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The Role of Bilingualism on Neuropsychological Test Performance among Spanish Speakers Tested in Their Native Language

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The Role of Bilingualism on Neuropsychological Test Performance among Spanish Speakers Tested in Their Native Language

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Clinical Psychology

by

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2013

The Dissertation of Paola Suárez is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California, San Diego

San Diego State University

2013

DEDICATION

I cannot thank my family enough for their sacrifice and support. My husband, who has put his career on hold in order to allow me the chance of pursuing one that will fulfill me for the rest of my life. Baby, I love you more than you will ever know. A mi papa, hermanos, a quien adoro, pero en especial a mi mamá por su amor, su bondad incondicional hacia mi y mis chiquitos y por permitirme salir de mi casa dándome la plena tranquilidad de que mis hijos estaban en las mejores manos. Su sacrificio no tiene precio (Mami, te amo!). Blanca, la verdad es que tengo palabras para agradecerle toda su ayuda y amor para con mi familia. Last, my classmates, and now close friends for being the collectivist group that you are (Mi Caro, TQM). Mis chiquitos, los amores de mi vida, quienes fueron el motor de este gran esfuerzo colectivo.

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ABSTRACT OF THE DISSERTATION

The Role of Bilingualism on Neuropsychological Test Performance among Spanish Speakers Tested in Their Native Language

by

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Doctor of Philosophy in Clinical Psychology

University of California, San Diego, 2013
San Diego State University, 2013

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Rationale: The cognitive science literature suggests both advantages and disadvantages of bilingualism for cognitive performance. However, little is known about the generalizability of such findings to clinical neuropsychology for diagnosing brain dysfunction in Spanish dominant bilinguals in the U.S. The present study examined the effects of bilingualism on Spanish-language neuropsychological test performance, and

whether or not these bilingual advantages could be explained by socioeconomic status (SES).

Design: Forty seven Spanish monolinguals and 42 Spanish-English bilinguals from the U.S. – Mexico border region were selected based on a ratio of English words to total words produced on a verbal fluency task in both language. Effects of bilingualism on neuropsychological test performance were examined as means comparisons between groups with comparable education, age, and sex. SES contributions were examined by comparing the performance of 28 bilingual and 28 monolingual participants with comparable demographic characteristics, and self-reported SES on tests where bilingual advantages were previously found.

Results: Controlling for education, bilinguals out-performed monolinguals on a test of executive function, and some tests of attention/working memory, and processing speed, with an unexpected advantage on a test of visual memory. No differences were found on tests of language abilities, learning, visuospatial, or motor skills. Bilinguals had higher childhood SES than monolinguals. After equating groups on childhood SES, bilinguals still outperformed monolinguals on tests of executive functioning (Trail Making Test B and Stroop Color-Word Interference Condition), a measure of attention and concentration (WAIS-R Digit Span), and a measure of processing speed (WAIS-III-Symbol Search).

Conclusion: These findings suggest that bilingual advantages observed in the cognitive science literature are seen on some neuropsychological tests that are commonly used in clinical settings, suggesting that learning a second language improves performance in a person's native language. These results suggest that bilingualism likely confers a true neuropsychological advantage beyond what can be explained by SES and education differences. This needs to be considered when interpreting test performance, adding complexity to the generation and application of test norms in bilingual groups.

Chapter 1: Introduction

Latinos are the fastest growing ethnic minority in the United States. According to the U.S. Census Bureau (2010), between 2000 and 2010 the Latino population increased by 15.2 million. Currently, 52 million Latinos live in the U.S. This same census estimated that approximately 20% of the U.S. population spoke a language other than English at home. Of this 20% of people (57 million) in the U.S. who spoke a second language, about 62% (35 million) spoke Spanish at home and about half were foreign born Spanish-speakers. More importantly, more than half of these Spanish-speakers reported that Spanish was their preferred language. Additionally, in 2010, 26.6% of Hispanics in the U.S. were living below the poverty level, compared to 9.9% of non-Hispanic Whites. These figures indicate that a substantial proportion of individuals in the U.S. are bilingual (regardless of their proficiency in their native language). However, to our knowledge, no study has attempted to disentangle the cognitive effects of bilingualism from socio-demographic influences, nor have studies examined the performance of Spanish-English bilinguals using a neuropsychological battery commonly used in clinical settings.

Given these census data, investigation of bilingualism and its relation to cognitive factors is particularly relevant to neuropsychological assessment, since the number of bilingual patients will likely continue to increase. Therefore, our country has an increasing need to assess individuals with varying degrees of English proficiency appropriately and sensitively, both in research and clinical settings. That is, culturally and linguistically appropriate assessment of cognitive functioning is necessary for the competent delivery of neuropsychological services, as well as for the reliability of research results in ethnically or linguistically diverse populations. To this end, this project identified the nature and predictors of test performance differences as a function of bilingualism. The findings make a strong argument for the need to account for second-language proficiency when interpreting neuropsychological test results.

A Transdisciplinary Approach to the Interference Hypothesis

A number of studies have examined the “bilingual effect” on tasks of verbal abilities. That is, bilinguals have been found to perform worse than monolinguals on tasks measuring verbal category fluency (Gollan, Montoya, & Werner, 2002) and picture naming (Gollan, Montoya, & Bonanni, 2005). Bilinguals have also been found to experience more “tip-of-the-tongue” states (TOTs) than do monolinguals (Gollan & Silverberg, 2001). According to most researchers, this phenomenon can be best explained by the Interference Hypothesis, which predicts that bilinguals will experience decreased performance on verbal tasks completed in their second language. More specifically, the Inhibitory Control Model (Green, 1998) suggests that the performance of bilinguals on verbal tasks will suffer because, in these tasks, one language must be suppressed in order to engage verbal abilities in the other language. A more recent theory, labeled “frequency lag,“ suggests that suppression alone does not account for the bilingual disadvantages on verbal tasks, and instead it is the reduced frequency of usage in any one language in the part of bilinguals when compared to a monolinguals (Gollan, Montoya, Cera, & Sandoval 2008).

The Inhibitory Control Model of bilingualism also suggests that bilinguals should perform better in tasks requiring executive abilities and attention because they constantly practice such inhibitory control as a function of suppressing one language to perform in another. In fact, research (Bialystok, 1999, 2001) has found a bilingual advantage in young children on tasks examining executive functioning. Similarly, once parental SES was accounted for, Carlson and Meltzoff (2008) showed that despite having lower verbal scores, Spanish-English bilingual children performed better than English monolinguals on executive functioning tasks.

Nonetheless, it is unclear how the "bilingual effect," or advantages/disadvantages shown by bilinguals on these experimental tasks, translates into performance on clinical assessment tools. This current dissertation study is novel in two ways. First, it examined bilingual effects in an adult sample with a range of age and education that is more representative of the general population in the U.S. Second, this study explored how theories of bilingual effects derived from cognitive science paradigms translate into performance on clinically relevant neuropsychological (NP) tests. To this end, a neuropsychological assessment battery that has been normed with healthy Spanish-speakers was used in the current project. Of note, this battery includes tests that are used widely to detect neurocognitive impairment associated with HIV and other conditions, as well as tests previously used in cognitive science paradigms. The aims of this study include:

Aim 1: To Determine Whether Bilingualism Confers Performance Advantages or Disadvantages on Neuropsychological Tests Commonly Used to Diagnose Brain Dysfunction in Clinical Populations

Rationale: As previously described, bilingualism research has found bilingual advantages and disadvantages in different cognitive tasks when compared to monolinguals. Researchers have relied on various theories of bilingualism to explain such advantages and disadvantages. This aim will specifically make predictions based on the

Interference Hypothesis to examine bilinguals' performance on neuropsychological tests commonly used for diagnosis in both research and clinical settings. The Interference Hypothesis is supported by studies showing that bilinguals outperformed monolinguals on the interference trials of the Stroop task and other executive functioning tasks that require executive and attentional control (Bialystok, Craik, & Luk, 2008a). Conversely, the literature supports a bilingual disadvantage on tasks requiring language abilities (Gollan et al., 2005; Gollan, Montoya, Fennema-Notestine, & Morris, 2005a, 2005b; Gollan et al., 2002).

Approach: Demographically similar bilinguals and monolinguals will be compared on a comprehensive NP test battery measuring seven ability domains. These include tests of verbal ability, executive functioning, attention/working memory, processing speed, learning, memory, and motor speed/dexterity (see Table 1).

Aim 2: To Determine Whether Bilingualism Exerts an Effect on Test Performance after Accounting for Socio-Demographic Variables that Might Affect Neuropsychological Performance and May Also Co-Occur with Better English Language Fluency

Rationale

Our preliminary data suggest that bilingual advantages may generalize to many areas of cognitive functioning beyond those requiring strictly inhibitory control. Educational attainment is a strong predictor of NP performance (Heaton & Taylor, 2004). However, simply counting years of education may fail to capture differences in education quality or other relevant experiences related to socioeconomic status (SES) that can affect development (e.g., access to health care, good nutrition, intellectually stimulating

Table 1. Bilingual Effect Predictions on the Neuropsychological Test Battery

Neuropsychological Test	**Bilingual Advantage**	**Bilingual Disadvantage**
VERBAL		
WAIS-R Vocabulary		+
Category Fluency		+
Boston Naming Test		+
LEARNING		
SVLT-Learning	**?+**	
Figure Learning	=	=
Story Learning	=	=
MEMORY		
SVLT Short Delay Free Recall	=	=
SVLT Long Delay Free Recall	=	=
Figure Delay	=	=
Story Delay	=	=
EXECUTIVE/ABSTRACTION		
Trails Making Test B	+	
WCST-Total errors	+	
WCST-Perserverative errors	+	
Halstead Category Test-Total errors	?+	

(table continues)

Table 1. Bilingual Effect Predictions on the Neuropsychological Test Battery, Continued

Stroop Test-Color/Word	+	
ATTENTION/WORKING MEMORY		
WAIS-III Letter Number Sequencing	+	
PASAT-Total correct	+	
WAIS-R Arithmetic	?+	
WAIS-R Digit Span	+	
PSYCHOMOTOR SPEED		
WAIS III- Digit Symbol	=	=
WAIS III-Symbol Search	=	=
Trail Making Test A	=	=
Stroop Test-Read	=	=
Stroop Test-Color	=	=
VISUOSPATIAL SKILLS		
Block Design	=	=
MOTOR ABILITIES		
Finger Tapping-Dominant Hand	=	=
Finger Tapping-Non Dominant Hand	=	=
Grooved Pegboard-Dominant Hand	=	=
Grooved Pegboard-Non Dominant Hand	=	=

environment, etc). For example, Manly, Byrd, Touradji, and Stern (2004) assessed different aspects of SES in African-Americans and proposed that disparities in quality of education lead to differences in problem-solving strategies, knowledge, familiarity, and practice; this may be manifested as lower NP test scores when compared to non-Hispanic whites with comparable years of education.

Among Latino immigrants to the U.S., bilinguals may have higher SES than Spanish monolingual immigrants. That is, becoming bilingual could be the result of social advantages, even in the context of comparable number of years of formal education. Thus, the general bilingual advantage that we have observed in our pilot data (Suarez et al., 2009) with Spanish-speaking immigrants, who have varying degrees of English fluency, may be attenuated after accounting for socio-economic status or indicators of quality of education, such as breadth of vocabulary. In support of this notion, recent work by Bialystok, Craik, and Luk (2008b) suggests that the bilingual advantage may diminish or in fact disappear after controlling for vocabulary scores. Therefore, this second aim will examine whether bilingualism is simply a proxy for socio-demographic factors that may affect test performance. If effects of bilingualism on test performance are maintained after accounting for SES or indicators of quality of education, this would strengthen the evidence supporting the idea that bilingualism results in true cognitive phenomena.

Approach

Self-report information on SES was collected in questionnaire form, including historical data about parents' education and occupation, educational environment, living conditions in childhood, access to health care, income, etc. The Vocabulary subtest of the

Wechsler Adult Intelligence Scale-III was collected as an indicator of quality of education. A study examining the direct effects of childhood SES on cognition and the indirect effects, through adult SES, as a mediator in middle life cognitive ability found the indirect model to be a better fit to explain the relationship between childhood SES (mother's education, father's education, father's financial education, financial hardship) and cognition later in life. In this study, approximately 10,000 civil servants from England offered information retrospectively and were tested using a cognitive battery. In this sample, education was found to be highly correlated with occupation, which was used as one measure of adult SES along with current salary. A structural equation modeling approach found that effects of childhood financial adversity on adult cognitive functioning are mediated by the effects of SES-related experiences throughout life (i.e., education), and that both, rather than either alone, can better account for cognition in middle age. Guided by this study, subjective SES in childhood, vocabulary scores, and years of education will be used as covariates for a bilingual effect on tests where differences are found.

