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Education, Bilingualism, And Cognitive Trajectories: Sacramento Area Latino Aging Study (SALSA)

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Abstract

Objective—This study examined the influence of education, country where education occurred, and monolingual–bilingual (English/Spanish) language usage on late life cognitive trajectories in the Sacramento Area Latino Study on Aging (SALSA), an epidemiological study of health and cognition in Hispanics, mostly of Mexican origin, age 60 and over (*N*=1,499).

Methods—The SALSA studied followed a large cohort of older Latinos for up to 7 assessment waves from 1998 to 2007. Global cognition was assessed using the Modified Mini Mental State Examination and the Spanish English Verbal Learning Test was used to measure episodic memory. Education, country of origin, and language usage patterns were collected at the baseline assessment and used as predictors of longitudinal trajectories of cognition. Parallel process mixed effects models were used to examine effects of education and language variables on baseline cognition and rate of cognitive decline.

Results—Mixed effects longitudinal models showed that education had strong effects on baseline global cognition and verbal memory but was not related to decline over up to 9 years of longitudinal follow-up. Differences in education effects between subgroups educated in Mexico and in the US were minor. Monolingual-bilingual language usage was not related to cognitive decline and bilinguals did not significantly differ from monolingual English speakers on baseline cognitive scores.

Conclusions—Hypotheses that higher education and bilingualism protect against late life cognitive decline were not supported and education effects on late-life cognitive trajectories did not substantially differ across US- and Mexico-educated groups.

Keywords

cognitive trajectories; bilingualism; Hispanic; education; aging

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Hispanic elderly are one of the fastest growing aging minority groups in the United States (Berastein, 2005) and this sets an imperative for the aging research community to understand aging outcomes within this population. Maintaining cognitive health is a critical component of successful aging. Studies have shown that the prevalence and incidence of cognitive impairment and dementia is as high or higher in older Hispanics as in non-Hispanic whites (Fitzpatrick et al., 2004; Gurland et al., 1999; Sandberg, Stewart, Smialek, & Troncoso, 2001; Tang et al., 2001) and this potentially translates into a large and growing population of older Hispanics with cognitive impairment. There is a clear need to better understand the cultural, environmental, and biological factors that influence successful and pathological cognitive aging in this population.

Studies have shown that demographic and life experience variables including ethnicity, migration, education, and linguistic background have important effects on cognitive test scores of Hispanics as well as older individuals from other racial/ethnic groups (Early et al., 2013; Glymour & Manly, 2008; Haan, Zeki Al-Hazzouri, & Aiello, 2011). However, effects on cross-sectional scores appear to be larger than effects on longitudinal change over time (Early et al., 2013; Farias, Mungas, Hinton, & Haan, 2011; Gross et al., 2015; Masel & Peek, 2009). The distinction between cross-sectional scores and longitudinal change is important because progressive cognitive decline is the hallmark of pathological cognitive aging associated with diseases like Alzheimer's disease and other diseases that cause cognitive impairment and dementia in older persons. Understanding factors that are associated with late life cognitive decline has important implications both for identifying and monitoring cognitive decline and designing interventions to promote successful cognitive aging. Potentially modifiable variables that promote resilience to disease effects on cognitive decline are of special interest because of their relevance for public policy and individual level efforts to promote late life cognitive health.

Cognitive reserve is a construct that has been used to explain the often-repeated observation that rates of cognitive decline are highly variable even in individuals with similar levels of brain injury and pathology. High reserve is conceptualized as a person specific characteristic that promotes resilience to disease related cognitive decline; alternately cognitive decline is more strongly related to brain pathology in individuals with low reserve (Reed et al., 2010; Stern, 2006, 2011). Fundamentally, higher cognitive reserve is associated with resilience to late life cognitive decline. Education and ability to speak multiple languages have been widely viewed as factors that protect against cognitive decline by promoting cognitive reserve (Freedman et al., 2014; Gollan, Salmon, Montoya, & Galasko, 2011; Stern, 2006). Effects on cognitive decline are especially relevant to understanding whether these variables confer resilience to diseases causing cognitive decline.

There recently has been increasing interest in positive effects of bilingualism on cognition. Studies involving a number of different languages have shown that bilinguals have better cross-sectional cognitive test performance than monolinguals (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004; Kave, Eyal, Shorek, & Cohen-Mansfield, 2008). Bilingualism has been linked to differences in brain structure (Mechelli et al., 2004) and connectivity (Grady, Luk, Craik, & Bialystok, 2015). In contrast to these studies reporting positive effects of bilingualism, de Bruin, Barbara, & Della Sala

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(2015) examined studies of bilingual advantages related to executive control and concluded that publication bias may preferentially exclude publication of negative results.

