bilingualism and SES were found, confirming that the role of bilingualism in modifying cognitive outcomes operates irrespective of level of SES.

These studies together provide compelling evidence that there is no confound between bilingualism and SES in the existing literature and that the cognitive benefits from bilingualism can be found at all levels of SES. What is less clear is how the experience of bilingualism is related to the reported cognitive outcomes. The general view is that the cognitive benefits are a result of the ongoing experience of managing attention to two jointly activated languages and that this practice in attention to language generalises to other domains. If that is the case, then there should be evidence for dose-related effects in which higher levels of bilingualism are associated with greater benefit. Such a finding would be particularly important in the case of Spanish–English bilingual children in the USA for whom academic achievement is compromised by SES and public policy is largely aimed at making their school environments more monolingual and English.

Two studies have examined the relation between children’s degree of bilingualism and executive control outcomes, tying the possible improvement in executive control more clearly to the experience of bilingualism. The first study by Bialystok and Barac (2012) examined children between 9- and 11-years old who were becoming bilingual through attending immersion education programmes. All the children were middle-class SES, so the background was comparable. The results showed that children’s performance on executive control conflict tasks was associated with their degree of bilingualism measured as the amount of time they had spent in the immersion programme and their level of proficiency in the second language. Thus, greater bilingualism was related to better executive control.

Second, Crivello et al. (2016) used a longitudinal approach to track the emergence of executive control ability in monolingual and bilingual toddlers. Consistent with previous research, the bilingual children outperformed the monolinguals on executive control tasks requiring conflict resolution, but not on those tasks for which there was no conflict (cf. Carlson and Meltzoff 2008; Martin-Rhee and Bialystok 2008). Moreover, performance of the bilingual children on the conflict tasks was significantly related to their degree of bilingualism, again confirming the role of bilingualism in these results.

The purpose of the present study was to determine if these results extend to low SES children who additionally face a variety of risk factors for cognitive development and academic achievement. As described above, the most at-risk children in the USA are Hispanic children who are dual language learners living in low SES circumstances. Following from previous research, the assumption was that the beneficial effects of bilingualism would be available to these children, and the specific hypothesis was that the extent of those benefits would be mediated by their degree of bilingualism. Thus, the prediction was that the more balanced the children’s language skills were between English and Spanish, the better they would perform on non-linguistic executive control tasks.

Method

Participants

Hispanic students in third grade with knowledge of both English and Spanish were recruited from a school district in California with a high population of Hispanics from low income backgrounds. Children were enrolled in either dual immersion or transitional/English-only

classrooms. To qualify for participation, the child's parents had to have had no more than a high school education, and have non-professional employment. Consistent with sociocultural and linguistic definitions (Carreira 2004; Ennis, Ríos-Vargas, and Albert 2011), designation of 'Hispanic' meant that the child was either born in a Spanish-speaking country and immigrated to the USA, or was a first or second generation US-born American whose parents or grandparents were born in a Spanish-speaking country and immigrated to the USA as adults. To obtain background and demographic information about the participants, a detailed questionnaire was administered to parents (distributed in Spanish and English). Since 80% of primary-school aged Hispanic children in the USA are born in the USA (U.S. Census 2012b), the majority of participants was born in the USA, and some had arrived before five years of age.

The final sample included 64 typically developing, right-handed children with a mean age of 8.8 years (range 8.2–9.4 years). The group was heterogeneous on a range of background measures, such as quantity of daily use in Spanish, and country of origin, although the majority was of Mexican origin.

Tasks

Consent forms and the Language and Social Background Questionnaire were distributed to parents in both English and Spanish. Classroom and resource teachers familiar with the families identified participating parents as literate in either Spanish or English and sent home the appropriate forms. Once consent was received, children participated in two sessions, one for each of English and Spanish verbal measures, no more than two weeks apart. The order of language testing was counterbalanced across participants. The sessions and ordering of tasks were as follows:

Session 1: Peabody Picture Vocabulary Test (PPVT, English); Raven test (general intelligence); Flanker task (executive control with conflict)

Session 2: Peabody Picture Vocabulary Test (TVIP, Spanish); Stop-Signal task (executive control with response inhibition); Frog task (working memory)

Children were tested in a quiet area of the classroom by a Spanish–English bilingual resource teacher with whom the child was familiar, in the language in which the child was most comfortable (except for the linguistic tasks).