Preliminary Studies

Capitalizing on data collected at the HNRC as part of a neuropsychological test norming project, we conducted a preliminary study examining the effects of bilingualism on neurocognitive performance in 192 adult native Spanish speakers from the U.S.–Mexico border region. All participants had normal neuromedical histories and responded to a language use questionnaire to ascertain Spanish preference. The Controlled Oral Word Association (COWAT) was administered (PMR in Spanish, FAS in English) to confirm language fluency (MAE; Benton, Hamsher, & Sivan, 1994). In this test, participants are asked to name as many words as possible in 60 minutes that start with one given letter. The letters used in English were FAS and PMR in Spanish (Artiola i Fortuny, Hermosillo Romo, Heaton, & Pardee, 1999). Relative English fluency (i.e., degree of bilingualism) was calculated as the ratio of English words to the total produced in both languages (the higher the ratio, the more bilingual). Participants received a comprehensive neuropsychological battery in Spanish. Effects of relative English fluency on test performance were examined with linear regression including age, years of education, sex, and years living in the U.S. as additional predictors. As expected, education was found to be a significant predictor of all of NP measures and was significantly correlated with the fluency ratio ($r = .67$, $p < .0001$)(see Table 2). When controlling for education, sex, age, and years in the U.S., higher English fluency ratio still predicted better performance on some language tests, tests of processing speed, and attention/working memory, with mixed results on tests of executive functioning and memory (Suarez et al., 2009, see Table 3). These findings are mixed with respect to predictions that would stem from the Interference Hypothesis and Inhibitory Control Model of bilingualism, and thus suggest the directions of inquiry for the current study: (1) to determine whether greater English fluency is generally associated with improved test performance in Spanish above and beyond the effects of education and other basic background factors; i.e., a generalized "bilingual advantage," (2) to explore whether socio-demographic differences such as early childhood environment and quality of education explain such a bilingual advantage; or conversely, whether the bilingual effects remain after accounting for such differences.

Table 2. Univariate Correlations between Predictors of NP Performance

	Age	Education	Sex	Dominance Index
Age	---	0.0093	0.12	-0.03
Education	0.0093	---	0.08	0.64
Sex	0.12	0.08	---	0.05
Dominance Index	-0.03	0.64	0.05	---

Table 3. Results of Multiple Regression Showing Effects of English Fluency on Spanish Language Test Performance with Covariates in the Model

Neuropsychological Test	R^2	*F* value	Dominance Index β (*p*. value)	Education β (*p*. value)	Age β (p. value)	Sex β (*p*.value).
VERBAL						
WAIS-R Vocabulary	0.45	(4, 163)=33.74	10.09	1.30***	0.34***	-0.8
Category Fluency	0.19	(4, 165)=10.13	2.78	0.89***	0.18*	1.34
Boston Naming Test	0.37	(4, 164)=24.74	0.71	0.90***	0.21***	-0.59
LEARNING						
SVLT-Learning	0.37	(4, 187)=27.86	5.92***	0.32***	-0.05	-0.5**
Figure Learning	0.24	(4, 185)=15.01	3.38	0.36 ***	-0.09**	-0.25
Story Learning	0.2	(4, 185)=11.83	6.61**	0.24**	-0.05	-0.55
MEMORY						

(table continues)

Table 3. Results of Multiple Regression Showing Effects of English Fluency on Spanish Language Test Performance with Covariates in the Model, Continued

SVLT Short Delay Free Recall	0.17	(4, 187)=10.04	3.47*	0.14**	-0.04	-0.11
SVLT Long Delay Free Recall	0.2	(4, 187)=11.59	4.35**	0.14*	-0.05*	-0.08
Figure Delay	0.23	(4, 185)=13.66	2.63*	0.16 ***	-0.03*	-0.17
Story Delay	0.22	(4, 185)=12.78	2.74	0.16**	-0.08***	-0.04
EXECUTIVE/ABSTRACTION						
Trails Making Test B	0.4	(4, 158)=26.50	-111.22**	-7.15***	1.05*	-1.83
WCST-Total errors	0.15	(4, 115)=5.18	-13.16	-1.30***	0.01	1.33
WCST-Perserverative errors	0.1	(4, 115)=3.16	1.24	-0.83*	0.04	0.84
Halstead Category Test-Total errors	0.42	(4, 165)=30.59	-12.78	-3.28***	0.76***	6.2***
Stroop Test-Color/Word	0.26	(4, 185)=16.25	10.69*	0.73***	-0.09	1.38*

(table continues)

Table 3. Results of Multiple Regression Showing Effects of English Fluency on Spanish Language Test Performance with Covariates in the Model, Continued

ATTENTION/WORKING MEMORY						
WAIS-III Letter Number Sequencing	0.54	(4, 120)=35.20	3.03*	0.38***	-0.02	-0.17
PASAT-Total correct	0.28	(4, 165)=15.83	21.09	3.31***	0.12	-8.82***
WAIS-R Arithmetic	0.36	(4,163)=24.49	3.56	0.34***	0.05*	-0.92***
WAIS-R Digit Span	0.22	(4, 185)= 13.66	5.92**	0.32***	-0.01	-0.53*
PSYCHOMOTOR SPEED						
WAIS III- Digit Symbol	0.63	(4, 118)=51.10	24.98 **	2.35***	-0.78***	2.90**
WAIS III-Symbol Search	0.56	(4, 120)=37.72	13.56 **	1.11***	-0.27***	0.3
Trail Making Test A	0.31	(4, 165)=19.09	0.3	-1.43***	0.41***	0.75
Stroop Test-Word Reading	0.17	(4, 185)=9.83	0.74	1.44***	0.72	0.4
Stroop Test-Color	0.2	(4, 185)=11.56	0.49	1.04***	-0.08	2.08**

(table continues)

Table 3. Results of Multiple Regression Showing Effects of English Fluency on Spanish Language Test Performance with Covariates in the Model, Continued

VISUOSPATIAL SKILLS						
Block Design	0.3	(4, 164)=17.43	4.89	0.099 ***	0	-2.11**
MOTOR ABILITIES						
Finger Tapping-Dominant Hand	0.3	(4, 163)=17.10	6.7	0.32 *	0.04	-2.94***
Finger Tapping-Non Dominant Hand	0.21	(4, 164)=11.18	4.56	0.23	-0.06	-2.12***
Grooved Pegboard-Dominant Hand	0.09	(4, 168)=3.93	4.61	-0.06 *	0.22 **	-1.16
Grooved Pegboard-Non Dominant Hand	0.08	(4, 165)=3.58	-5.94	-0.52	0.24	-0.88

Note: *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

Chapter 2: Aims and Hypotheses

Aim 1: To Determine Whether Bilingualism Confers Performance Advantages or Disadvantages on Neuropsychological Tests Commonly Used to Diagnose Brain Dysfunction in Clinical Populations

Prediction 1.1

Consistent with the Interference Hypothesis, bilinguals will obtain lower scores than demographically comparable monolinguals on tests requiring verbal language abilities to be performed under time pressure. This is particularly true in semantic fluency, which is highly sensitive to interference from the non-target language in bilinguals (Gollan et al., 2002; Sandoval, Gollan, Ferreira, & Salmon, 2010). Similar results are likely in the case of the Boston Naming Test.

Prediction 1.2

Consistent with the Inhibitory Control Model, bilinguals will perform better than monolinguals on tests requiring inhibition of prepotent responses and attentional control. These include the color-word incongruent condition of the Stroop task, perseverative errors on the Wisconsin Card Sorting Test, and the Trail Making Test part B, as well as WAIS-III Letter-Number sequencing, and Digit Span, and PASAT.

Prediction 1.3

Consistent with the above mentioned models, no performance differences between bilinguals and monolinguals are expected on tests of other abilities, including nonverbal processing speed (i.e., WAIS-III Digit Symbol test, WAIS-III Symbol Search Test, Trail Making Test part A), learning and memory (i.e., Story Memory Test and

Figure Memory Test), and motor ability (i.e., Grooved Pegboard Test and Finger Tapping). (See Table 1 for a list of predictions)

Aim 2: To Determine Whether the Influence of Bilingualism on Test Performance Remains after Accounting for Socio-Demographic Variables that May Affect Neuropsychological Performance and May Co-Occur with Better English Language Fluency

Prediction 2.1a

Overall, participants with higher childhood socioeconomic status will perform better than participants with lower childhood socio-economic status.

Prediction 2.1b

Across the entire sample, bilinguals will have come from more enriched socioeconomic backgrounds than their monolingual counterparts. Specifically, bilinguals are expected to have higher self-reported childhood SES (e.g., higher self-reporting social class standing, better schools, less likely to have worked as children, etc.)

Prediction 2.2

When socioeconomic status and vocabulary score are included as predictors, previously observed bilingual advantages in test performance will be attenuated but not eliminated completely.

Chapter 3: Methods

Participants

Participants were selected from two larger normative studies of native Spanish speakers from the U.S. – Mexico border region (see Table 4). This resulted in inclusion of 192 subjects from San Diego, CA and Tucson, AZ who were participants in a norming effort for an expanded Halstead-Reitan battery in Spanish, and 11 participants from the normative group for La Batería Neuropsicológica en Español (Artiola i Fortuny et al., 1999). As part of the larger normative studies, efforts were made to recruit participants into equal sized cells according to sex, as well as pre-set age and education ranges. The resulting sample for the present study consisted of 91 men and 101 women ranging in age from 20 to 63 years (*M* = 37.4, *SD* = 9.5) with educational attainment between 0 and 20 years (*M* = 10.06, *SD* = 4.3; see Table 3).

Table 4. Aim 1 Sample Characteristics

	ALL (*N* = 192)	Bilinguals (*n* = 42)	Monolinguals (*n* = 47)
Age, mean (sd)	37.4 (9.5)	36.4 (10.9)	36.6 (9.2)
Education, mean (sd)	10.7 (4.4)	11.9 (1.8)	11.5 (2.5)
% Male	47	35	44
PMR, mean (sd)	38.5 (12.6)	42.4 (13.3)	40.2 (12.2)
FAS, mean (sd)	19.6 (14.0)	32.0 (10.7)	12.8 (6.8)
Dominance ratio, mean (sd)	0.30 (0.15)	0.42 (0.06)	0.24 (0.07)

Original Normative Sample Recruitment and Inclusion Criteria

Study participants responded to flyers or direct contact with recruiters in community settings. They were selected if they had reason to spend time in the United States on a regular basis (e.g., for work, school, place of residence). All participants were required to be at least 18 years of age, be native Spanish speakers, and have the ability to give informed consent. All participants reported to be native Spanish-speakers and expressed a desire to be tested in Spanish. A language use questionnaire was administered to confirm that Spanish was their preferred language. However, given that participants had contact with an English-speaking environment, and were expected to have some level of English language ability, an objective measure of English fluency was utilized in order to confirm language dominance. As such, and as suggested by Artiola i Fortuny et al. (1999), the Controlled Oral Word Association Test (COWAT) was administered in both English and Spanish and a measure of relative English fluency was calculated.

Exclusion Criteria

1. Neurologic: brain injury with loss of consciousness for greater than 30 minutes (or resulting in neurologic complications), penetrating skull wounds, brain surgery, active seizure disorder, or other CNS disorders that might affect neuropsychological functioning (e.g., meningitis, stroke, heavy metal poisoning, Parkinson's disease).
2. Medical: e.g., collagen vascular disorders (e.g., lupus), chronic renal disease, chronic pulmonary disease.

3. Psychiatric: schizophrenia or active psychotic symptoms, bipolar illness, or current major depressive disorder.
4. Substance abuse: lifetime diagnosis of any substance dependence, active substance abuse within the last 30 days, or current intoxication as determined by on-site urine toxicology for illicit or prescribed substances, breathalyzer test, and clinical assessment.
5. Developmental: evidence of mental retardation or learning disability.

The resulting sample for the present study consisted of 91 men and 101 women ranging in age from 20 to 63 years (*M* = 37.4, *SD* = 9.5), and with educational attainment between 0 and 20 years (*M* = 10.06, *SD* = 4.3; see Table 4).

Language Use Determination

In order to confirm that Spanish was the appropriate language for neuropsychological testing, (a) self-report information was obtained regarding predominant language use (i.e., first language and best language; language spoken at home and with friends; predominant language of education, predominant language for reading, TV, radio; thinking and dreaming, and (b) word fluency was tested in both languages (letters F-A-S in English and P-M-R in Spanish). Based on normative data for FAS (Heaton, Grant, & Matthews, 1991) and PMR (Artiola i Fortuny et al., 1999), age and education corrected T-scores generated for the same raw score (total number of words generated) for FAS in English and PMR in Spanish were correlated at .99 (as computed for examples with ages of 26 and 40, and education levels of 12 and 14 years). Thus, despite linguistic differences, a comparison of the number of words generated in each language is a reasonable indicator of fluency, given that the letter sets F, A, S and P, M, R are thought to have similar word frequencies and difficulty in the respective languages (Artiola i Fortuny et al., 1999). On average, participants generated 38.5 (*SD* = 12.5) words in Spanish with letters P-M-R, compared to 19.5 (*SD* = 14.0) words in English using the letters F-A-S.

