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The Independent and Interactive Associations of Bilingualism and Sex on Cognitive Performance in Hispanics/Latinos of the Hispanic Community Health Study/Study of Latinos

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Abstract

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SUPPLEMENTARY MATERIAL

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Sixty percent of Hispanics/Latinos are bilingual which research suggests may confer certain cognitive advantages. Female sex confers cognitive advantages in verbal learning and memory compared to male sex, regardless of race or ethnicity. Understanding the independent and interactive associations of bilingualism and sex with cognition may aid in predicting cognitive aging in Hispanics/Latinos. We examined baseline (2008–2011) data from the Hispanic Community Health Study/Study of Latinos, a multicenter, prospective community-based study. Our analyses included 6,110 males and females ≥45 years old who self-reported birth and parents' origin outside of the continental US, Spanish as their first language, and were evaluated in Spanish. Bilingualism was assessed along a Likert scale (1 = only Spanish to 4 = English>Spanish) for language proficiency (reading/spoken) and patterns of use (thinking/socializing). Cognitive testing included verbal learning, memory, fluency, and Digit Symbol Substitution (DSS). Linear regression models adjusted for relevant confounders, the complex survey design, and sampling weights. Participants' self-reported language proficiency was Spanish better than English, while patterns of use suggested more Spanish than English. Higher language proficiency was associated with higher performance on all cognitive indices while higher patterns of use associated with higher fluency and DSS scores (p-values < 0.01). Female sex was associated with higher performance on all cognitive indices (p-values < 0.05). There were no significant interactions with bilingualism (regardless of metric) by sex on cognition. For Hispanics/Latinos residing in the continental US and reporting birth and parents' origin elsewhere, bilingualism and female sex have independent cognitive benefits that are important to consider when evaluating cognitive performance.

Keywords

Bilingualism; cognition; Hispanics/Latinos; memory; serial learning; sex differences

INTRODUCTION

Hispanics/Latinos represent the fastest growing segment of the total US elderly population [1]. Among Hispanics/Latinos, 60% are English/Spanish bilingual [2]. Bilingualism, the ability to speak two languages and their frequency of use, has been shown to be related to language and executive function performance including attention and inhibitory control [3–7]; its impact on learning and memory has received less attention [8]. This is despite the fact that performance on tasks of learning and memory have been shown to be critical in identifying early-stage dementia, particularly Alzheimer's dementia [9]. Thus, expanding the investigation of how bilingualism relates to cognitive performance among Hispanics/Latinos to include learning and memory may shed light on whether bilingualism is associated with key cognitive outcomes of risk for and development of dementia.

A large body of research has documented cognitive profiles in bilingual speakers across the lifespan regardless of race or ethnicity, as well as proposed reasons for these strengths and weaknesses [10]. For example, documented verbal fluency reductions in bilingual individuals [7, 11] have been thought to result from the fact that compared to monolinguals, individuals who are bilingual use each language less frequently, which leads to weaker connections between lexical representations and the words associated with them for each language spoken [6]. In contrast, the very fact that speaking multiple languages involves the inhibition and switching between languages [12] has been thought to account for “the bilingual advantage” on executive functions including mental flexibility and attentional control [3, 13–15]. These findings and their underlying theories, however, are not without conflicting results [16–19], opposing interpretations [18, 20], and much debate. Even within this context, less evidence (pro or con) exists regarding the role of bilingual status on verbal learning and memory [19]. This is despite the fact that a growing literature exists investigating the pathological results of impaired verbal learning and memory in bilinguals, i.e., risk for and development of dementia [21,22]. Studies investigating profiles of verbal learning and memory in normal aging bilingual and monolingual speakers may facilitate this work, and provide an opportunity to incorporate recent findings addressing known sex differences in risk for and development of dementia [23, 24].

Increasing evidence is emerging that males are more often diagnosed with mild cognitive impairment (MCI) prior to conversion to Alzheimer’s dementia, while females are diagnosed with MCI less often than males but account for nearly two thirds of Alzheimer’s cases in the US [25]. In fact, age- and sex-specific incidents rates for MCI [26], particularly amnestic MCI [27], are higher in men compared to women. Potential reasons for these sex-differences in diagnostic staging were first reported using one of the largest studies of Alzheimer’s dementia, cognition, and neuroimaging, the Alzheimer’s Disease Neuroimaging Initiative (ADNI). In addition to reporting the well-documented female advantage for verbal learning and memory over males, investigators concomitantly reported neuroimaging evidence of greater structural vulnerability for females compared to males in hippocampal regions associated with learning and memory [23]. This better performance at a lower level of hippocampal volume in females compared to males has been replicated using alternative neuroimaging data including amyloid positron emissions tomography (PET) and deoxyglucose PET by this same group [24]. These studies not only add to the large literature suggesting that females have a distinct advantage on verbal learning and memory tasks [28], but also suggest that this advantage may delay detection of neurodegeneration and associated cognitive impairment in females.