A number of studies have examined bilingualism in relation to age of dementia and Alzheimer's disease onset. Several studies that retrospectively examined age of symptom onset in patients with dementia or Alzheimer's disease found later age of onset in bilinguals or multilinguals (Alladi et al., 2013; Chertkow et al., 2010; Freedman et al., 2014; Gollan, Sandoval, & Salmon, 2011). Prospective studies of age of onset have found different results. Zahodne et al. (2014) showed that English proficiency in individuals with Spanish as their primary language was not associated with later conversion to dementia. Lawton et al. (2014), using the Sacramento Latino Study of Aging (SALSA) cohort (the cohort used in this study), found that age of dementia onset did not differ between bilinguals and monolinguals.

Effects of bilingualism on late life cognitive decline are especially relevant to the hypothesis that bilingualism increases cognitive reserve, since cognitive reserve confers protection against age and disease related cognitive decline. Longitudinal studies of rate of decline of continuous measures of cognition are limited, and the one large study (Zahodne, Schofield, Farrell, Stern, & Manly, 2014) did not show an association with bilingualism. This is far from a settled issue and additional studies involving different populations and languages spoken are important. The large number of Hispanics in the US who are diverse in linguistic background present both a necessity and an opportunity for studying how linguistic background influences late life cognition. This study is intended to fill that gap.

Previous research involving African Americans and non-Hispanic Whites within the US has shown that regional differences associated with the quality and quantity of education influence late life cognitive test scores (Glymour, Kawachi, Jencks, & Berkman, 2008; Glymour & Manly, 2008). As detailed in Glymour & Manly (2008), African Americans growing up in the segregated southern US received less education and poorer quality education in comparison with non-Hispanic whites. This markedly different educational experience likely impacted their opportunities to learn. Even among Whites, regional differences in the quality of education have been shown to be associated with late life cognitive test scores (Glymour et al., 2008; Glymour & Manly, 2008)

Regional difference in education opportunities might similarly impact Hispanics, but have not been studied. Older Hispanics living in the US southwest are predominantly of Mexican ancestry. Many migrated to the US after completing formal schooling, but a substantial fraction were born and educated in the US. This raises an obvious question about whether education in the US might have different effects than education in Mexico on late life cognition. In a previous study based on the SALSA cohort, (Haan et al., 2011) showed higher baseline scores on tests of global cognition and episodic memory for participants who were born in the US, but did not show an association of country of birth and cognitive change.

The overarching purpose of this study was to examine how education and bilingualism relate to cognitive decline in a large, representative sample of older Hispanics living in northern California. This group has highly variable levels of formal education ranging from none to doctoral degrees, and in addition, varies considerably in migration history and where they received their education (US versus Mexico). Similarly, there is considerable variability in language proficiency and usage with substantial numbers of bilingual English-Spanish speakers, monolingual Spanish speakers, and monolingual English speakers. The heterogeneity in education and linguistic background in this population make it especially suited for studying how these variables relate to cognitive decline. A secondary goal was to examine effects of country of education on cognitive trajectories.

We hypothesized, based on previous findings in this (Farias, Mungas, Hinton, & Haan, 2011) and other samples (Early et al., 2013; Gross et al., 2015; Masel & Peek, 2009), that education would have a large effect on baseline cognitive test scores but would have more limited effects on cognitive change. We also hypothesized that country where education occurred (Mexico versus US) would interact with the effect of education on baseline test scores, and specifically, that education in the US would be more strongly related to cognitive outcomes than education in Mexico. Finally, we used this linguistically diverse sample of older Hispanics to test the hypothesis that bilingualism has beneficial effects on late life cognitive trajectories. Specifically, we hypothesized that individuals who use both languages on a regular basis would show less cognitive decline in comparison with those who speak only Spanish or only English.