The Dominance Index

Given the original interest in the effects of second language ability on native language test performance, a continuous language dominance index reflecting relative English fluency was calculated as follows: (FAS/FAS+ PMR). Thus, the index provides the ratio of English words to total words produced in both languages. A ratio is preferred over a raw English fluency score because it avoids using level of performance on one neuropsychological test (phonemic fluency) to predict level of performance on another neuropsychological test, which would be expected to be correlated for reasons not related to bilingual language control. With this measure, two participants with very different levels of overall ability could have comparable indices of language dominance. To illustrate, a person who produced 25 words in English and 50 words in Spanish (25/75 = 0.33) would have a comparable level of relative English-to-Spanish fluency to that of a person who produced 5 words in English and 10 words in Spanish (5/15 = 0.33). While their overall levels of performance are quite different, relative English–to-Spanish fluency is equivalent. Moreover, using overall fluency as the denominator makes the range of English ability easy to interpret, with 0 corresponding to no English fluency (i.e., complete Spanish dominance), 0.5 reflecting identical English and Spanish ability, and 1 corresponding to complete English dominance (i.e., no Spanish fluency).

The dominance index scores ranged from 0 to 0.66 (*M* = 0.35, *SD* = 0.12) with a higher score corresponding to higher relative English fluency. Because there is no established cut-point for deciding what degree of difference between Spanish letter fluency (PMR) and English letter fluency (FAS) scores ought to be considered a meaningful difference, and because we wanted to capture a wider range of English fluency, 11 participants were included with scores above 0.50 but not exceeding the upper tertile of the distribution on the dominance index (>.66), which would indicate strong English dominance. Although these few individuals obtained higher English than Spanish COWAT scores, all preferred to be tested in Spanish and reported being Spanish-dominant on the language use assessment questionnaires. The average difference between FAS and PMR raw scores for these participants was 19.8 (*SD*=12.33).

Bilingual vs. Monolingual Classification

Participants were dichotomized into bilingual and monolingual based on the dominance index. Based on our original rationale of dividing the dominance index into tertiles in order to exclude persons who were strongly English dominant (>0.66), participants in the lower tertile (index ≤ 0.33) were classified as Spanish-dominant and those with indices in the middle tertile (between 0.34 and 0.66) were classified as bilingual. This resulted in 88 bilinguals and 104 monolinguals. While the resulting groups of bilingual and monolinguals had comparable numbers of men and women, and comparable age, the bilingual group had, on average, 5 more years of education (*M* = 13.4, *SD* = 3.2) than the monolingual group (*M* = 8.4, *SD* = 3.8) $F(1,190) = 91.74$, $p<0.001$. Of the resulting bilingual group, only four participants had 7 or fewer years of education compared to 44 monolinguals in this education range. Therefore, all participants with less than 7 years of education were excluded. Given that no monolingual participant had more than 16 years of education, compared to 11 bilinguals with graduate education, all bilingual participants with more than 16 years of education were excluded. However, the remaining groups were still significantly different with regard to level of education, $F(1, 10) = 5.07$, $p = 0.02$. Among bilinguals 40% had at least 12 years of education, compared to 12% of monolinguals. At this point, bilingual individuals on the upper end of the education distribution were trimmed as were monolinguals with lower levels of education, while ensuring preservation of comparability in age and sex distributions. This ensured that bilingual and monolinguals had comparable numbers across different levels of education. The resulting sample was comprised of 42 bilingual and 47 monolinguals (see Figure 1). For example, of the resulting sample, 6 bilinguals and 10 monolingual had 9 years of education, 5 bilingual and 2 monolingual had 10 years of education, 19 bilingual and 16 monolingual had 12 years of education, and 2 bilingual and 5 monolingual had 16 years of education.

Procedure and Measures

Neuropsychological Testing

Neuropsychological (NP) testing and psychosocial evaluations for all subjects were performed according to the protocol used in the original normative studies. Briefly, the NP battery, which took approximately four hours, was administered by trained bilingual psychometrists *(see full list of tests by domain below).* Test protocols were double-scored for accuracy by an independent psychometrist. Raw scores were used for the purpose of this study. Of note, the WAIS-R Vocabulary subtest was administered as an index of quality of education.

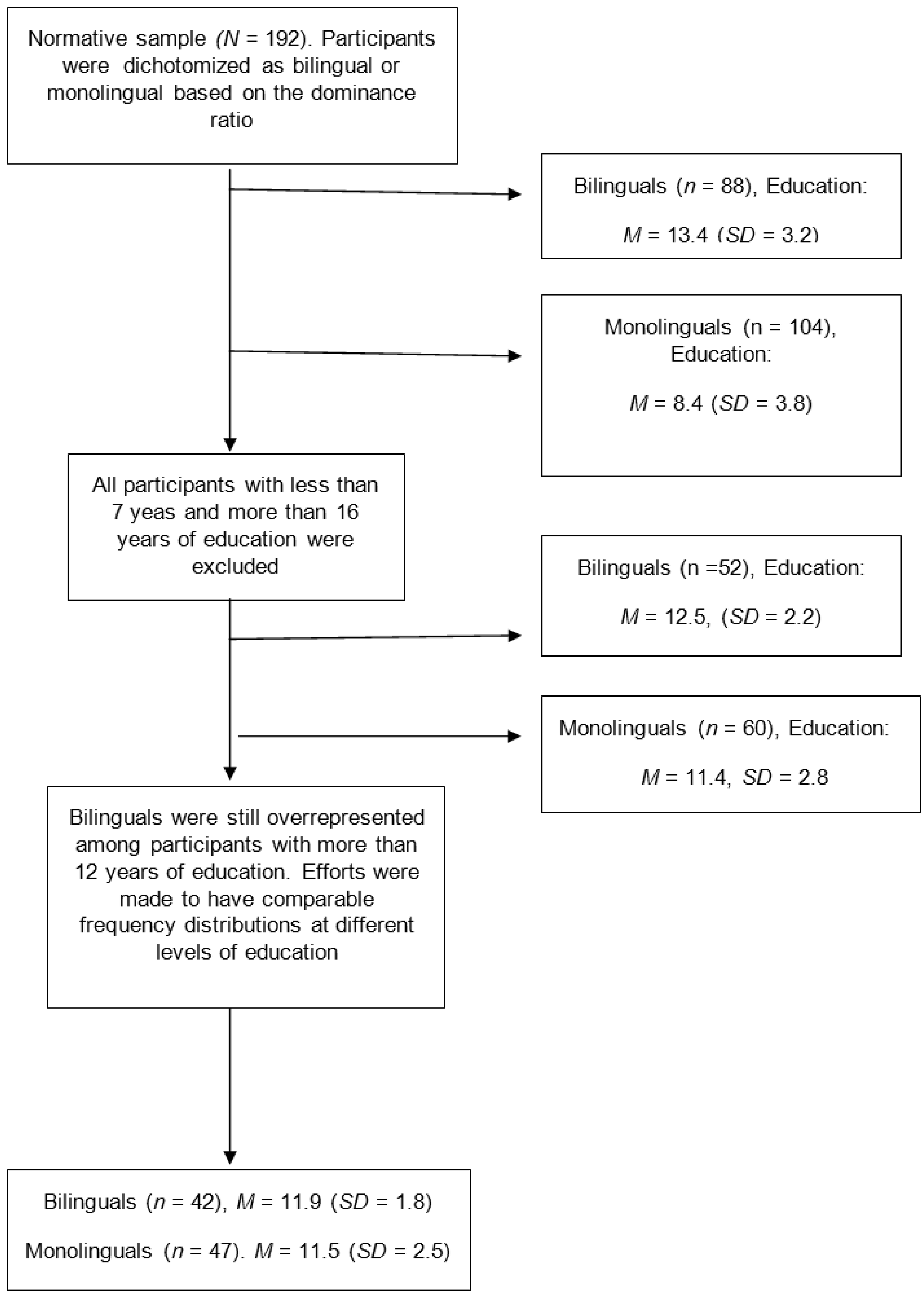

Figure 1. Participant selection flowchart.

Socio-Economic Status

In order to assess socio-economic status, participants completed a questionnaire on their educational and social background. More specifically, questions pertained to (1) current employment and salary, years living in the United States, highest employment in any country; (2) living conditions while growing up (e.g., access to electricity and running water, number of rooms and people in the home); (3) educational experiences, including years of education completed in the U.S. vs. their home country, and questions assessing quality of education (e.g., number of children in classroom, large vs. small school); (4) access to health care while growing up (e.g., seeing a doctor, childhood vaccinations); and (5) other indicators of poverty (e.g., going to bed hungry, age at first job, and reasons to start working if this was before completing high school). For the purpose of analyses, the questionnaire was explored by examining correlations between variables. The variable that best captured participant's experiences growing up was chosen as a covariate variable (*see results section below*).

Study Design

Neurocognitive functioning was compared between bilingual (n = 42) and monolingual subjects (n = 47). In each study, 42 bilingual subjects were compared to 47 Spanish monolingual subjects. Participants, on average, had education levels within 1 year, age within 5 years, and comparable percentages of men and women. Outcomes for different for domains of neurocognitive functioning are detailed below.

Dependent variables used for hypothesis testing. Language Functioning: Number of correct responses on the Category Fluency test and the Boston Naming Test.

Executive Functioning: Stroop incongruent condition (color-word) score and interference ratio [color-word (color x word/color + word)], Trail Making Test B time to completion, perseverative errors on the Wisconsin Card Sorting Test, number of errors on the Halstead Category test.

Attention/Working Memory: Number correct on WAIS-III Letter Number Sequencing, Paced Auditory Serial Addition Task, and WAIS-R Digit Span.

Additional tests in domains not predicted to show differences were examined to determine the specificity or generalizability of the predicted bilingual effects.

Control variables. Bilingual and monolingual groups were comparable with respect to level of education, age, and sex. They were also comparable with respect to levels of Spanish fluency based on their scores on the Controlled Oral Word Association Test with letters P-M-R, and WAIS-III Vocabulary scores.

Predictor. Bilingual vs. monolingual group membership.

Covariate (for AIM 2). Index of socioeconomic status.

Data Analytic Plan

Power Analysis

The study for AIM 1 consisted of 89 subjects: 42 bilinguals and 47 monolinguals. With this number of subjects per group, power analyses suggest that a medium effect size of d = 0.63 can be detected with 80% power, at level alpha = 0.05 (two-sided). Further gains in power were obtained through obtaining demographically matched participants in the two groups on the above-described variables, which is expected to reduce variability between groups. Gains in power for AIM 2 were also obtained by matching the two groups on relevant variables.

Statistical Analyses

To assess the effects of bilingualism on each neuropsychological test, bilingual and monolingual subjects were compared using an ANOVA model, and the difference between the matched pairs as a response for Aim 1. For Aim 2, bilingual and monolingual subjects were compared using ANOVA as well, but this time the role of SES (i.e., subjective SES growing up), and quality of education (Vocabulary score) were used as covariates. A statistical difference was declared if the response was significantly different from zero at alpha = 0.05. Post-hoc Cohen's *d* were calculated for each comparison in order to calculate effect sizes.

Chapter 4: Results

Aim 1

Sample Characteristics

As shown in Table 4, bilingual and monolingual participants did not significantly differ in their demographic characteristics. Additionally, they did not differ in WAIS-R Vocabulary scores or their Spanish fluency scores (PMR), but they significantly differed with respect to English fluency scores (FAS) where bilingual participants produced, on average, more than twice as many words in English ($M = 32.1$, $SD = 10.7$) than did their monolingual counterparts ($M = 12.9$, $SD = 7.2$), $F(1,87) = 93.06$, $p<0.001$. Pairwise bivariate correlations among control variables revealed that Vocabulary scores were associated with higher education ($r = 0.40$, $p<0.001$), as expected, and higher age ($r = 0.45$, $p<0.001$). There were no other significant correlations between control variables. While women were slightly over-represented in our final sample (59%), men and women did not differ statistically with respect to education or group distribution (bilingual vs. monolingual). Women represented 64% of the bilingual sample (n=27) and 55% of the monolingual sample (n=26).