Language and Social Background Questionnaire (Luk and Bialystok 2013)—

This instrument was used to assess the child's language, ethnic and socioeconomic background, and home language environment. Parents or caregivers completed a written questionnaire that included questions about the child's language background and proficiency, home/community language use, and parental/family origins, language use, education and employment. Parents were asked to indicate their current employment and identify their education level on a five-point scale: (1) No high school diploma; (2) High-school graduate; (3) Some college or college diploma (in Spanish this refers to technical/trade schools); (4) Bachelor's degree; and (5) Post-graduate degree. In the data analysis, a mean score for parental education was used as an independent variable representing SES,

where the mother's education and father's education were averaged and entered into the regression model.

Peabody Picture Vocabulary Test (English PPVT (Dunn and Dunn 2007), Spanish TVIP Dunn et al. 1986)—These tests were used to determine the children's degree of bilingualism by assessing their receptive vocabulary in both English and Spanish. The difference between vocabulary sizes has previously been used to determine the degree of balanced proficiency in the two languages (Umbel et al. 2008).

In these untimed tasks, single words (nouns, verbs, and adjectives) are presented to the child aurally, and the child is asked to select from one of four visual representations the one that best matches the word. Items become increasingly difficult, and testing continues until a criterion number of errors is made and a score is calculated according to standardized procedures ($\mu = 100$, $SD = 15$). A bilingualism ratio was calculated as the absolute difference between the English and Spanish tests multiplied by -1 to reverse the ordering of scores (so that the larger numbers indicated better balance in language skills), and adding a constant of 100 so that a score of 100 indicated perfect balance and lower scores indicate less balanced proficiency [$100 + (-1 * \text{Abs}(\text{English} - \text{Spanish}))$].

Raven's Progressive Matrices (Raven 1989)—This is a test of nonverbal intelligence that is frequently used in educational settings and provides reliable estimates of fluid intelligence for individuals of different ethnic, racial and socioeconomic backgrounds. Scores were calculated as standard scores from published tables ($\mu = 100$, $SD = 15$).

Flanker Task—This task was used to examine executive control functions associated with conflict resolution. The task was programmed in E-Prime and presented on a laptop computer with a response key placed on each side. Participants saw a series of five arrowheads (chevrons) arranged in a horizontal row in the centre of the monitor and were asked to indicate the direction that the middle chevron was pointing by pressing the response key on the corresponding side of the computer.

There were two types of control trials, baseline and neutral, and two types of experimental trials, congruent and incongruent. Control blocks and experimental blocks were presented separately. In the control block, baseline trials consisted of a single chevron in the centre of the screen and neutral trials displayed a central chevron surrounded by four diamond shapes that made the display more complex but did not provide directional information. In experimental blocks, congruent trials presented the central chevron surrounded by four flanking chevrons pointing in the same direction, and in incongruent trials the four flanking chevrons pointed in the opposite direction, creating conflict. Each test trial began with a fixation presented for 250 ms, followed by the stimulus display for 2000 ms. There were a total of 48 trials baseline trials (24 per Baseline Block), 48 neutral trials (24 per Neutral Block), and 48 mixed trials consisting of 24 congruent and 24 incongruent trials.

Children completed two control blocks and two experimental blocks with the control blocks presented in the first and last positions in the order. For the control blocks, the relevant variables were reaction time (RT) and accuracy; for the experimental blocks, scores were

also calculated for congruent and incongruent trials and the difference between them (flanker effect). The overall mean RT across all blocks was used as the dependent variable in the regression models.

Stop-Signal Task (Logan 1994)—This task, also programmed in E-Prime, primarily measures response inhibition as the ability to withhold an automatic response to a stimulus when presented with a signal. Participants saw a prompt on a computer screen (e.g. star) and were instructed to click the mouse if they saw the stimulus, but do nothing if they heard a signal at around the same time as the stimulus appeared. Once the participant reached 50% accuracy, the stop-signal delay between the visual and auditory stimuli was increased or decreased, depending on the successful inhibition of responses so that performance was maintained at 50%. The relevant variable is the length of delay they can sustain and maintain performance at 50% accuracy with smaller delay indicating better performance. The task began with a control block of 16 trials in which there was no stop signal. This was followed by five blocks of trials in which 25% of trials included a stop signal. Following standard practice, the variable used in the present study was the mean stop signal RT achieved on the last four blocks of the task.

Frog Recall Task (Morales, Calvo, and Bialystok 2013)—This task was used to assess working memory, an important aspect of executive control. Participants were asked to recall the positions occupied by a series of frogs presented in a 3×3 matrix of ‘ponds’ on a computer screen. The frogs were presented either simultaneously or individually depending on the condition in series that increase from 2 to 6 frogs. Each presentation was followed by an intervening blank screen and then a response screen on a touch-screen monitor.