Method

Participant Sample

Participants in this study were all part of the Sacramento Area Latino Study on Aging (SALSA). SALSA is a longitudinal cohort study of health and cognition in older Hispanics and this is the same cohort studied by Lawton et al. (2014). Recruitment methods have been extensively described previously (González, Mungas, Reed, Marshall, & Haan, 2001; Haan et al., 2003; Hinton, Haan, Geller, & Mungas, 2003). Briefly, SALSA recruitment targeted Census tracts of Sacramento County and neighboring counties with proportional densities of Hispanics greater than 5% based on 1990 and 1998 U.S. Census information. Eligible individuals were: (1) self-identified as Latino or Hispanic, (2) age 60 or above, (3) Spanish or English speakers, and (4) living in a non-institutionalized setting. Approximately 22% of the total eligible population of Sacramento County, CA was recruited. At baseline a total of 1,789 Hispanics age 60 and over were enrolled in the SALSA study. The initial recruitment occurred between 1998 and 1999 and follow-up evaluations continued through 2007. Follow-ups were conducted every 12 to 15 months. The follow-up sample included individuals with normal cognition, dementia, and with cognitive impairment but not dementia. This study was reviewed and approved by Human Subjects Institutional Review Boards at the University of California, Davis and University of Michigan. Participants provided informed consent for their participation.

Cognitive Assessment—The Modified Mini Mental State Exam (3MS; Teng & Chui, 1987) was used to measure global cognitive functioning. The 3MS was translated and back translated from English to Spanish. Previous publications from the SALSA project have shown that the 3MS is related to a diagnosis of dementia, (Haan et al., 2003) to structural and functional brain imaging (Haan et al., 2003; Jagust et al., 2006), to the presence of a metabolic syndrome, (Yaffe et al., 2007) diabetes (Mayeda, Haan, Yaffe, Kanaya, & Neuhaus, 2015), and to folate deficiency (Ramos et al., 2005). The 3MS includes one item that involves reading (maximum 3 points), 1 that involves writing (5 points), and one that requires spelling (5 points). Consequently, individuals with limited education might score 13 points lower on the overall test and this may well contribute to education differences for baseline scores. Change over time, however, would not be affected because lack of education would similarly impact ability to respond to these items at all assessments.

Verbal Memory was assessed using the Spanish and English Verbal Learning Test (SEVLT; González et al., 2001). The SEVLT uses a 15 word list that is presented for five learning trials in a standard word-list learning test format, followed by presentation of a distractor task, and then by free recall of the initial list. The Verbal Memory measure was a composite measure of scores from the learning trials and delayed recall trials. This measure has been used in previous studies involving the SALSA sample as well as in independent studies of ethnically diverse English and Spanish speakers, and it has been shown to be sensitive to clinically relevant cognitive change as well as to MRI measures of brain structure (Carmichael et al., 2012; Farias et al., 2012; Mungas et al., 2010; Mungas, Reed, Farias, & Decarli, 2009). VM utilizes auditory-verbal administration and does not require reading or writing.

Predictor Variables—Years of formal education was a primary independent variable used to explain baseline cognitive scores and rate of decline. Country of education was not explicitly assessed in SALSA, but we did collect information about where participants were born and their age of migration to the US. These variables were used to categorize country of education (in the US; in Mexico; or uncertain/both countries) in the following manner. It was coded as occurring in the US for those born in the US and for those who migrated to the US before age 6 years. It was coded as occurring in Mexico if age at migration was greater than years of formal education plus six (assuming formal education begins at 6 years old, on average). Country of education was coded as uncertain/both countries if age at migration was at age 6 or older and years of education plus 6 was greater than age of migration. In effect this variable coded whether all education occurred in Mexico or the US, and classified as missing those cases where education occurred in both countries.

Self-reported language usage was collected as part of the Acculturation Rating Scale for Mexican Americans – Version II (ARSMA-II; Cuellar, Arnold, & Maldonado, 1995). The ARSMA-II contains two items that record frequency of usage of English and Spanish. Monolingual Spanish was coded if Spanish was spoken “very often” or “almost always” and English was spoken “not at all” or “not very often”; monolingual English was the opposite. Bilingual was coded if both English and Spanish were spoken “very often” or “almost always”. Bilingual status was coded as two indicator variables representing monolingual Spanish (1 if yes, 0 otherwise) and bilingual (1 if yes, 0 otherwise). Monolingual English was represented by 0’s on both indicator variables and was the reference group.

Self reported language proficiency was obtained for a subsample that was involved in more detailed baseline cognitive assessment and dementia ascertainment protocols. Participants rated how well they spoke English and Spanish on four-point scales: 0 – not at all, 1 – a little, 2 – well, 3 – very well. These two variables were used to define bilingual proficiency in a manner similar to that for language use: Monolingual Spanish – Spanish well or very well and English not at all or a little, Bilingual – both Spanish and English well or very well, Monolingual English - English well or very well and Spanish not at all or a little. Two indicator coded variables were created, monolingual Spanish and Bilingual, with monolingual English as the reference (0's on both).