Prediction 1.1

Results were not consistent with the original prediction that bilinguals would perform worse on tests of language abilities. The one-way ANOVA showed that the bilingual and monolingual groups did not differ significantly in the number of semantically-related words they were able to produce under time pressure. Bilinguals and monolinguals were able to produce comparable number of animals, fruits, and vegetables (see Table 5). Results also indicated no interference from the second language (English)

Table 5. Unadjusted Raw NP Performance Differences between Monolingual and Bilingual Groups Matched on Education

Neuropsychological Test	Bilingual *Mean* (SD)	Monolingual *Mean* (SD)	F value (*df*) *F*	*p* value	Effect size Cohen's *d*
VERBAL					
WAIS-R Vocabulary	48.6 (8.9)	46.5 (9.3)	(1, 87) 1.2	0.28	0.19
Boston Naming Test	49.0 (6.6)	50.0 (5.4)	(1, 86) 0.6	0.42	0.17
Category Fluency	49.8 (10.1)	49.5 (9.0)	(1, 87) 0.02	0.82	0.03
LEARNING					
SVLT Trials 1 -5	57.1 (8.4)	55.6 (8.7)	(1, 87) 0.7	0.39	0.18
Story Learning	12.0 (4.6)	10.3 (4.0)	(1, 86) 3.3	0.07	0.4
Figure Learning	8.1 (4.1)	7.1 (3.4)	(1, 85) 1.4	0.24	0.27
MEMORY					
SVLT Short Delay Free Recall	12.4 (2.2)	11.7 (2.4)	(1, 87) 1.2	0.27	0.3
SVLT Long Delay Free Recall	12.8 (2.7)	12.0 (2.5)	(1, 87) 2.4	0.12	0.34

(table continues)

Table 5. Unadjusted Raw NP Performance Differences between Monolingual and Bilingual Groups Matched on Education, Continued

Figure Delay	15.1 (1.4)	14.4 (1.7)	(1, 85) 4.1	0.04	0.45
Story Delay	15.2 (2.9)	14.8 (2.6)	(1, 86) 0.4	0.52	0.15
EXECUTIVE/ABSTRACTION					
Trails Making Test B	69.9 (29.4)	91.4 (44.4)	(1, 86) 7.0	0.009	0.56
Stroop Test-Color Word	44.4 (6.2)	41.6 (9.2)	(1, 86) 2.9	0.09	0.35
Hasltead Category	54.4 (30.1)	60.4 (21.8)	(1, 87) 1.2	0.28	0.23
PASAT-Correct	107.2 (30.9)	106.7 (32.4)	(1, 87) 0.006	0.93	0.02
WCST-Total errors	26.5 (17.1)	29.6 (14.5)	(1, 59) 0.6	0.44	0.2
WCST-Perserverative errors	13.4 (9.9)	14.7 (9.1)	(1, 59) 0.3	0.59	0.09

(table continues)

Table 5. Unadjusted Raw NP Performance Differences between Monolingual and Bilingual Groups Matched on Education, Continued

ATTENTION/WORKING MEMORY					
WAIS-III Letter Number Sequencing	10.1 (2.1)	9.0 (1.9)	(1, 61) 4.1	0.04	0.5
WAIS-R Arithmetic	10.5 (3.1)	9.4 (2.9)	(1, 86) 2.7	0.1	0.37
WAIS-R Digit Span	13.3 (3.3)	10.9 (2.7)	(1, 87) 13.9	0.001	
VISUOSPATIAL FUNCTIONING					
WAIS-R Block Design	23.8 (8.3)	24.0 (8.7)	(1, 87) 2.5	0.11	0.34
PSYCHOMOTOR SPEED					
Trails A	28.8 (8.8)	31.4 (9.1)	(1, 87) 1.8	0.12	0.29
WAIS III- Digit Symbol	76.4 (14.7)	67.0 (14.4)	(1, 60) 6.4	0.01	0.65
WAIS III-Symbol Search	32.3 (6.1)	27.8 (6.1)	(1, 61) 8.7	0.004	0.76

(table continues)

Table 5. Unadjusted Raw NP Performance Differences between Monolingual and Bilingual Groups Matched on Education, Continued

Stroop Word Reading	108.2 (14.3)	103.9 (14.7)	(1, 86) 1.8	0.17	0.29
Stroop Color Naming	76.4 (9.4)	71.0 (11.8)	(1, 86) 5.4	0.02	0.5
MOTOR ABILITIES					
Finger Tapping-Dominant Hand	51.5 (6.6)	50.3 (5.8)	(1, 86) 0.8	0.37	0.19
Finger Tapping-Non Dominant Hand	47.3 (6.4)	45.8 (5.8)	(1, 87) 0.2	0.15	0.31
Grooved Pegboard-Dominant Hand	62.8 (9.4)	61.5 (9.5)	(1, 87) 0.4	0.52	0.14
Grooved Pegboard-Non Dominant Hand	71.4 (10.7)	72.4 (12.6)	(1, 87) 0.1	0.7	0.08

on the first language (Spanish) on a test of confrontation naming. That is, both bilingual and monolinguals were able to name a comparable number of objects [Bilinguals (*M* = 49.0, *SD* = 6.6) and Monolinguals (*M* = 49.9, *SD* = 5.4)].

Prediction 1.2

Results in support of the Inhibitory Control Model were equivocal. That is, bilinguals (*M* = 69.9, *SD* = 29.3) outperformed monolinguals (*M* = 90.5, *SD* = 43.8) on a cognitive set-shifting task (Trail Making Test B; $F(1,86) = 6.99$, $p<0.001$; Cohen's $d = 0.37$). Bilinguals also outperformed monolinguals on two tests requiring concentration, attention and mental control [WAIS-III Letter Number Sequencing (Cohen's $d = 0.49$) and WAIS-R Digit Span size (Cohen's $d = 0.64$); see Table 6]. In contrast, bilinguals and monolinguals did not differ on a separate test of working memory, auditory processing speed, and attention (PASAT), where a floor effect was observed, with the both groups answering only about 50% of the items correctly overall [Bilinguals (*M* = 107.2, *SD* = 30.9); Monolinguals (*M* = 106.7, SD = 32.4)]. Groups did not differ on a test of novel problem solving and perseverative thinking (WCST) or a test of logical analysis and new concept formation (Category Test). While there were trend-level differences between bilinguals (*M* = 44.4, *SD* = 6.2) and monolinguals (*M* = 41.6, *SD* = 9.2) on a test requiring the inhibition of the prepotent response, (Stroop Color-Word)(p = 0.09), a post-hoc mean comparison analysis revealed a medium effect size (Cohen's $d = 0.37$).

Prediction 1.3

Results were not consistent with the prediction that, by way of dissociation, bilinguals and monolinguals would not differ on tests of memory or processing speed. Specifically, bilinguals outscored monolinguals on speeded test of copying symbols and a

Table 6. Socioeconomic Status (SES) Information in Whole Sample and Aim 2 Subsample

Variable Name	**ALL** (***N*** **= 170)**	**Bilingual** (***n*** **= 28)**	**Monolinguals** (***n*** **= 28)**
Current Salary, mean (sd)	8809.0 (10082)	10192.1 (9279)	9839.3 (8455.6)
Years Living in the US, mean (sd)	9.4 (9.4)	13.8 (11.5)	7.5 (8.3)
Years Living in Mexico, mean (sd)	27.8 (11.9)	21.1 (14.2)	27.1 (7.7)
Education in the US, mean (sd)	1.74 (3.4)	3.5 (4.3)	0.8 (0.9)
Education in Mexico, mean (sd)	8.4 (4.4)	7.4 (4.4)	10.2 (1.7)
Subjective SES as a child			
% in very poor	6	--	--
% in poor class	26	18	21
% in middle class	57	82	78
% in upper class	10	--	--
Ratio of number of people by bedrooms, mean (sd)	2.6 (0.25)	2.8 (0.25)	2.9 (1.6)
Why did you stop going to school			
% because of financial problems	26	11	14
% because did not like school	14	28	14
% Other	36	52	60

(table continues)

Table 6. Socioeconomic Status (SES) Information in Whole Sample and Aim 2 Subsample, Continued

% who attended a large school with many classrooms and room to play	52	66	61
% who where hungry as a child	11	10	9
% who worked as a child	51	57	50
Age when started working, mean (sd)	13.2 (3.0)	14.7 (1.8)	12.9 (3.1)
Why did you start working			
% To support family	2	6	0
% To help family	33	6	28
% For my own benefit	65	87	72
% Stopped going to school because of work	31	68	71

visual scanning task. Bilinguals were also able to name colors faster than did monolinguals (see Table 5).

Bilinguals and monolinguals did not differ in their ability to read words in a speeded manner (Stroop Test- Word Reading) or on a test of visual scanning and number sequencing (Trail Making Test A; see Table 5). Table 7 also shows that bilingual and monolinguals did not differ on a simple motor speed test (Finger Tapping) or on a test of fine motor coordination (Grooved Pegboard).

Table 7. Correlations between Current Salary and Neuropsychological Performance

Test Name	**All** ***r* (p. value)**	**Bilinguals** ***r* (*p*. value)**	**Monolinguals** ***r* (*p*. value)**
EXECUTIVE FUNCTION			
Halstead Category Test-Total errors	0.26 (p = 0.04)	0.20 (NS)	0.34 (p = 0.054)
ATTENTION/WORKING MEMORY			
PASAT-Total correct	0.31 (p = 0.009)	0.24 (NS)	0.40 (p = 0.02)
PROCESSING SPEED			
Trails A	0.25 (p = 0.05)	0.14 (NS)	0.37 (p = 0.03)
VISUOSPATIAL SKILLS			
Block Design	0.37 (p = 0.003)	45 (p = 0.008)	0.30 (NS)
MOTOR ABILITIES			
Finger Tapping-Dominant Hand	0.32 (p = 0.01)	0.007 (NS)	0.61 (p = 0.003)
Finger Tapping-Non Dominant Hand	0.26 (p = 0.03)	0.007 (NS)	0.52 (p = 0.003)

Bilingual and monolinguals did not differ in their ability to learn a list of words, learn a story or a number of figures. However, the difference between bilinguals (M = 12.0, SD 4.5) and monolinguals (M = 10.2, SD = 4.04) on the Story Learning trials yielded a medium effect size), $F(1, 86) = 3.32$, $p = 0.07$ (Cohen's d = 0.41; p = 0.07). With respect to memory, bilingual and monolinguals were able to remember a comparable number of words from a list, and were able to remember the same number of details from a story; but bilinguals (M = 15.1, SD = 1.4) were more efficient at recalling figures after a delay than were monolinguals (M = 14.4, SD = 1.7), $F(1, 85) = 4.12$, $p = 0.04$ (Cohen's d = 0.45)

Aim 2

Sample Characteristics

From our original sample of 192, 170 (68 bilinguals and 102 monolinguals) completed the socioeconomic questionnaire. Men comprised 55% of the sample. Overall, participants' education ranged from 0 to 20 (M = 10.01, SD = 4.2) and age ranged from 20 to 55 (M = 37.2, SD = 9.6). On average, participants had lived 9.4 years (SD = 9.4) in the United States, and 27.8 years (SD = 11.9) in Mexico, where they received the majority of their education (M = 8.43, SD = 4.4). The current salary of the sample ranged between no income at all to $50,000 ($M$ = $8,909, SD = $10,082). Years of education in the US significantly, but conservatively, correlated with current salary ($r = 0.16$, p = 0.03) and degree of bilingualism ($r = 0.52$, $p<0.001$), as expected. Also as expected, salary was significantly correlated with participants level of education ($r = 0.34$, $p<0.0001$), and their dominance index ($r = 0.21$, $p<0.0006$). Table 6 shows additional detailed information of other indicators of participants SES growing up (e.g., quality of education, work history, access to healthcare).

Prediction 2.1a

Current salary was first used as a measure of current socio-economic status and was found to be predictive of better neuropsychological performance on different tests across several domains (see Table 7). With regard to self-reported social class growing up, 10 people (6%) reported they were "very poor" as children, 45 (26%) were "poor," 98 (57%) were "middle class," and 17 (10%) were "upper class." A one-way ANOVA using each neuropsychological test as a dependent variable showed that participants who reported to have grown up in the "upper class" had better performance across neuropsychological test than those in the "middle class," who had better performances than those in the "poor" class, who had better performances than those in the "very poor" class on WAIS-R Digit Span, $F(3, 166) = 6.03$, $p<0.001$, Stroop Test Color, $F(3, 164) = 5.73$, $p<0.001$, Stroop Test Reading, $F(3, 164) = 3.99$, $p<0.001$, Stroop Test Reading, $F(3, 164) = 5.73$, $p<0.001$, Story Learning, $F(3, 164) = 2.88$, $p<0.03$, Trails B, $F(3, 166) = 3.75$, $p<0.01$, WAIS-III Digit Symbol, $F(3, 119) = 3.22$, $p<0.02$, WAIS-III Letter Number Sequencing, $F(3, 121) = 2.80$, $p<0.04$, and trends in the same direction for Trails Making Test A, $F(3, 166) = 2.52$, $p<0.06$, and WAIS-R Vocabulary scores, $F(3, 164) = 2.42$, $p<0.06$ (See Figures 2a through 2e).

Prediction 2.1b

As predicted, a significant chi-square analysis χ^2 $(3, N = 170) = 15.7$, ($p = 0.001$) showed that out of the 10 people that came from a "very poor" background, eight were monolingual participants and only 2 were bilinguals, while out of the 17 participants who reportedly grew up in the "upper class," 12 were bilinguals while 5 were monolinguals. Monolinguals were also over-represented among participants who reported to be "poor" (73%), but were equally represented among those who reported to be from the middle class (55%). An additional chi-square analysis χ^2 $(1, N = 170) = 6.6$, ($p = 0.01$), showed

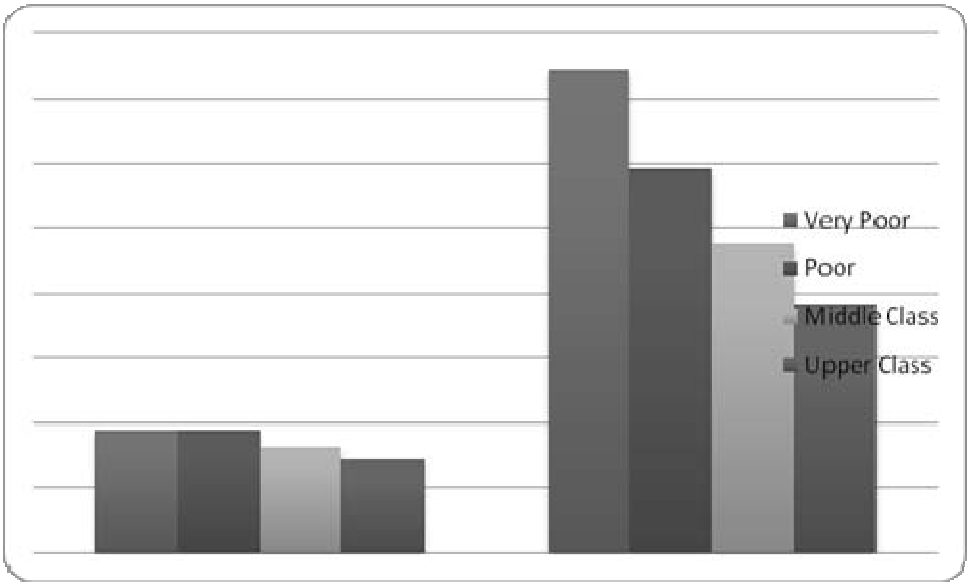

Figure 2a. Subjective SES and trail making test performance.