Within the Hispanic/Latino community age 65 and older, there are 127 females for every 100 men and this ratio increases to 192:100 by age 85 [29]. Sex-related differences in cognition across verbal learning, memory, verbal fluency, and mental processing speed have been noted in some [19, 30], but not all studies involving Hispanics/Latinos [31]. Our study will extend previous work in HCHS/SOL that demonstrated a female advantage across all cognitive tests in the HCHS/SOL cognitive protocol [19, 30], to explore, for the first time, whether sex-related differences in cognitive performance interact with bilingualism to enhance cognition, particularly among bilingual females.

The aim of this study is to examine the independent and interactive effects of bilingualism and sex on cognition in Hispanics/Latinos using data from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL). We quantified bilingualism as separate continuous measures of self-reported ability to speak or read in Spanish and English, i.e., language proficiency, and Spanish and English patterns of use in different situations. Given previous studies, we hypothesize that higher levels of self-reported language proficiency in both

Spanish and English as well as higher patterns of both Spanish and English language use would be associated with higher levels of cognitive performance on tests of verbal learning and memory, and attention/information processing speed but (given previous studies) not verbal fluency after adjusting for age, education, and other relevant confounders. We also expect to replicate previous findings in HCHS/SOL regarding the female advantage across all cognitive test variables. Lastly, we will directly explore, for what may be the first time, whether self-reported language proficiency or patterns of language use interact with sex as it relates to cognitive performance.

MATERIALS AND METHODS

The HCHS/SOL is a population-based prospective cohort study of 16,415 Hispanics/Latinos aged 18–74 years from four US cities (Chicago, IL; Miami, FL; Bronx, NY; San Diego, CA) that oversampled persons ages 45–74 to facilitate examination of target outcomes based on a multistage stratified probability sampling design [32]. The baseline examination (2008 to 2011) consisted of comprehensive biological, behavioral, and sociodemographic assessments [33]. Cognitive testing was also conducted during this baseline examination, but only for individuals 45 years and older. The cohort includes participants who self-identified as being of Central American, Cuban, Dominican, Mexican, Puerto Rican, or South American backgrounds. The sample design and cohort selection have been described in detail elsewhere [32]. The HCHS/SOL was approved by the Institutional Review Boards at all sites and all participants provided written informed consent. Procedures were conducted in accordance to UIC policies as well as the Helsinki Declaration of 1975.

Participants

Males and females aged ≥45 years who self-reported their birth and their parents' origin outside of the continental US, also self-reported their first language, i.e., the language they used as a child, and their preferred language for their HCHS/SOL evaluation as 'only' Spanish or Spanish, respectively, and had available cognitive and covariable data for analyses were included in this study ($n = 6,964$). We chose to include only individuals who described their birth and their parents' origin outside of the continental US in an attempt to control for the immigration and acculturation experience. For the purposes of these analyses, Puerto Ricans born in the US territory of Puerto Rico were included in those that 'immigrated' and acculturated to the 50 US states. Our rationale for this inclusion is that our research is focused on language proficiency and patterns of use post arrival to the continental US, aspects of acculturation that individuals adjusting to a new society and its contextual socioenvironmental determinants experience regardless of their point of origin outside of the 50 US states [34].

From this sample of eligible individuals, we excluded those who, during their baseline evaluation, self-reported acute stroke ($n = 103$) and/or substance abuse ($n = 185$), or were found to have psychotropic medication use including anti-anxiolytics, antidepressants, and antipsychotics based on medication review ($n = 566$). This left 6,110 participants in the current study. Both stroke [35] and substance abuse [36] can negatively impact cognitive health; likewise, psychotropic medication use suggests the presence of anxiety, depression, and/or psychotic disorders serious enough to warrant pharmacological intervention. These conditions, and at times the medications used to treat them [37, 38], may negatively impact cognition; were we to include these conditions and individuals using such medications in our analyses, results would be more difficult to interpret within the conceptual framework of bilingualism, sex, and cognition.

Determination of bilingualism: Language proficiency and patterns of use

We conducted an extensive review of the literature, both previous studies (e.g., [39, 40]), and recommendations for future research encouraging the assessment of bilingualism as a continuous variable [41], and considered this review within the context of the available information in HCHS/SOL. As a result, bilingualism in this study was defined as two separate continuous variables reflective of participants' 1) degree of proficiency in Spanish and English and 2) patterns of Spanish and English language use [41–43]. This was accomplished through several self-report questions.