There were four conditions that increased in difficulty: (1) basic recall of frog positions presented simultaneously in which the frogs could be indicated in any order; (2) masked condition in which the intervening screen contained an irrelevant display of frogs as a distraction prior to the response screen; (3) sequential condition in which the frogs were presented individually and recall needed to preserve both order and position information; and (4) backward condition in which the frogs appeared sequentially but the recall required that the positions be indicated in the reverse sequence from their presentation. For basic and masked conditions, the display was shown for 2000 ms then followed by either a blank set of ponds or the masked ponds for 2000 ms. After this delay, a ‘ding’ sound indicated that the child must respond. For the sequential and backward conditions, each frog was presented individually for 1000 ms, and the ‘ding’ occurred after the final frog was presented indicating that children should respond. In both of the sequentially presented conditions, scores included a point for each of order and position accuracy. The maximum score possible for the basic and masked conditions was 40, and for the sequential and backward condition was 80. These scores were converted to percentage correct for ease of comparison.

Results

The mean scores and standard deviations for background measures are presented in Table 1. The mean scores for education level were averaged from the five-point rating scale described

in the methods, and the bilingualism score represent the average balance of bilingualism across participants, with 100 representing the most equal balance.

Results for the three executive control tasks are presented in Table 2. The accuracy scores for the flanker task were high and were not analysed further. The remaining outcome scores from the three tasks were used as the dependent variables in a regression model to evaluate the contribution of the background measures to performance on that task. Each model included child's age, parents' education, Raven matrices standard score (non-verbal intelligence), English PPVT, and bilingualism score, entered in that order.

Results of the regression analyses are presented in Table 3. The model examining the role of these factors in Stop-Signal performance accounted for 15.2% of the variance, but neither the overall model, $F(5, 33) = 1.18$, n.s., nor any of the individual factors was significant for this task.

For the flanker task, regression models were calculated both by using individual scores for congruent and incongruent trials and the overall average for the task. In research with bilinguals, group differences are most often found in both congruent and incongruent trials (for review see Hilchey and Klein 2011) so differences in the flanker effect, that is, the RT difference between these types of trials, is not generally significant (for exceptions in studies with children, see Poarch and Bialystok 2015 and Poarch and Van Hell 2012). Consistent with this pattern, using the flanker effect as the dependent variable in the regression model showed no significant effect of bilingualism. The model accounted for 17.1% of the variance and was not significant, $F(5, 40) = 1.65$, n.s. and bilingualism had no significant contribution, $t < 1$. In contrast the results were similar for both models based on congruent and incongruent trials and for those based on overall average, so only the latter is reported here. This model accounts for 25.6% of the variance, $F(5, 40) = 2.76$, $p < .03$.

For the frog task, performance on the two simplest conditions was at ceiling, so these were not included in the regression model. The regression model was calculated on the mean percent correct calculated across the two difficult conditions, namely sequence and backward. This model accounts for 22.7% of the variance, $F(5, 40) = 2.35$, $p = .05$.

For both tasks, the bilingualism ratio score entered on the last step accounted for significant variance in the outcome, with higher bilingualism scores associated with better performance. No other variables were significantly related to the outcome measures.

Discussion

In most research investigating the cognitive consequences of bilingualism in children, the approach is to compare groups of children who are designated as monolingual or bilingual to determine whether there are reliable performance differences between groups. This approach inevitably leaves many factors uncontrolled as group differences may extend beyond the number of languages children speak. At the same time, studies that have attempted to control for SES to determine whether bilingualism affects cognitive ability in low SES populations (e.g. Engel de Abreu et al. 2012) have assured comparable SES for the two groups, but still relied on comparisons between groups in which other factors might nonetheless be

operative. The present study takes a different approach to ask a more subtle question: Within a population of low SES bilinguals, does being *more* bilingual lead to better performance outcomes, all else being equal? This approach avoids the problem of between-groups comparisons and provides a clearer interpretation of bilingualism being the relevant factor in children's performance.

In two of the three executive control tasks used in the present study, there was a significant association between the child's degree of bilingualism and executive control performance after other background factors had been considered. There was no significant effect of any background factor on outcomes from the stop-signal task. This task is generally considered to be a measure of executive control that is sensitive to attention ability and is diagnostic of attention disorders (see Alderson, Rapport, and Kofler 2007 for review). However, the task is based primarily on response inhibition, a process found in previous research to be unaffected by bilingualism (Carlson and Meltzoff 2008; Engel de Abreu et al. 2012; Martin-Rhee and Bialystok 2008). Moreover, there is no research at this point that has shown an effect of bilingualism on stop-signal performance, so it is not surprising that no effect was found in the present study.

In contrast, both the flanker task (Yang, Yang, and Lust 2011) and frog task (Morales, Calvo, and Bialystok 2013) have been shown in previous research to be performed better by bilingual than monolingual children. Those studies, however, were conducted with children younger than those included in the present study, specifically five- and six-years old, respectively. Thus, children in the present study, who were almost nine-years old, obtained higher scores on both tasks than found in previous studies. More importantly, their level of performance was significantly related to their level of bilingualism, with more balanced bilingualism being associated with better performance.