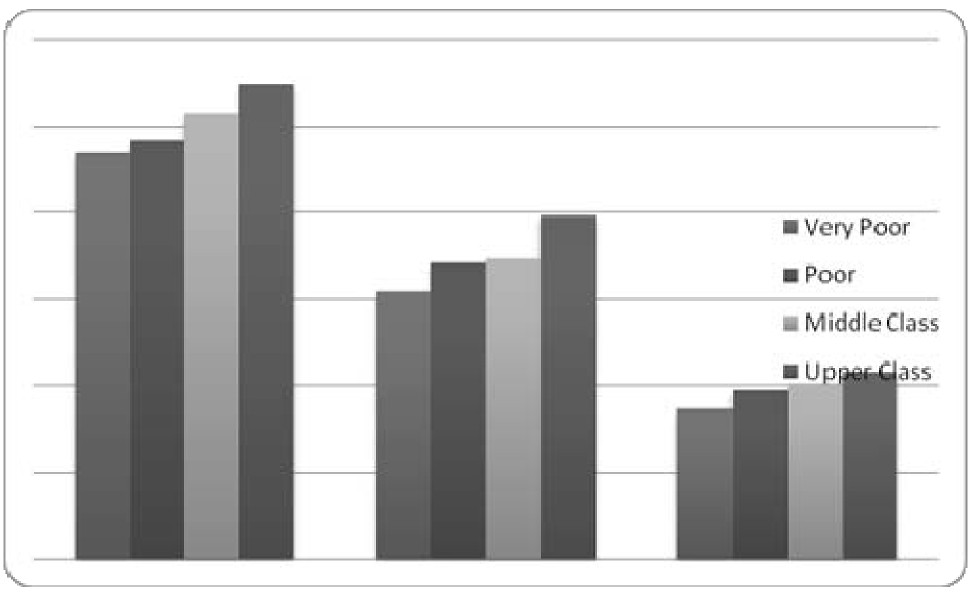

Figure 2b. Subjective SES and Stroop performance.

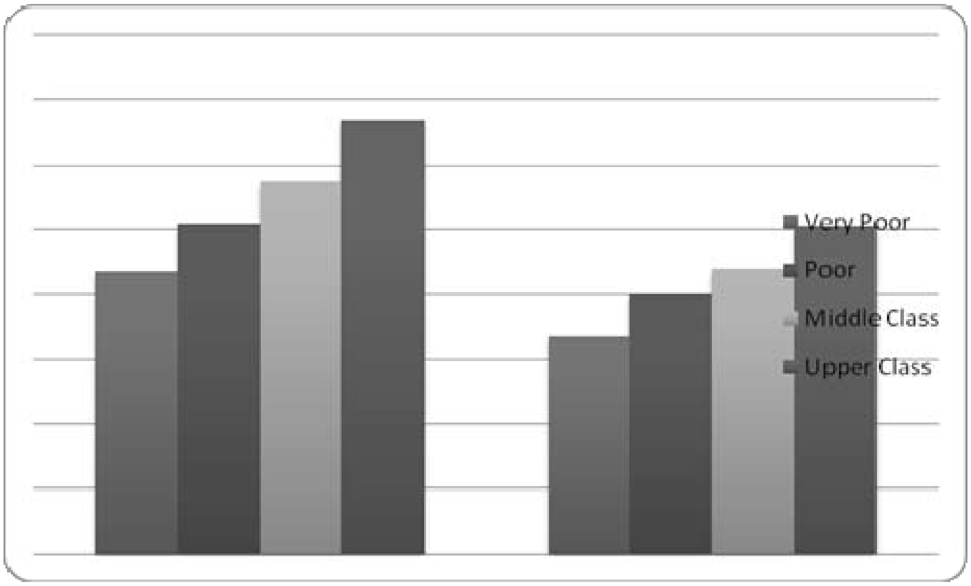

Figure 2c. Subjective SES by working memory performances.

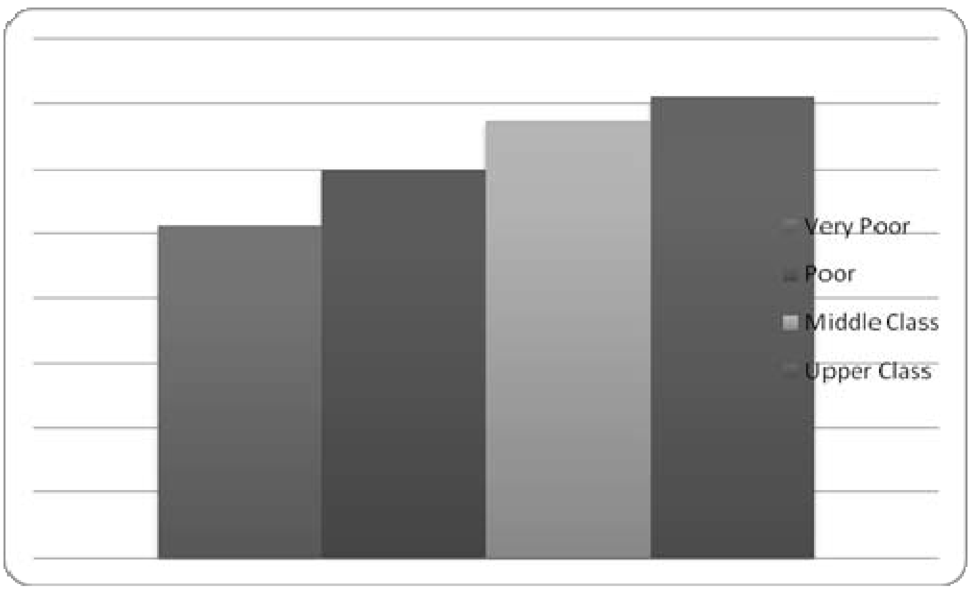

Figure 2d. Subjective SES by WAIS-III digit symbol.

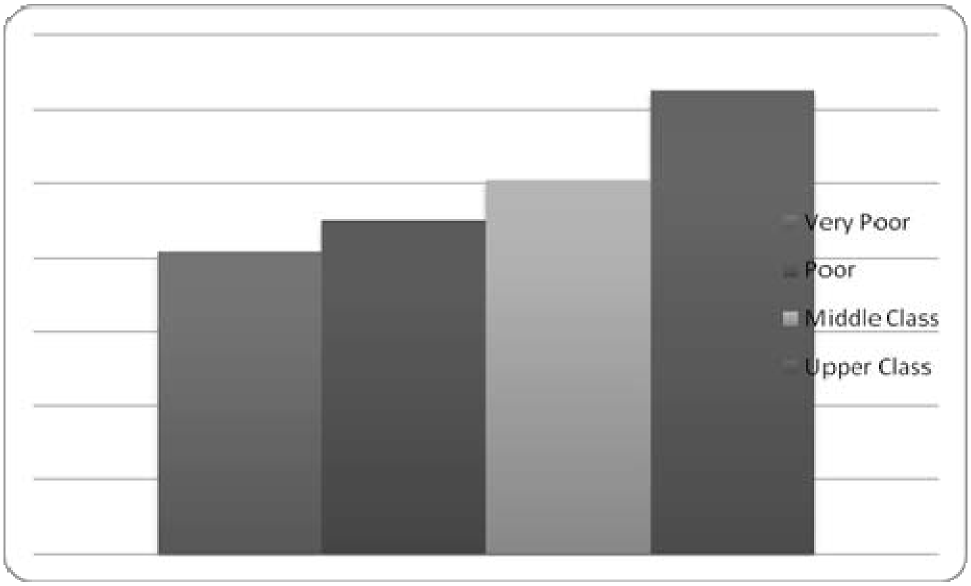

Figure 2e. Subjective SES and story learning performance.

that of the 88 participants who reportedly worked as children, 69% were monolingual. Also, monolingual participants started working at significantly younger age (*M* = 12.6, *SD* = 3.2) than did the bilingual participants ($p = 0.005$). Of the 37 participants who reported to have worked as children to help their family, 32 were monolingual and 5 were bilingual. In contrast, of the 74 who reported they worked as children for their own benefit (to have their own money), 34 were bilingual and 40 monolingual χ^2 (2, N = 113) = 12.6, (p = 0.001). Additionally, of the 54 participants who reportedly stopped going to school because they had to work, 77 vs. 22 percent were monolingual χ^2 (2, N = 113) = 10.9, ($p<0.001$).

With regard to quality of education, a chi-square χ^2 (2, N = 169) = 9.1, (p = 0.01) showed that a greater proportion of bilinguals (58% vs. 48%) attended a large size school with several classrooms per grade and playgrounds, while 8 (8%) monolinguals, but no bilingual, attended a small school with mixed grades in the same classroom.

With regard to health, chi-square analysis χ^2 (1, N = 170) = 9.1, (p = 0.002) showed that of the 19 participants who reported to have experienced hunger as children, 17 were monolingual, and out of the 11 who reported to have been malnourished as children, 10 were monolingual speakers χ^2 (1, N = 170) = 5.64, (p = 0.01).

Prediction 2.2

Selection of SES predictor**:** Given the immigrant status of our sample, it was determined that current salary may not accurately capture experiences growing up that are thought to be associated with cognition later in life (i.e., quality of education, access to health care, basic resources). This was in fact the case, as current salary was not significantly associated with quality of education indicators, the need to work or the reasons to enter the work force as a child, or having been hungry as a child. Instead, self-reported social class as a child was determined to be the best single indicator of overall status, given that it was significantly associated with other indicators of SES growing up. That is, of the 10 participants who reported to be "very poor" growing up, four reported to have experienced hunger growing up while none of the 17 participants in the "upper class" reported to have experienced hunger growing up χ^2 (3, N = 170) = 15.14 (p = 0.002). Of the participants who reported to have been "poor" and "middle class", few reported suffering from hunger growing up (6 % and 4% respectively). When asked whether or not they "had" to work as children, all 10 participants who reported to have been "very poor" as children also had to work, but no person from the "upper class" respondents reported to have worked as children χ^2 (3, N = 170) = 48.1, ($p < 0.001$). The participants in the "poor" and "middle class" were comparable with regard to the proportion who worked as children (19% and 26%). The "poor" and "very poor" were also comparable in the mean age at which they began to work (M = 13.0, SD = 2.8 & M = 13.84, SD = 2.86, respectively), but both differed significantly from when the "very poor" first began to work (M = 10.0 = 8, SD = 4.0). In addition to the association between self-reported SES and other SES indicators during childhood, self-reported SES was also associated with education attainment, $F(3, 166) = 6.4$, $p<0.001$, (see Figure 3) where the very poor had a mean education of 7.1 (4.9), the poor had a mean education of 8.5 (4.4), the middle class had a mean education of 10.8 (3.8), and the upper class had a mean education of 11.8 (2.8). While comparable proportions of men and women reported to have belonged to the very poor (5% vs. 5%), poor (24% vs. 21%), and middle class (54% vs. 44%), more women (12%) reported to have been “upper class” as a child than did men (5%).