Language proficiency was determined by asking participants the following questions: 1) In general, what language(s) do you read and speak? and 2) What languages(s) do you usually speak at home?

Responses were recorded based on 1-only Spanish, 2-Spanish better than English, 3-both equally, 4-English better than Spanish, 5-only English. The second of these questions was recoded to create a language sub-score modeled after the Multi-Ethnic Study of Atherosclerosis that queries for the language(s) spoken in the home (0-only Spanish, 0.5-more Spanish than English, 1.0-both equally, 1.5-more English than Spanish, 2.0-only English). Given that all participants were native Spanish speakers as a criterion for inclusion in the current analyses, there was a paucity of 'only' English responses ($n = 2$). Thus, we excluded these two participants from further analyses, and scores on these questions ranged from 0 to 4, or 0 to 1.5, respectively. A total score for language proficiency was created by taking the sum total of both questions.

Patterns of Spanish and English language use were determined with questions from the Short Acculturation Scale for Hispanics (SASH) [44]. These questions were as follows: In which language(s) do you usually 1) think? and 2) speak with friends?

Responses were recorded based on 1-only Spanish, 2-more Spanish than English, 3-both equally, 4-more English than Spanish. A total score for pattern of language use was created by taking the sum total of both questions.

Cognitive testing

Test measures, outlined below, were administered in the participants' preferred language during face-to-face interviews by study staff trained and supervised by doctorate-level, licensed, clinical neuropsychologists. Our brief neuropsychological assessment was designed to limit participant burden during the 6-h clinic visit and structured to include important outcomes associated with aging including learning, memory, and attention/executive functioning.

The Brief Spanish English Verbal Learning Test (B-SEVLT) [30] assessed participants' ability to recall items from a 15-item list presented for three consecutive 'learning' trials. This is followed by a 15-item distractor list and a free recall trial immediately following the distractor trial [45, 46]. Variables of interest included total learning across all 3 trials (range = 0–45) and recall post-interference (memory; range = 0–15). The Verbal Fluency test assessed participants' ability to generate as many words as possible within 60 s that began with a specific letter [47,48]. In HCHS/SOL we assessed phonemic or letter fluency with two trials using the letters 'F' and 'A'. The total number of correctly generated words was summed across both trials (range = 0–50) and represents the executive ability of establishing and maintaining mental set as well as word retrieval flexibility. The Digit Symbol Substitution subtest (DSS) of the Wechsler Adult Intelligence Scale-Revised measures working memory and information processing speed [49] by assessing participants' ability to rapidly copy and encode symbols to numbers within a 90-s period. The variable of interest was the total number of correctly transcribed symbols during the time allotted (range = 0–80).

A brief Six-Item Screener (SIS) [50] queried general orientation and mental status. Given previous work with patients with dementia [50] as well as within the cognitive studies involving HCHS/SOL [30], a dichotomous SIS indicator was generated to determine the proportion of participants exhibiting low mental status functioning. A score of 4 or less out of a total possible score of 6 indicated low mental functioning (SIS ≤4).

Relevant covariates

In addition to age and education (i.e., less than high school, high school, greater than high school), information was obtained on several other relevant covariates. During the baseline examination, participants self-identified as having a Central American, Cuban, Dominican, Mexican, Puerto-Rican, or South American background. This information was used to adjust for documented differences between HCHS/SOL background groups on cognition [30]. A 10-item version of the Center for Epidemiologic Studies of Depression scale [51] measured subjective depression symptoms (CESD-10) given the role of depressive symptoms on cognition in older adults [52, 53]. Information was obtained on annual family income (i.e., less than $20,000, $20,000–50,000, greater than $50,000), current occupation (i.e., non-skilled worker, service worker, skilled worker, professional/administrative/office worker, other or not reported), and years of US residency (less than or greater than 10 years), all of which can impact levels of acculturation.

Lastly, physical activity, known to affect cognitive health [54], was evaluated using the World Health Organization Global Physical Activity Questionnaire [55] to determine levels of physical activity (i.e., inactive: no activity beyond baseline activities of daily living; low: activity beyond baseline but fewer than 150 min of moderate-intensity physical activity a week or the equivalent amount of vigorous-intensity activity or the equivalent combination of moderate and vigorous activity; medium: 150 min to 300 min of moderate-intensity activity a week, or 75 to 150 min of vigorous-intensity physical activity a week, or the equivalent combination of moderate and vigorous activity; and high: more than the equivalent of 300 min of moderate-intensity physical activity a week, or more than 150 min of vigorous activity, or an equivalent combination of both) per the 2008 physical activity guidelines available at the time of the HCHS/SOL Visit 1 (http://www.health.gov/paguidelines/guidelines/default.aspx). Activity had to be performed in episodes of at least 10 min.