The primary interpretation of these results is that in addition to the facilitating effects of bilingualism previously reported in low SES samples when compared to monolinguals, there are incremental benefits for children from low SES backgrounds who are more equally fluent in both languages, or rather, who exhibit more balanced degrees of bilingualism than their bilingual peers who have less equivalent language proficiency. Within bilingualism, therefore, more balanced bilingualism confers greater benefits in executive control more than asymmetrical bilingualism, even when children are at a social disadvantage for executive control.

These results have implications for social and education policy. Executive control is one of the most important cognitive abilities acquired in childhood and so modifications in its development are consequential. Children's level of executive control has been shown to predict educational achievement, long-term health, and earning potential (Best, Miller, and Naglieri 2011; Blair and Razza 2007; Duncan, Ziol-Guest, and Kalil 2010; Jacob and Ludwig 2009). Children from minority language backgrounds and of low SES in the USA, such as Hispanic children, are known to be at risk for all these outcomes and also tend to perform poorly on measures of executive control (Aydemir and Sweetman 2006). Importantly, however, most of these children have some degree of bilingualism. Policies that encourage bilingualism, such as educational programmes that maintain and further develop

minority language skills, such as Spanish, may have the surprising but serendipitous benefit of also improving the development of this crucial set of cognitive abilities.

The results of the present study are considered to be exploratory in that the sample was small for this type of design. Nonetheless, even with this limited sample the pattern was clear. As in a previous study with emerging bilingualism through immersion education (Bialystok and Barac 2012), children in the present study who were more bilingual performed better on executive control tasks. More definitive conclusions about the degree of bilingualism necessary, the kinds of executive control tasks affected, and the demographic circumstances supportive of these effects require further research. Nevertheless, the present study contributes clearly to our understanding that bilingualism, even among disadvantaged groups, offers additive, and not subtractive, cognitive effects, which can have a number of socially relevant consequences for educational attainment and future socioeconomic success.

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Table 1

Mean score and standard deviation for background measures.

Task category	Variable	Mean	SD
Education	Mother's education	2.68	1.16
	Father's education	2.18	1.13
	Mean education	2.44	0.81
Background measures	Raven's matrices standard	93.09	17.02
	PPVT English standard	86.23	15.91
	TVIP Spanish standard	88.94	19.36
	Bilingualism score	84.40	14.12

Table 2

Means scores for executive control tasks.

Task, outcome measure	Measure type	Mean	SD
Flanker RTs (ms)	Baseline RT	570	127
	Neutral RT	739	147
	Congruent RT	790	165
	Incongruent RT	875	159
	Overall mean	741	138
Flanker accuracy (proportion correct)	Baseline	0.91	0.10
	Neutral	0.90	
	Congruent	0.92	0.08
	Incongruent	0.87	0.11
	Overall mean	0.90	0.07
Frog accuracy (% correct)	Basic	98.9	0.03
	Masked	94.9	0.03
	Sequence	78.9	0.09
	Backward	77.6	0.08
	Mean % sequence + backward	78.3	0.06
Stop signal RT (ms)	Mean RT on last four blocks	342	130

Table 3

Regression models for dependent measures of Flanker task and Frog task

Variable	B	SE B	β	% R ²	t
(a) Flanker task: R ² = 25.6%					
Age	-0.81	5.20	-0.02	0.6%	-0.16
Parent Education	-14.24	16.38	-0.13	0.8%	-0.87
Raven test	-0.67	1.21	-0.09	2.4%	0.56
PPVT English	-1.93	1.26	-0.23	6.3%	-1.53
Bilingualism	20.38	7.08	0.40	15.4%	2.88**
(b) Frog task: R ² = 22.7%					
Age	-0.17	0.09	-0.27	8.6%	-1.94
Parent Education	-0.02	0.28	-0.01	1.0%	-0.07
Raven test	0.02	0.03	0.13	3.7%	0.83
PPVT English	0.02	0.02	0.14	1.0%	0.93
Bilingualism	0.25	0.12	0.30	8.4%	2.08*
(c) Stop signal task: R ² = 15.2%					
Age	-4.01	5.70	-0.12	3.2%	-0.70
Parent Education	-18.98	17.29	-0.20	4.9%	-1.10
Raven test	-1.16	1.25	-0.18	1.5%	-0.93
PPVT English	0.89	1.26	0.12	1.2%	0.70
Bilingualism	11.27	8.59	0.22	4.4%	1.31

* $p < .05$,** $p < .01$