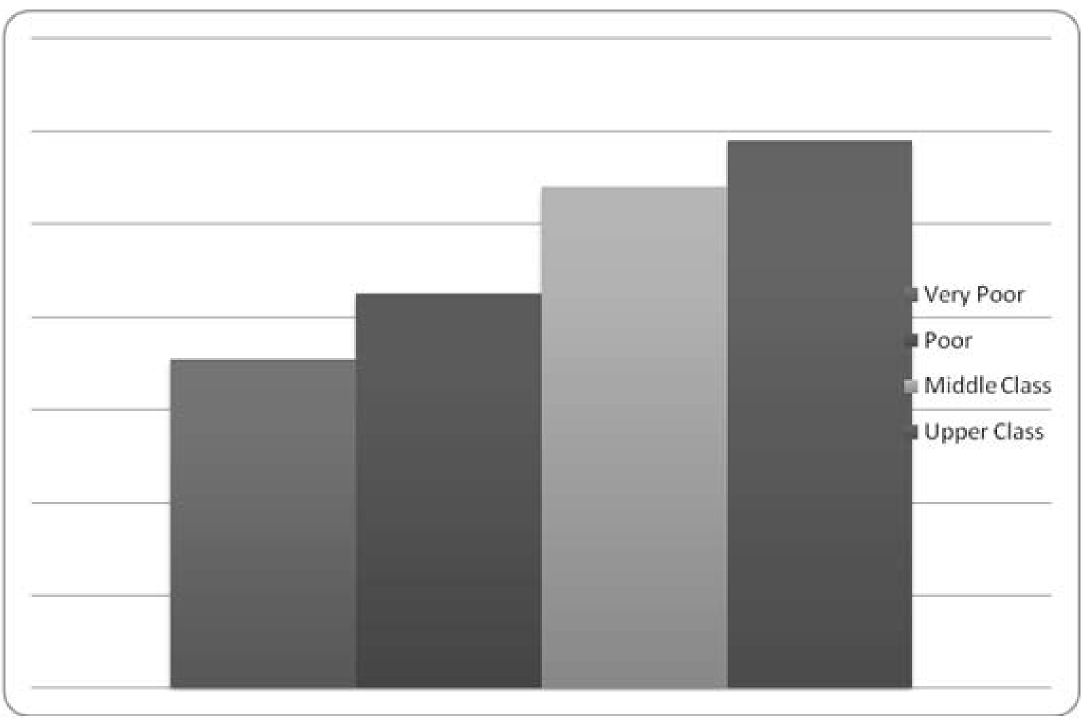

Figure 3. Subjective SES and years of education.

Selection of matched groups: As described above, while the "poor" and "middle class" groups were more similar to one another, the "very poor" and "upper class" were quite distinct. Therefore, given that higher self-reported SES as a child was also associated with higher degree of bilingualism (see Figure 4), participants in these two SES extremes (e.g., very poor and upper class) were excluded from the sample in order to better isolate potential bilingual effects. Again, the purpose of this analysis was to attempt to isolate the effects of bilingualism, rather than examine the effects of SES on neuropsychological performance. Therefore, we wanted to explore the effects of bilingualism presuming some homogeneity of experiences growing up. While ANCOVA was considered as an analytic strategy, it has been suggested that this approach is not optimal for dealing with fundamental differences between study groups (Adams, Brown, & Grant, 1985). Therefore, selecting a subset of bilinguals and monolinguals with comparable age, education, vocabulary scores and SES, and using ANOVAS was deemed a better option for isolating effects of bilingualism. The resulting 28 monolingual and 28 bilinguals were matched for education level within 1 year, age within 5 years, and comparable proportions of men and women. Of note, the vocabulary scores of the resulting groups were within 1 point as well, suggesting comparable verbal IQ. (see Table 8 for sample demographics). Bilinguals and monolinguals did not differ statistically in their current salary or any other indicator of childhood SES.

Neuropsychological results: In order to avoid further multiple comparisons, the next set of analyses examined only those measures in which differences between bilinguals and monolinguals had been found in the larger groups not matched for SES. After controlling for SES, bilingual individuals (M = 44.3 SD = 1.3) outperformed

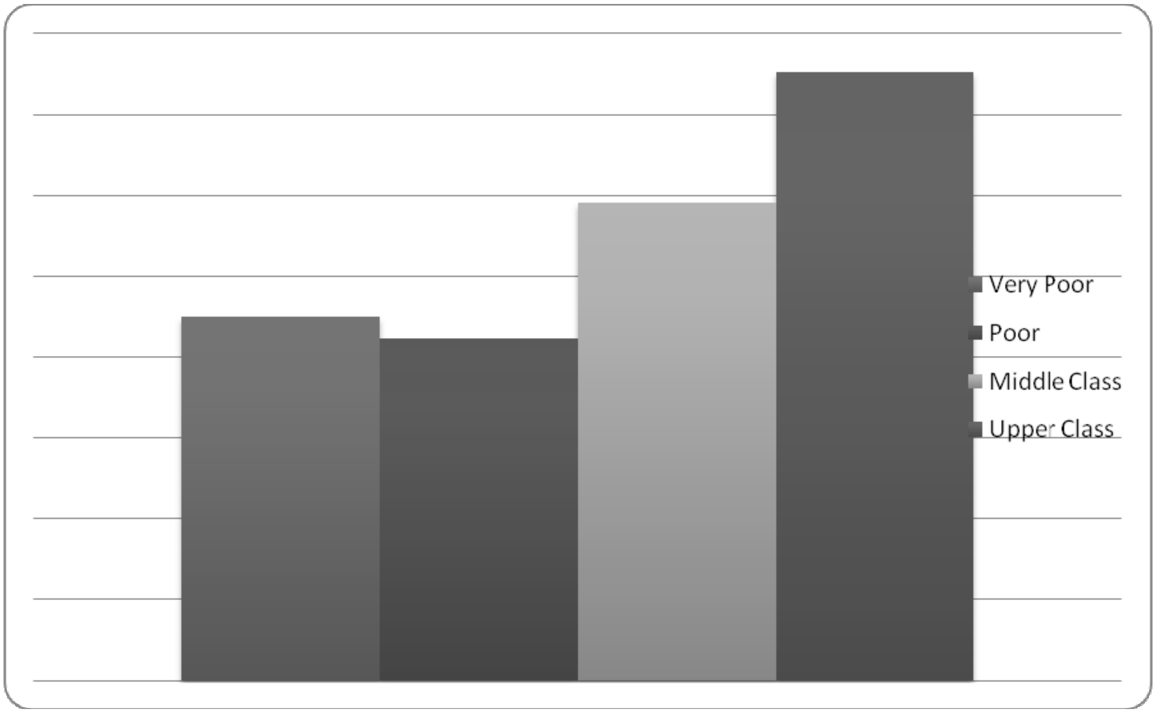

Figure 4. Subjective SES and dominance index.

Table 8. Aim 2 Sample Characteristics

Variable	Bilinguals (*n*=28)	Monolinguals (*n*=28)
Age, *mean* (*sd*)	34.7 (9.5)	34.6 (8.9)
Education, *mean* (*sd*)	11.2 (1.9)	10.4 (1.7)
% Male	42	53
WAIS-R Vocabulary, mean (*sd*)	46.9 (5.5)	46.0 (7.1)
PMR, *mean* (*sd*)	40.8 (14.2)	38.2 (10.4)
FAS, *mean* (*sd*)	29.5 (10.4)	11.5 (5.8)
Dominance Index, *mean* (*sd*)	0.41 (0.05)	0.22 (0.08)

monolinguals (*M* = 39.9, *SD* = 1.4) in response inhibition, F (1, 53) = 5.08, p = 0.02, (Cohen's d = 0.65) and cognitive set-shifting, F(1, 54) = 47.58, p = 0.008), (Cohen's d = 0.75). In addition, bilingual individuals outperformed monolinguals on a measure of attention and concentration (WAIS-R Digit Span), F (1, 54) = 4.04, p = 0.04, (Cohen's d = 0.43), and a measure of processing speed measure requiring divided attention (WAIS-III-Symbol Search), F (1, 37) = 8.00, p = 0.008 (Cohen's d = 0.91). No significant differences were found for other neuropsychological tests, but given the small sample size and possible lack of power, post-hoc effect sizes were calculated. These calculations yielded medium effect sizes for a color-naming test [Stroop Test-Color (Cohen's d = 0.52)]. Medium effect sizes were also found on a different measure of attention [WAIS-III-Letter Number Sequencing (Cohen's d = 0.49)], and a measure of processing speed while copying symbols [WAIS-III-Digit Symbol (Cohen's d = 0.44)], and for Figure Delay (Cohen's d = 0.54)]. A Small effect size between bilingual and monolinguals was found for Story Learning (Cohen's d = 0.07) when controlling for SES (see Table 9).

Table 9. Raw NP Test Differences between Monolingual and Bilingual Groups Matched on SES, WAIS-R Vocabulary and Education

Neuropsychological Test	Bilingual Mean (*SD*)	Monolingual Mean (*SD*)	F value (*df*) *F*	p value	Effect size Cohen's *d*
LEARNING					
Story Learning	11.3 (4.2)	11.0 (4.0)	(1, 53) 0.08	NS	0.07
MEMORY					
Figure Delay	15.3 (1.2)	14.6 (1.4)	(1, 54) 3.2	NS	0.54
EXECUTIVE/ABSTRACTION					
Trails Making Test B	69.2 (25.6)	97.8 (48.6)	(1, 54) 7.7	p=0.008	0.74
Stroop Test-Color Word	44.3 (5.8)	39.7 (8.3)	(1, 53) 5.8	p=0.02	0.65
ATTENTION/WORKING MEMORY					
WAIS-III Letter Number Sequencing	10.2 (2.2)	9.3 (1.4)	(1, 37) 2.4	NS	0.49
WAIS-R Digit Span	12.9 (3.6)	11.2 (2.4)	(1, 54) 4.0	p=0.04	0.43

(table continues)

Table 9. Raw NP Test Differences between Monolingual and Bilingual Groups Matched on SES, WAIS-R Vocabulary and Education, Continued

PSYCHOMOTOR SPEED					
WAIS III- Digit Symbol	76.4 (13.8)	70.5 (13.2)	(1, 36) 1.7	NS	0.44
WAIS III-Symbol Search	32.5 (5.3)	28.0 (4.5)	(1, 37) 8.0	*p*=0.008	0.91
Stroop Color Naming	73.9 (8.1)	69.5 (8.7)	(1, 53) 3.7	NS	0.52

Chapter 5: Discussion

Aim 1

The overarching goal of this project was to investigate the effects of bilingualism on neuropsychological performance among Spanish speakers in the U.S. on tests that are commonly used in clinical settings. Most of the effects of bilingualism on cognition that have been previously described have been studied under experimental conditions, in laboratory settings, and typically with college populations. At the same time, such studies have examined the effects of bilingualism on performance in the second language, or the language of the dominant culture. These types of experimental paradigms are less informative when attempting to understand effects of bilingualism in immigrant groups with variable levels of second language ability. As a first step to translate the findings from the cognitive science literature into the clinical setting, a preliminary study including 192 participants examined the effects of varying degrees of second language fluency (English) on neuropsychological performance in the first language (Spanish). Results showed that greater relative English fluency, used as continuous variable, predicted better performance on tests across several domains, even after controlling for education, age, sex, and years living in the U.S. While relative English fluency uniquely accounted for some of the variance in neuropsychological functioning, the significant correlation between education and the dominance ratio (r=.67, $p < .0001$) could arguably be considered a confounding factor. Therefore, a more stringent subject matching approach was used in order to control for differences in education to better isolate the effects of bilingualism.

To this end, we categorized participants as either bilingual or monolingual based on the dominance index and selected a subset that resulted in comparable education, age, and sex distributions between the groups. Overall, results indicated that learning a second language improves neuropsychological performance in a person's native language. This is despite comparable native language fluency (that is, it was not the case that monolinguals had better Spanish fluency). These findings suggest that previously found bilingual advantages from the cognitive literature translate into some neuropsychological tests that are commonly used in clinical settings to diagnose brain dysfunction. More specifically, our findings support previously found bilingual advantages on tests of control inhibition (after controlling for SES), cognitive set-shifting, and tests of attention, concentration, and mental control. Additional advantages were found on tests of processing speed that require fast manipulation and maintenance of parallel information. Unexpected advantages were found on tests of verbal learning and memory as well as visual memory. Our test results did not support the previously observed bilingual disadvantages on language tests such as confrontation naming, category fluency, or vocabulary. Bilingual participants reported higher SES as children than did monolinguals, therefore, additional analyses were conducted exploring whether or not bilingual advantages were better accounted for by SES.

Language Abilities: Lack of Support for Bilingual Disadvantages

Findings from the cognitive science literature regarding bilingual disadvantages on verbal tasks were not replicated in this study. That is, bilinguals and monolinguals did not differ statistically with respect to vocabulary scores, semantic fluency (animals, fruits, and vegetables) or in confrontation naming scores. Bialystok, Craik, Green, and Gollan

(2009) and Bialystok, Luk, Peets, and Yang (2010), suggest that previously found disadvantages in bilingual children and adults are the result of smaller vocabulary in each of the bilingual two languages, but not necessarily reduced vocabulary when both languages are taken into account. Participants in these studies were fairly balanced bilinguals, were tested in the language of the dominant culture, and presumably used both of their languages fairly regularly. Perhaps, the lack of differences between bilingual and monolingual participants on verbal tasks in the current study offers some support for the frequency lag theory proposed by Gollan and colleagues (2008). That is, the participants in the current study were tested in their native Spanish language and lived in the Mexico-US border region. In this context, the use of first language (Spanish) is sufficient for communication and daily engagement in community activities. The frequency of Spanish use in the population studied in the current study may be equivalent to that of any other monolingual who lives in Mexico, for example, and speaks only Spanish on a regular basis and therefore no "costs" on first language verbal abilities are incurred.