Statistical analyses

All statistical analyses were conducted in SAS 9.4 and accounted for the HCHS/SOL sample design including sampling weights, cluster sampling, and stratification to allow appropriate generalization to the target population [32]. Descriptive statistics are reported including individual and total levels of language proficiency and patterns of language use.

Cognitive outcomes were deemed normal based on Q-Q plots and Kolmogorov-Smirnov testing [56]. For each cognitive outcome (B-SEVLT learning and memory, phonemic fluency, and DSS test scores), we fit two survey linear regression models per bilingual measurement (language proficiency total score, range = 1.0 to 5.5 reflecting a shift from 'only Spanish' to Spanish better than English, to both equally, to English better than Spanish; and patterns of language use total score, range = 2 to 8 reflecting a shift from 'only Spanish' to Spanish more than English, to both equally, to English more than Spanish), and per sex (female versus male). Model 1 included a bilingual measurement or sex, independently, as the main predictor variable and adjusted for age. Model 2 included additional adjustments for sex (only for bilingual measurement modeling), education, background, CESD-10, income, current occupation, years of US residency, and physical activity based on the rationale cited in the *Relevant Covariates* section above. Finally, fully-adjusted models included terms for age, sex, a single bilingualism measurement, education, background, CESD-10, income, current occupation, years of US residency, and physical activity, as well as the interaction term of a bilingualism measurement*sex in order to test the interactive effect of these indicators. Initial power calculations taking into account the design effects inherent in HCHS/SOL and the confounders in a multiple linear regression model [57] suggested we had 92% power to detect the effects of bilingualism and sex on cognition ($p = 0.05$). The statistical significance of the parameters in the models was evaluated using $p < 0.05$ (two-tailed) and 95% confidence intervals (CIs).

RESULTS

Descriptive characteristics of our analytic sample are outlined in Table 1. Weighted means to allow appropriate generalization to the target population, cluster sampling, and stratification revealed a sample that was approximately 56 years of age, 55% female, and relatively evenly divided between education groups representing < high school and greater than high school categorizations. Individuals of Mexican and Cuban background comprised the majority of our sample and only 14% of individuals fell within the low mental status range on the SIS, i.e., SIS ≤4.

Bilingualism measurements suggested that participants viewed their overall language proficiency in a range from only Spanish to Spanish better than English, and their overall patterns of use in a range of more Spanish than English to using both Spanish and English equally. These total scores are in keeping with our inclusion criteria of native Spanish speakers who identified their language spoken as a child to be 'only Spanish' and chose to receive their HCHS/SOL evaluation in Spanish.

Independent effects of bilingualism and sex on cognitive testing

Language proficiency—Regardless of sex, higher levels of second-language (English) proficiency were significantly associated with better performance across all measures of cognition, regardless of adjustment (Table 2, all p-values < 0.05) resulting in upwards of 2 additional points on select cognitive test measures in fully-adjusted models. Significant confounders of these reported effects of interest included sex, education, Hispanic/Latino background, and CESD-10 scores (all p-values < 0.05). Full model results including beta weights for all terms in the fully-adjusted models may be found in Supplementary Table 1.

Patterns of language use

Regardless of sex, higher levels of second-language (English) use were associated with better performance across learning, phonemic fluency, and DSS test performance after adjusting for age only (Model 1B p-values < 0.01; Table 2). After additional adjustments for sex, education, background, CESD-10, income, current occupation, years of US residency, and physical activity level (Model 2B, Table 2), patterns of use remained positively associated with phonemic fluency and DSS only ($p < 0.001$). Significant confounders of these reported effects of interest included sex, education, Hispanic/Latino background, CESD-10 scores, income, and occupation level (all p-values < 0.05). Full model results including beta weights for all terms in the fully-adjusted models may be found in Supplementary Table 2.

Sex—Regardless of bilingualism measurement, females outperformed males across verbal learning and memory scores (p-values < 0.001) and DSS performance ($p < 0.01$) after adjusting for age (Model 1C, Table 2). With additional adjustments for education, background, CESD-10, income, current occupation, years of US residency, and physical activity level, these female advantages remained significant (p-values < 0.001) and females also outperformed males on phonemic fluency ($p < 0.05$; Model 2C, Table 2), verifying previously reported results [19, 30]. Significant confounders of these reported effects of interest included education, Hispanic/Latino background, and income (all p-values < 0.05). Full model results including beta weights for all terms in the fully-adjusted models may be found in Supplementary Table 3.

Interactive effects of bilingualism and sex on cognitive testing

Analyses did not reveal a significant language proficiency*sex interaction or a separate patterns of use*sex interaction for any cognitive test variable in fully adjusted models; although the patterns of use*sex interaction for DSS performance approached significance (Table 3). Significant confounders across these non-significant models included education, Hispanic/Latino background, CESD-10, and income; occupation level contributed to learning, phonemic fluency and DSS scores only (all p-values < 0.05). Full model results including beta weights for all terms in the fully adjusted model may be found in Supplementary Tables 4 and 5.

Sensitivity analysis

Given that a small percentage of our sample (14%) met criteria for low mental status based on the SIS, we re-ran our analyses excluding those individuals. The pattern of results outlined above did not change (data not shown) suggesting that individuals with low mental status did not unduly affect our results.

DISCUSSION

In this study, we investigated the independent and interactive associations of bilingualism (both language proficiency and patterns of use, separately) and sex on cognitive functioning in over 4,000 middle-aged and older Hispanics/Latinos. We observed that higher levels of self-reported language proficiency in Spanish and English associated with higher levels of cognitive performance regardless of task; however, higher patterns of use in both languages associated with measures of verbal fluency and information processing speed only. Furthermore, we found a female advantage for all cognitive tests, verifying previously reported results in HCHS/SOL [30]. We did not find support for a significant interaction of bilingualism (in either form) by sex on cognitive performance. Thus, our results suggest that the bilingual advantage in our population extends to learning and memory as assessed in the HCHS/SOL when considering language proficiency but not patterns of use. Furthermore, the female advantage across measures of cognition does not interact with advantages associated with bilingualism. The lack of any significant interactions, however, does not negate the importance of considering multiple aspects of bilingualism and using sex-adjusted norms when evaluating cognitive performance in Hispanics/Latinos.

Our work investigating the independent and interactive effects of bilingualism and sex on cognition in middle-aged and older Hispanics/Latinos adds to the existing literature in several ways. Importantly, we are one of the first studies to answer the call for research on bilingualism as a multi-faceted construct and a continuous variable [41], evaluating not only language proficiency but also patterns of use across a range of scores. Additionally, our results support previous findings from others showing an association between bilingualism and better information processing speed [4, 58, 59] and extend this work to include a positive association between bilingual language proficiency and learning as well as memory. Furthermore, we confirm previous findings from our group [30] regarding the Latina advantage across test measures of verbal learning, memory, and fluency, and information processing speed. We were, however, unable to demonstrate that the Latina advantage in cognition combined with the bilingual advantage as it relates to cognitive performance. Nonetheless, this study provides results that inform the literature on associations between distinct aspects of bilingualism and cognition in a relatively homogeneous group of native Spanish speakers self-reporting their birth and their parents' origin outside of the continental US and choosing to receive their HCHS/SOL evaluation in Spanish—a group that is increasingly presenting in memory clinics across the US.

While examining the mechanisms underlying the associations reported in this study are beyond the scope of this cross-sectional study, explanations for our results may be found in the literature as well as the significant confounders in our models. As previously stated, the fact that bilingual speakers 'switch' between different languages whereas monolingual speakers do not [13–15] may help explain DSS results given this is a task of attention that requires mental flexibility and information processing speed. Our results in native Spanish speakers showed that higher levels of English language proficiency (total scores reflected proficiency ranged from only Spanish to Spanish better than English) and/or patterns of use reflecting a range of more Spanish than English to both Spanish and English equally also associated with higher levels of performance on phonemic fluency which is in conflict, with some [7, 16] but not all [11] previous studies. While these results run counter to associated theories that bilinguals may have weaker connections between lexical representations [6], level of second language proficiency can differentially affect fluency, particularly phonemic or letter fluency as assessed in HCHS/SOL [40]. Furthermore, vocabulary size is a mediator of phonemic fluency performance when comparing groups of bilingual and monolingual participants [3] suggesting our native Spanish speaking participants with higher levels of self-reported English proficiency and/or equal Spanish/English language use may have had a larger vocabulary size. This assertion is further supported by the fact that significant confounders of the relationship of higher levels of English proficiency and use with higher phonemic fluency performance included higher education and income levels as well as more professional level occupational status. Lastly, given the cross-sectional nature of our work, we cannot rule out the possibility that individuals with higher verbal fluency or overall cognitive functioning more generally may be more likely to score higher on our measures of bilingualism. Longitudinal follow-up in this and other samples of bilingual participants may help to explain conflicting results, explore the contribution of noted confounders as well as baseline cognitive functioning, and provide greater clarity on directionality of the current findings.