An earlier study by Portocarreno, Burright, and Donovick (2007) had found bilingual disadvantages in vocabulary scores when comparing 39 monolingual and 39 bilingual college students. For the bilingual group, they found better vocabulary scores as years living in the U.S. increased. Also, vocabulary scores improved with age. In these two studies, differences in vocabulary scores between bilinguals and monolinguals were examined using the dominant culture language with participants that received the majority of their education in their second language. It follows then, that the frequency lag theory could account for such differences given than bilinguals are less likely to utilize any one language with the same frequency and to the same extent than a monolingual person, regardless of years of education in the second language. The participants in the present study, on the other hand, received 9.5 years of education in Mexico and 2.2 in the U.S., on average. Furthermore, a closer look at vocabulary scores in the current sample revealed that years living in the U.S. did not impact vocabulary scores as would have been expected. This was the case for the entire sample and was not different between bilinguals and monolinguals. Vocabulary scores in the current sample were correlated with years of education in the country of origin comparably for bilinguals ($r = 0.35$, $p= 0.02$) and monolinguals ($r = 0.42$, $p= 0.002$), as was age for both groups as well. Clinicians, therefore, can feel some confidence in using vocabulary scores as an indication of pre-morbid functioning in bilinguals who received most of their formal education in their country of origin.

In the present study, there were no significant group differences on tests of language ability; this raises the possibility of a threshold for language exposure before second language interference takes place. An alternative explanation would be that such interference effects are less likely to occur when a person has received the majority of their education in their country of origin, regardless of years spent immersed in the second language. A study by Salvatierra, Roselli, Acevedo and Duara, (2007) found no bilingual disadvantages for semantic fluency comparing healthy participants to a population with Alzheimer's disease. On average, however, these participants began learning English after they were 20 years old, and most likely had received their education in their country of origin. Other studies that have found bilingual disadvantages have examined differences between bilinguals and monolinguals by testing participants in the mainstream language. For example, Gollan et al. (2002) tested bilingual college students in the United States and found bilinguals to have worse performances than monolinguals on semantic fluency tasks even when allowed to answer in either language. Another study by Rosselli et al., (2000) found a bilingual disadvantage on semantic, but not phonemic, fluency tasks, with the semantic fluency disadvantage for bilinguals moderated by age of second language acquisition. That is, bilinguals tested in Spanish produced, on average, 7 fewer words in English if they began learning English before the age of 12. Again, these findings suggest that costs for bilinguals in their native language are moderated by years spent in the United States, such that disadvantages on verbal tasks occur for bilinguals who have received most of their education immersed in the second language.

Emmorey, Petrich, and Gollan (2013), Gollan and Acenas (2004), Gollan et al. (2008), Gollan, Weissberger, Runnqvist, Montoya, and Cera (2012), and Sandoval et al. (2010), have studied bilingual and monolingual differences on confrontation naming. They posit different possible mechanisms by which bilingual confrontation naming suffers, and they offer suggestions for how to account for this deficit in clinical settings. One of their hypotheses is that less frequent language use results in reduced naming abilities. Another theory suggests that increased tip-of-the-tongue experiences for cognates (words that sound the same in both languages) lead to overall reduced confrontation naming scores for bilinguals (Gollan & Acenas, 2004). Again, as in the case for vocabulary and semantic fluency, it is possible that second language interference in confrontation naming does not occur for bilingual individuals who have received the majority of their education in their native language. Comparisons of BNT scores from our sample means with those from an Argentinean normative study revealed nearly identical scores. This was true also when bilingual and monolingual groups were further divided into different education levels. In sum, both bilingual and monolingual participants in the current study were able to name the same number of pictures as would be expected based on a monolingual Spanish-speaking normative sample, across different levels of education. The present confrontation naming results provide further evidence for the idea that second language learning is not necessarily a hindrance for bilingual language abilities, as long as the majority of formal education has been received in one's native language.

Bilingual Advantages

The results of this dissertation study support a bilingual advantage on tests measuring cognitive flexibility (Trails B), as well as attention, concentration, and mental control (WAIS-III Letter-Number Sequencing & Digit Span). The results also support a bilingual advantage for response inhibition (Stroop Color-Word), when controlling for SES. These findings suggest the possibility that advantages in executive function happen at early stages of bilingualism, even when interacting in the native language. As it has been pointed out by Bialystok et al. (2009) in an extensive review, the clinical implications for bilingualism on verbal tasks are more easily discerned, as literature from the cognitive science area shares many of the same instruments used in clinical settings (e.g., PPVT, expressive vocabulary test, BNT, etc.). However, with the exception of the Stroop task, the translation between previously found advantages of bilingualism on executive functioning has not been well studied for English or Spanish neuropsychological tests. The current findings make a substantial contribution to the existing literature in that this study has attempted to bridge the gap between cognitive science paradigms and neuropsychological tests with clinical application.

Response inhibition. Response inhibition using the Stroop Test (color-word interference condition) is one of the most widely studied effects in bilingualism. This test is also commonly used in neuropsychology to diagnose executive dysfunction. The current study found smaller Stroop effects, albeit not significant, for bilingual participants. A post-hoc regression analysis treating bilingualism as a continuous variable (dominance index) found higher degree of bilingualism predicted better performance on the Stroop Color-Word condition, controlling for years of education, age, and sex. Thus, participants with greater relative second-language ability demonstrated better abilities to suppress the automatic reading response in their native language. Given that our groups were comparable with respect to education, these differences are not likely explained by education. Some have suggested that, as English fluency increases, word reading abilities in Spanish decline, thereby reducing the Stroop effect and improving incongruent trial scores (Anstey, Matters, Brown, & Lord, 2000; Moering, Schinka, Mortimer, & Graves, 2004). However, this explanation seems unlikely for the current results, given that bilinguals were actually slightly better at the Stroop Word reading than monolinguals (104.6 and 108.2 respectively) and slightly better verbal fluency scores in Spanish (PMR) (42.4 and 40.3 respectively). This suggests that the advantage conferred by greater second language fluency may be related to improved inhibitory control, rather than a handicap in the first language.

Previous studies examining the Stroop effect in bilingual individuals have shown mixed results. When bilingual advantages are not found, studies have often been based on even smaller sample sizes than ours, and as the methods have differed from those in our study, results are not directly comparable (Gasquoine, Croyle, Cavazos-Gonzalez, & Sandoval, 2007; Rosselli et al., 2002). A larger study with a multi-ethnic group of bilingual adults also failed to find a bilingual effect on the Stroop test (Razani, Burciaga, Madore, & Wong, 2007). However, in this study, participants from diverse language backgrounds and unknown level of English language ability were responding to the Stroop test in English.

In line with the present findings, a recent study also found bilingual advantages on the Stroop effect (better inhibition of the unwanted response), tested in both their first and second language, among Chinese-English bilinguals whose first language was Chinese when compared to Chinese-English bilinguals whose first language was English. (Codere, Van Heuven, & Conklin, 2013). The authors concluded that Chinese-English bilinguals who had been immersed in their second language (English), practice cognitive control more so than do bilinguals living in environments where their first language is spoken. However, better inhibition on the Stroop test was found for Hindi-Marati bilinguals who had higher degree of subjective bilingualism tested in their first language Marati; the most widely used language in Pune, India, where the study was conducted (Kamat et al., 2012).

As suggested by Bialystok and colleagues (2008a), the inhibitory control required for the incongruent condition of the Stroop test would be representative of the process that bilinguals engage in to suppress their first language when speaking in the second language. It remains to be understood whether individuals who become successful bilinguals are better “inhibitors” to begin with, and therefore have an easier time acquiring a second language, or whether the ability to inhibit improves over time as an individual becomes more bilingual and increasingly exercises inhibitory control. Regardless, this body of research suggests that the role of bilingualism should not be ignored when making clinical inferences based on neuropsychological tests measuring response inhibition, even when testing a person in their native language.

Cognitive set-shifting. Bialystok and colleagues (2009) suggest that the exercise of inhibiting access to competing languages in order to attend to the language in use, results in advantages across domains that require maintaining attentional set. Bialystok (2010) contends that this practice of conflict resolution is just one aspect of better executive functioning abilities in bilinguals. She has also demonstrated that bilingual advantages exist in aspects of executive functioning not related to conflict resolution but to mental flexibility, as measured by a set-shifting task. In a study using the Trail Making Test (TMT), Bialystok (2010) found that bilingual children outperformed monolingual 6-year old children on both the simple processing speed component (Trails A) and the set-shifting component (Trails B) of the TMT.

Our results on the TMT are consistent with the above-mentioned findings from studies with children, only with regard to Trails B performance, offering further evidence for the specificity of the bilingual advantage in set-shifting ability for adults, given that bilinguals in the current study did not significantly outperform monolinguals on Trails A. The specificity of this finding suggests that bilingualism in adults does not necessarily represent an overall advantage in processing speed, but it may represent an advantage in real-time mental flexibility under time pressure. In order to further confirm this, a regression analysis was conducted where Trails A and group membership were examined as predictors of Trails B performance. This analysis revealed that bilingual group membership, but not Trails A, significantly predicted performance on Trails B scores. Further analysis reveled that Trails A and Trails B were comparably correlated for bilinguals ($r = 0.39$, $p = 0.01$) and monolinguals ($r = 0.40$, $p = 0.005$). Therefore, the dissociation between Trails A and Trails B, coupled with better performance on Trails B in bilinguals, seem to represent a true advantage of second language learning.

An alternative explanation for the bilingual advantage on Trails B was offered by Lu and Bigler (2002), who found that Chinese immigrants who had been living in the United States for a longer time had better performances on both Trails A and Trails B. Testing this possibility in the present study, when entered into a regression equation along with age, education, and sex, being bilingual predicted better Trails B performance, but years living in the United States did not. A closer look at the relationship between years living in the United States for bilinguals and monolinguals showed no association with TMT performance for bilinguals (r = 0.007), but a strong positive correlation for monolinguals (r = 0.57, p < 0.001) such that monolinguals who lived in the U.S. for a longer time performed worse on the Trails B. Given that our groups are fairly comparable with regard to education, age, sex and SES (see later discussion), these results suggest that bilingualism strongly buffers the monolingual disadvantage, especially considering that those who had resided longer in the US would be expected to be more acculturated, and therefore more "test savvy," as acculturation has been found to affect test performance.

Finally, in a study that examined the equivalence of the Color Trails Test and the TMT in a nonnative English-speaking sample of Turkish students, the authors proposed that different language abilities (e.g., verbal fluency) result in differences in Trails B because of the language component of the test (Dugbartey, Townes, & Mahurin, 2000). This is not a likely explanation in the present study, given that bilinguals and monolinguals showed no differences on any of the verbal measures on our battery (except English fluency). Additional analysis showed no relationship between any of the verbal measures (vocabulary, category fluency, and BNT) and Trails B for either group. In sum, no demographic factors explicitly measured in this study (age, education, sex, years living in the U.S.) or implicitly presumed (acculturation) could account for the large effect (Cohen's $d' = 0.67$) of bilingualism on a task of measuring mental flexibility.

Working memory. Working memory, the ability to temporarily maintain and manipulate information for later execution of verbal and non-verbal tasks, is closely related to executive functioning. As with executive functioning, bilingual advantages would be expected in working memory tasks, as bilingual speakers need to engage in maintenance and manipulation of parallel information (English and Spanish). However, our findings on tests of working memory are mixed, as it is the literature, according to a review by Bialystok et al. (2009). We found bilingual advantages on two tests requiring aural attention, concentration and mental control (WAIS-III Letter Number Sequencing and WAIS-R Digit Span), but not on a test of requiring these abilities as well as processing speed and simple arithmetic (PASAT). The reason for this discrepant finding is not clear, but it may be the result of floor effects, as both groups produced correct responses for just over 50% of the PASAT items. Regardless, our results offer some evidence for the specificity of a bilingual advantage in working memory and suggest this effect translates from laboratory paradigms into clinically applicable neuropsychological tests such as Letter-Number Sequencing and Digit Span.

Unexpected Findings

In this study, bilingual advantages were also found on some tests for which no clear rationale exists given the current theories of bilingualism. With the exception of one study examining cultural differences in Digit Symbol, there is little evidence in the literature to explain the bilingual advantages presently observed on tests of verbal learning as well as verbal and non-verbal memory. Harris, Wagner, and Cullum (2007) examined performance differences between non-Hispanic monolingual English speakers, Hispanic bilingual, and Spanish dominant speakers who received all their education in Mexico. Given the discrepancy in education ranges between the Spanish dominant speakers and the other two groups, participants who were Spanish dominant were further divided into higher education (9 or more years) and lower education groups for the purpose of the analysis. Performance differences were attributed to education, as the lower educated Spanish-dominant group performed significantly worse than the other 3 groups, who did not differ from each other. Findings from the present study, however, cannot be attributed to education differences since bilinguals and monolinguals had comparable years of education. This result, coupled with the current finding on Symbol Search, suggest that constant monitoring of parallel information may result in bilingual advantages on these two tasks (Colzato et al., 2008; Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009).