The lack of a significant language proficiency by sex interaction or a separate significant pattern of use by sex interaction may be due to several factors. While we did estimate the percent power to detect a significant interaction of bilingualism by sex at the outset of this study, we also assumed an additive effect of bilingualism and sex on cognition. Not only was this not reflected in our results, it is not reflected in the literature, i.e., to our knowledge, no study has investigated this particular interaction effect. However, it has been shown that the incidence of cognitive impairment for foreign-born Mexican-American males and females differed from their US-born counterparts on the basis of time of immigration to the US [60]. Thus, foreign-born Mexican-American males who immigrated in mid-life had a lower risk of cognitive impairment while foreign-born Mexican-American females who immigrated later in life had a higher risk of cognitive impairment. These investigators did not compare cognitive risk by time of immigration *within* their foreign-born participants. Although we included years of US residency (fewer in females than males of our study) as a covariate in our analyses it did not significantly contribute to any model. Thus, time of immigration to the continental US may be a more important consideration for cognitive performance that could have impacted our results, particularly for late-migrating women, and should be considered in future research. For now, our results suggest that higher language proficiency and being female has widespread but independent associations with cognition, while higher patterns of use are associated with a limited number of cognitive tests; neither metric combines with female sex as it relates to performance which may suggest different underlying mechanisms for these independent predictors that do not combine to further impact performance.

Several limitations should be noted when considering our results. The cross-sectional design of this study limits our ability to clarify the direction of the associations reported in our work. This is noted above as related to our unexpected finding with phonemic fluency. Additionally, there is variability in the literature regarding the bilingual advantage in cognition that may stem from several distinct factors including acculturation factors, as well as differences in occupation, income, and/or overall health. While we attempted to address many of these issues by including time in the US, level of occupation, and income as covariates in our analyses, we may not be capturing other important considerations in minority health research such as language used in the workplace (e.g., English only workplaces regardless of a worker's language proficiency), educational rigor [61], stereotype threat, or perceived discrimination [62] that may address the type and quality of time spent in the US. By including only individuals self-reporting their birth and their parents' origin outside of the continental US, we attempted to equate many of the factors that are associated with the acculturation experience and provide results in a group that is increasingly presenting in memory clinics across the US, i.e., native Spanish speakers who prefer to be evaluated in Spanish but report some level of English proficiency and use Spanish more than English or both equally. While scientifically and perhaps even clinically justified, we may have unwittingly omitted other key, unmeasured confounders, in addition to limiting the generalizability of our results. There is likely a bias in self-reported bilingualism given that males tend to self-report higher proficiency than females across a variety of topics [63]; allowing for consideration of continuous variables of bilingualism as opposed to binary yes/no categorization may have offset this somewhat but not entirely. Language fluency testing to confirm self-reports would have further strengthened our study and should be considered in future research. Lastly, given that the focus of the HCHS/SOL study was not cognition [32], our cognitive testing was limited; however, it incorporated important outcomes associated with pathological aging and dementia including learning and memory, as well as cognitive outcomes often investigated in the bilingual literature, i.e., verbal fluency, attention, and executive functions.

Despite these limitations, this study also had its strengths. It represents one of the largest cohort studies of Hispanics/Latinos from six distinct backgrounds. As previously stated, by focusing on individuals self-reporting their birth and their parents' origin outside of the continental US we attempted to exclude the inherent confounds that may exist when increasing the heterogeneity of bilingual and/or monolingual groups by including US-born participants and/or second generation Hispanic/Latino Americans. Although additional longitudinal data are needed to validate and extend these findings to include an investigation of cognitive change, investigating the independent and interactive effects of bilingualism and sex on cognitive performance in Hispanics/Latinos answers important questions regarding a) what to consider, i.e., bilingualism as a multi-faceted construct and sex-adjusted norms, when evaluating cognitive profiles for the detection of risk for and development of dementia in bilingual Hispanics/Latinos, b) how to conceptualize aspects of bilingualism including language proficiency, patterns of use, and perhaps time in the US as it relates to cognitive performance, and c) what to advise if asked about the potential cognitive advantages of learning a second language.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Characterization of the HCHS/SOL target population

	Target Population *n* = 6,110
Female, %	55.50 [53.70–57.30]
Age, y	56.27 [55.95–56.60]
Education %	
<High School	40.75 [38.40–43.10]
High School graduate	22.19 [20.43–23.95]
Greater than high school	37.06 [35.07–39.04]
Hispanic/Latino Background %	
Mexican	33.31 [29.21–37.42]
Cuban	29.50 [25.06–33.95]
Puerto Rican	9.53 [8.08–10.97]
Dominican	10.36 [8.66–12.06]
Central	8.16 [7.03–9.30]
South American	7.09 [6.13–8.05]
Other	2.05 [1.24–2.86]
Six Item Screener, total score	5.32 [5.29–5.36]
Six Item Screener, % <4	14.29 [12.67–15.91]
10-item CESD	6.73 [6.51–6.95]
Annual Family Income, %	
<$20,000	45.93 [43.55–48.31]
$20,000–50,000	36.65 [34.60–38.70]
>50,000	8.43 [6.69–10.16]
Not reported	8.99 [7.92–10.06]
Current Occupation, %	
Non-skilled worker	12.90 [11.68–14.13]
Service worker	12.14 [10.89–13.40]
Skilled worker	9.84 [8.70–10.97]
Professional, administrative, office	4.37 [3.41–5.34]
Other	8.63 [7.33–9.93]

	Target Population n = 6,110
Not Reported	52.11 [50.09–54.13]
US residence, % >10 y	74.09 [71.70–76.49]
Physical Activity Level, %	
Inactive	27.26 [25.32–29.21]
Low activity	15.03 [13.63–16.43]
Medium activity	11.17 [10.06–12.28]
High activity	46.54 [44.63–48.45]
Language Proficiency and Patterns of Use Scores	
Language(s) read and speak	1.48 [1.45–1.52]
MESA Language-based acculturation	0.16 [0.15–0.18]
Total Score, Language Proficiency	1.65 [1.61–1.69]
Language to think	1.29 [1.27–1.32]
Language speak with friends	1.41 [1.38–1.44]
Total Score, Patterns of Language Use	2.70 [2.65–2.76]

All values presented as weighted mean (95% confidence interval), unless a different metric (e.g., %) is noted, account for the HCHS/SOL sample design (including sampling weights, cluster sampling, and stratification) to allow appropriate generalization to the target population, cluster sampling, and stratification [32]. MESA, Multi-Ethic Study of Atherosclerosis. For all variables: 1 = monolingual Spanish, 3 = both Spanish and English equally with the exception of the MESA Language-based acculturation score where 0 = monolingual Spanish, 1 = both Spanish and English equally.

Table 2

The independent associations of bilingual status and sex with cognition in Hispanics/Latinos

		Cognitive function			
		Learning Beta [95% CI] *p*	**Memory Beta [95% CI] *p***	**Fluency Beta [95% CI] *p***	**DSS Beta [95% CI] *p***
Model 1					
A	Language Proficiency	**0.52 [0.31–0.72]** *p* **< 0.0001**	**0.17 [0.07–0.27]** *p* = **0.001**	**1.43 [1.16–1.69]** *p* **< 0.0001**	**3.43 [2.98–3.89]** *p* **< 0.0001**
B	Patterns of Use	**0.21 [0.07–0.35]** *p* = **0.004**	0.05 [−0.02–0.12] *p* = 0.13	**0.87 [0.68–1.06]** *p* **< 0.0001**	**1.94 [1.58–2.30]** *p* **< 0.0001**
C	Females versus Males	**0.02 [0.02–0.02]** *p* **< 0.0001**	**0.01 [0.01–0.01]** *p* **< 0.0001**	0.002 [−0.00–0.01] *p* = 0.30	**0.01 [0.00–0.02]** *p* = **0.008**
Model 2					
A	Language Proficiency	**0.29 [0.06–0.52]** *p* = **0.01**	**0.11 [0.01–0.22]** *p* = **0.03**	**0.67 [0.39–0.95]** *p* **< 0.0001**	**2.03 [1.63–2.43]** *p* **< 0.0001**
B	Patterns of Use	0.11 [−0.04–0.25] *p* = 0.15	0.04 [−0.03–0.11] *p* = 0.25	**0.44 [0.25–0.63]** *p* **< 0.0001**	**1.10 [0.77–1.43]** *p* **< 0.0001**
C	Females versus Males	**0.02 [0.02–0.03]** *p* **< 0.0001**	**0.01 [0.01–0.01]** *p* **< 0.0001**	**0.01 [0.00–0.01]** *p* = **0.04**	**0.02 [0.01–0.03]** *p* **< 0.0001**

DSS, Digit Symbol Substitution subtest; cognitive test score ranges were as follows: B-SEVLT Learning = 0–45, B-SEVLT Memory = 0–15, Fluency = 0–50, DSS = 0–80. Bolded entries denote significance at $p < 0.05$ with exact *p*-values outlined within the table. Model 1: Age-adjusted. Model 2: Adjusted for age as well as education, background, 10-item Center for Epidemiologic Studies of Depression score, annual family income, current occupation, years of US residency, and physical activity level; sex was also included as a covariable in Model 2A and Model 2B but as the predictor variable in Model 2C.