Further unexpected results were found by way of bilingual advantages on a test of visual memory ($p = 0.04$) and a trend ($p = 0.07$) for learning a story (Cohen's d 0.38). The small available literature is mixed with regard to bilingual effects in this area. For example, Kormi-Nouri, Moniri and Nilsson (2003) found that bilingual children were more effective than monolinguals at recalling verbal information under short delay free and cued recall conditions. On the other hand, Fernandez, Craik, Bialystok, and Kreuger (2007) found poorer word recall in bilingual adults. However, despite worse initial word recall for bilinguals, no differences were found between monolinguals and bilinguals when asked to recall words under a divided attention paradigm. These results might suggest that working memory advantages may pose as a buffer in the face of poorer verbal recall for bilinguals. In the current study, however, we found that better working memory (Digit Span) was predictive of better story learning in monolinguals but not in bilinguals, suggesting that working memory did not account for better learning of verbal contextual information. In line with our findings, Papagno and Vallar (1995) found advantages in verbal short-term memory in polyglots versus non-polygot Italian participants. Of note, this same study found no effects of visual short-term memory.

Bilingualism and SES (Aim 2)

As predicted, aspects of SES in this sample revealed greater childhood socio-economic advantages for bilinguals that only partially accounted for the cognitive advantages observed. That is, after controlling for subjective SES, education and vocabulary scores, bilingual advantages were still present in cognitive set-shifting and response inhibition as well as mental control and processing speed while managing parallel information. Arguably, in the current study, a lack of significant findings on tests where we previously found differences could have resulted from reduced power, especially given the lingering medium effect sizes observed for all but one measure (i.e., Story Learning). In light of the small sample size, the persisting findings on response inhibition, mental flexibility, attention and concentration, speak to the robustness of these effects. These findings are therefore consistent with work by Carlson and Meltzoff (2008) who found bilingual (Spanish-English) advantages in children on executive functioning after controlling for SES, vocabulary and age.

That these differences between bilinguals and monolinguals in executive functions (i.e., cognitive flexibility and response inhibition) persisted even after controlling for SES further argues for a "true bilingual" advantage. Studies have found a strong correlation between executive functioning and SES (Aran-Filipetti & Richaud de Minzi, 2012; Ardila, Roselli, Matute, & Guajardo, 2005; Hackman & Farah, 2009; Hackman, Farah, & Meaney, 2010; Sarsour et al., 2011), but we found persisting bilingual advantages on executive functioning after controlling for subjective SES. Given that our bilingual and monolingual groups were comparable with regard to subjective social status (i.e., self-reported) growing up, the differences found in our study could not be best accounted for by SES. Of note, previous research has found single parent home vs. the home where two parents to be a mediator between SES and executive functioning. The current study, however, had the same proportion of bilingual and monolinguals lived in a single parent home vs. a home where two parents were present. In sum, bilingualism advantages on executive functioning in the current study seem to go beyond the possible effects of SES on cognition.

Chapter 6: Summary and Conclusion

Even if some bilingual advantages persisted after controlling for SES, arguably, in general, bilingual individuals seemed to have come from different backgrounds and experiences growing up that have been found to correlate with higher scores on tests of cognition (e.g., higher SES, more education, more exposure to the United States culture). Therefore, the bilingual advantages on executive functioning and the lack of bilingual disadvantages on verbal tests may merely represent a bilingual advantage that is not necessarily limited to the linguistic experience. This may be the case given that, by and large, bilingual participants performed better across most tests than did monolinguals. These results do not exclude the possibility that improved executive functioning, as a result of higher socioeconomic status growing up, could play a mediating role in people's ability to learn a second language. While empirical data utilizing a longitudinal study design is needed to disentangle the directionality of these effects, the significant differences in background experiences growing up between the immigrants that ultimately became bilinguals and the ones who remained monolingual Spanish-speakers raise this possibility.

All things considered, however, results from the present study suggest that learning a second language is advantageous for cognitive functioning, even when interacting in the native language given that advantages were found on tests that most resemble the daily experience of language switching, monitoring and inhibiting the unwanted response. Second language fluency seems to have a positive effect across several domains. However, at least for relatively new immigrants who are late second language learners, bilingual disadvantages and advantages may be distinct from those bilinguals who learned a second language early in life and received the majority of their education in the second language. Importantly, these findings offer some specificity for the bilingual effects on Spanish neuropsychological tests for clinical purposes.

With regard to verbal abilities, the lack of a bilingual disadvantage in the present study, which examined late English learners, coupled with previously found disadvantages for bilinguals who grew speaking both languages, suggest that language costs for bilinguals in the native language may be moderated by years living in the U.S. That is, bilingual disadvantages in verbal tasks may occur for bilinguals who have received the majority of their education in their second language, but not for late second language learners educated in their countries of origin.

On the other hand, cognitive set-shifting and response inhibition seem to represent a "true bilingual" advantage for late second language learners when tested in their native language. These effects persisted even after controlling for subjective SES, education, and vocabulary scores, suggesting that these covariates do not fully provide an explanation for advantages in executive functioning among bilingual late language learners. The specificity of findings in this study may be due to an effect of language use or exposure, such that a threshold for language exposure is needed before second language interference on first language verbal abilities takes place. An alternative explanation would be that such interference effects are less permeable when a person has received the majority of their education in their country of origin regardless of years spent immersed in the second language. Comparable performances between bilinguals and monolinguals on language tests, coupled with relative strengths in cognitive set-shifting and response inhibition for bilinguals, suggest the possibility that advantages in executive function occur at earlier stages of second language exposure. Bilinguals immersed in the second language may inevitably engage in the suppression of the first or second language and/or switching between the two on a daily basis when engaging in community activities (e.g., shopping, working, etc.) and therefore engage in the constant practice of inhibiting, switching, and monitoring.

Clinically, the language test findings provide evaluators with some confidence that native language neuropsychological tests of verbal abilities (i.e., vocabulary, confrontation naming, semantic fluency) in late second language learners represent a fair indication of functioning. Moreover, a decline in cognitive set-shifting and/or response inhibition for a bilingual patient may represent a greater deficit than it would for a monolingual patient if baseline performance is taken into account. Ignoring a patient's bilingual abilities when tested in their native language may, therefore, result in reduced sensitivity of neuropsychological tests. Additionally, after controlling for subjective SES and vocabulary scores, effect sizes on some tests of working memory and processing speed suggest scores from bilingual patients, even when performing in their native language, should be interpreted conservatively.

The current study provides evidence in favor of gathering thorough information about a patient's level of second language ability in the course of neuropsychological assessments, since interpretation standards for measures of executive function may need to take into account second language fluency. If norms based on monolinguals are utilized, declines in executive functions may be underestimated in speakers of a second language. In order to illustrate this point, demographically corrected (age, sex, education) T-scores were generated for each test score, based on the performance of a larger U.S.-

Mexico border sample that includes this study's sample. In order to determine whether rates of impairment are comparable between bilinguals and monolinguals using these norms, T-scores for each test were converted deficit scores, which index only impaired test performances (i.e., all scores better than or equal to one standard deviation below the mean are set to zero, and one deficit point is assigned for every additional half SD below the mean). Individual test deficit scores were then averaged across the entire battery as well as within each ability domain (Carey et al., 2004). As expected, bilinguals had a lower global deficit score (M=0.13, SD=0.17; 8% impaired) than did monolinguals (M=0.20, SD=0.24; 12% impaired). In general, rates of impairments were lower for bilinguals than monolinguals (see Table 10). Additionally, rates of impairment for monolinguals most resembled the rates of impairment expected given the normal distribution for a any normative group (-1 SD = 16%). These data suggests that while deriving norms for Spanish-speakers living in the United States, monolingual speakers are more likely to be deemed impaired when they are not. Bilingual individuals, on the other hand, may be more likely to be deemed "normal" when a true decline from pre-morbid ability has taken place. Therefore, in the future, the field may consider adjusting normative standards for degree of second-language knowledge as part of test score adjustments. A relative English fluency index of the type used in the current study could serve to guide a clinician regarding performances that deviate from normal in this population.

Even if an individual is tested in Spanish, it is important to acknowledge that English fluency may affect the specificity of tests, such that average scores may represent a decline in abilities for bilingual individuals. Therefore, when interpreting

Table 10. Percent of Bilinguals and Monolinguals Scoring in the Impaired Range Based on T-Score ≤ 40 for Individual Tests and Deficit Score ≥ 0.5 for Each Ability Domain

	Bilingual	Monolingual	p value
	(n=50)	(n=73)	
LEARNING	6	8	NS
Story Learning	12	8	NS
Figure Learning	8	15	NS
MEMORY	6	11	NS
Figure Delay	4	17	0.02
Story Delay	14	17	NS
VERBAL	12	11	NS
Category Fluency	12	11	NS
MOTOR ABILITIES	14	12	NS
Grooved Pegboard-Dominant Hand	22	15	NS
Grooved Pegboard-Non- Dominant Hand	16	18	NS
EXECUTIVE/ABSTRACTION	8	19	0.07
Trails Making Test B	10	18	NS
Stroop Test-Color Word	4	14	NS
Hasltead Category	14	15	NS
ATTENTION/WORKING MEMORY	2	11	0.04
WAIS-III Letter Number Sequencing	8	6	NS
PASAT-Correct	6	12	NS

(table continues)

Table 10. Percent of Bilinguals and Monolinguals Scoring in the Impaired Range Based on T-Score ≤ 40 for Individual Tests and Deficit Score ≥ 0.5 for Each Ability Domain, Continued

PSYCHOMOTOR SPEED	6	16	NS
Trail Making Test A	14	21	NS
WAIS III- Digit Symbol	6	18	0.04
WAIS III-Symbol Search	4	18	0.01
Stroop Word Reading	8	13	NS
Stroop Color Naming	8	10	NS

neuropsychological testing results for a bilingual patient, it would important to utilize clinical judgment based on the present findings in order to draw conclusions about abilities that represent a true deviation from normality for that specific patient. Many challenges are already present when working with a bilingual immigrant; development of norms for Spanish language neuropsychological tests that take relative English fluency into account may provide more accurate data, which may lead to more appropriate interpretation of and recommendations. Furthermore, childhood SES should not be ignored in clinical or research settings. While it may be challenging to control for SES in a clinical setting, it is important for clinicians to be mindful that socio-economic disadvantages might impact test performance and possibly clinical outcomes.

Chapter 7: Strengths and Limitations

Strengths

The main strength of this study lies in the population that was used to study the effects of bilingualism. As previously mentioned, prior studies assessing bilingualism have been conducted in controlled experiments under manipulated conditions, where college students are the main studied populations. This study examined the effects of bilingualism in an understudied population of Spanish-dominant immigrants of Mexican-descent with a broad range of age and education, presumably more representative of the general population. In my review of the literature, there has been little research studying the effects of bilingualism on neuropsychological measures administered in the native, and preferred, language. The results of this study, therefore, can be utilized as a tool that might aid in making clinical inferences with Spanish-speakers in both clinical and research domains. In addition, while we decided to dichotomize the sample based on a language dominance ratio, this uses a continuous variable based on objective estimates of language ability, which is a closer reflection of the state of second language fluency that would be encountered in typical clinical situations in the U.S.

Limitations

The proposed study may be limited in generalizability to Spanish/English bilinguals of Mexican-descent with comparable age and education levels and who acquired English later in life. Further research is required to understand whether similar results would be obtained in bilinguals who come from other Spanish-speaking countries or who reside in other parts of the world. While the use of an objective measure of bilingualism is a strength in this investigation, it should be noted that fluency is only one aspect of bilingualism and that this classification was not validated by using a subjective account of language usage. This is particularly true in light of a recent study by Gollan et al. (2012), suggesting that one single measure of bilingualism may fail to accurately capture a person's degree of bilingualism. Another limitation of the current study is that SES data was analyzed retrospectively using a questionnaire with no established psychometric properties and was one that was not specifically intended for the purpose of this analysis. Therefore, this analysis should be considered exploratory in nature. Again, the original purpose of the data gathering efforts was not to examine the effects of bilingualism while controlling for SES, therefore, no efforts were made to ensure large number of participants with comparable levels of SES. The resulting sample for the present study may be smaller, and therefore potentially underpowered, to make such comparisons. For this reason, effect sizes were examined and interpreted with caution.

Future Directions

Future research may focus on the biological underpinnings of how second language acquisition modifies brain function. It may also examine the interaction between second language acquisition and SES among immigrant groups, as the current study only sought to control for SES, rather than explore effects of SES on test performance. Indeed, future work would be enhanced by using both objective and subjective measures of bilingualism and measures of acculturation which are often included in studies where performance of bilinguals is examined. Such measures would have enhanced the current study since it is likely that participants with higher degrees of bilingualism would report higher levels of acculturation and therefore possibly be more ”test savvy.” Additionally, a well-designed longitudinal study might examine the interaction of SES and bilingualism, and its mediating effects on cognitive development through childhood and into adulthood.

Future research might also examine the effects of bilingualism on neuropsychological performance in other Hispanic groups, since English-Spanish bilinguals are a heterogeneous group and results of the current study may not be generalizable to bilinguals in other parts of the U.S. Validating the psychometric properties of the dominance index utilized here may provide useful for future administration in clinical settings. Moreover, given the results of the current study, the dominance index should be considered as an independent measure in norm development for Spanish-speakers in order to improve test specificity.

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