Table 3

The associations of language status, sex and their interaction with cognition in Hispanics/Latinos

		Cognitive function			
		Learning Beta [95% CI] p	Memory Beta [95% CI] p	Fluency Beta [95% CI] p	DSS Beta [95% CI] p
Model 1A					
	Language Proficiency	**0.62** **[0.31–0.94]** p = **0.0001**	**0.24** **[0.10–0.39]** p = **0.001**	**1.42** **[1.06–1.78]** p **< 0.0001**	**3.08** **[2.39–3.77]** p **< 0.0001**
	Females versus Males	**0.02** **[0.01–0.03]** p **< 0.0001**	**0.01** **[0.01–0.01]** p **< 0.0001**	0.00 [−0.01–0.01] p = 0.47	0.003 [−0.01–0.02] p = 0.71
	Sex by Language Proficiency	0.00002 [−0.00–0.00] p = 0.99	−0.0004 [−0.00–0.00] p = 0.65	0.0006 [−0.00–0.01] p = 0.80	0.01 [−0.00–0.02] p = 0.08
Model 1B					
	Patterns of Use	**0.23** **[0.03–0.44]** p = **0.02**	0.08 [−0.01–0.17] p = 0.09	**0.80** **[0.53–1.06]** p **< 0.0001**	**1.62** **[1.12–2.11]** p **< 0.0001**
	Females versus Males	**0.02** **[0.01–0.02]** p = **0.0006**	**0.01** **[0.00–0.01]** p = **0.0001**	−0.0006 [−0.01–0.01] p = 0.91	−0.01 [−0.03–0.01] p = 0.54
	Sex by Patterns of Use	0.002 [−0.00–0.00] p = 0.16	0.0006 [−0.00–0.00] p = 0.41	0.00 [−0.00–0.01] p = 0.20	**0.01** **[0.00–0.02]** p = **0.01**
Model 2A					
	Language Proficiency	0.31 [−0.04–0.66] p = 0.08	0.13 [−0.02–0.28] p = 0.08	**0.68** **[0.28–1.09]** p = **0.0009**	**1.83** **[1.26–2.40]** p **< 0.0001**
	Females versus Males	**0.02** **[0.01–0.03]** p **< 0.0001**	**0.01** **[0.01–0.02]** p **< 0.0001**	0.01 [−0.00–0.02] p = 0.23	**0.02** **[0.00–0.03]** p = **0.01**
	Sex by Language Proficiency	−0.0005 [−0.00–0.00] p = 0.81	−0.0004 [−0.00–0.00] p = 0.67	−0.0002 [−0.01–0.00] p = 0.92	0.00 [−0.00–0.01] p = 0.33
Model 2B					

	Cognitive function			
	Learning Beta [95% CI] p	**Memory Beta [95% CI] p**	**Fluency Beta [95% CI] p**	**DSS Beta [95% CI] p**
Patterns of Use	0.04 [−0.15–0.23] *p* = 0.70	−0.02 [−0.07–0.11] *p* = 0.69	**0.38** **[0.10–0.65]** *p* = **0.007**	**0.84** **[0.41–1.28]** *p* = **0.0001**
Females versus Males	**0.02** **[0.01–0.03]** *p* **< 0.0001**	**0.01** **[0.01–0.01]** *p* **< 0.0001**	0.003 [−0.01–0.01] *p* = 0.64	0.01 [−0.01–0.03] *p* = 0.26
Sex by Patterns of Use	0.001 [−0.00–0.00] *p* = 0.25	0.0005 [−0.00–0.00] *p* = 0.48	0.001 [−0.00–0.00] *p* = 0.45	0.01 [−0.00–0.01] *p* = 0.06

DSS, Digit Symbol Substitution subtest; cognitive test score ranges were as follows: B-SEVLT Learning = 0–45, B-SEVLT Memory = 0–15, Fluency = 0–50, DSS = 0–80. Bolded entries denote significance at $p < 0.05$ with exact p-values outlined within the table. Model 1: Sex, bilingualism measurement of interest, interaction of sex with bilingualism measurement of interest, and age in the model. Model 2: Sex, bilingualism measurement of interest, interaction of sex with bilingualism measurement of interest in the model with adjustments for age as well as education, background, 10-item Center for Epidemiologic Studies of Depression score, annual family income, current occupation, years of US residency, and physical activity level.