Data Analysis

Cognitive outcomes included the 3MS and Verbal Memory. The 3MS was not normally distributed, and like the Mini Mental State Exam from which it was derived, does not provide linear measurement across the ability continuum (Mungas & Reed, 2000; Mungas, Reed, Crane, Haan, & González, 2004). That is, a one unit difference in total score at the upper end of the 3MS scale is associated with a substantially larger difference in underlying ability than a one unit difference at a lower score. To address this problem, item response theory (IRT) methods were used to calibrate and score the 3MS. Baseline scores were used for calibration. Individual item scores were recoded into ordinal scores with 10 or less categories and R ltm (Rizopoulos, 2006) was used to fit a graded response IRT model (Samejima, 1969). Item parameters from this calibration were then used to estimate IRT ability (theta) scores using an empirical Bayes scoring algorithm. IRT scoring has a distinct advantage in that it maps test performance onto a linear measurement scale. However, it does not completely solve the measurement limitations of the 3MS because high ability is measured with less precision than low ability. The IRT score from the 3MS was reasonably normally distributed and so was appropriate for subsequent analyses. The baseline evaluation mean and standard deviation of the 3MS IRT score were used to transform the score to have a mean of 100 and standard deviation of 15. Verbal Memory (VM) was an IRT based composite measure combining scores from the learning trials and delayed recall trials, described in a previous publication (Mungas et al., 2004). It also was scaled to have a mean of 100 and a standard deviation of 15 in the baseline SALSA sample.

Linear mixed effects models were applied to individuals who had received at least two cognitive assessments to evaluate the effects on cognitive trajectories of education, country in which education occurred, and bilingualism. The first step of model building examined the unconditional trajectories of the 3MS and VM measures, modeled as parallel processes. This model included random intercept and slope effects for each cognitive outcome. The intercept random effect estimated each individual's score at baseline and the slope random effect estimated each individual's linear change across all longitudinal evaluations. These random effects were allowed to freely correlate within and across the two cognitive outcomes. In effect, 3S and VM were simultaneously modeled as correlated outcomes that were regressed on education and bilingualism variables. Neither variable was in the causal pathway from independent variables to the other cognitive outcome. This parallel process model serves the purpose of evaluating effects of independent variables on cognitive trajectories, but does so in a more efficient manner that simultaneously adjusts for error in the measurement of both outcomes.

Time in years from the baseline evaluation was used as the time metric. We added a term to the base model to account for variability associated with dropout. This was accomplished using an indicator variable coded as 1 if the current observation was non-missing but the next observation was missing, and coded as 0 if the current and next observation both were non-missing. It was entered as a within subjects effect.

We next added covariates, age, gender, and language of test administration, and evaluated their effects on baseline and change components for the 3MS and VM. We added education as an independent variable in the third step, first continuous education and then, in a separate model, categorical education. Continuous education was centered at 8 years. Categorical education was recoded into four groups roughly representing quartiles of the distribution of continuous education, and was captured by three indicator variables: 1) 0–3 years, 2) 4–6 years, and 3) 7–12 years. More than 12 years was the reference group.

We next used multiple group models to test whether education effects differed according to country of education. We compared models in which education effects were constrained to be the same in Mexico-educated and US-educated groups with models that allowed education effect parameters to differ in the two groups. These were nested models and the likelihood ratio test (Satorra & Bentler, 2001) was used to determine if model fit was significantly worse when education effect parameters were constrained to be the same. We performed separate tests for the 3MS and VM that simultaneously evaluated differential education effects on intercept and change random effects. If the overall test for a cognitive outcome was significant, we then separately evaluated individual effects on specific random effect trajectory components. We allowed means and variances of 3MS and VM baseline and change components to differ across country of education groups.

The final step of analysis examined effects of monolingual-bilingual status on cognitive trajectories using a similar parallel process models of 3MS and VM. Monolingual-bilingual status was coded as two indicator variables: monolingual Spanish usage, and bilingual usage. Scores of 0 on both variables corresponded to monolingual English, the reference group. These indicator variables were entered into a mixed effects model along with age, gender, and continuous education as covariates. The primary analysis used self-rated language usage, which was available on the full sample, to define bilingual status. A secondary analysis used self-rated proficiency, which was available on a sub sample. An additional secondary analysis dropped education as a covariate from the model involving language usage.

Mixed effects longitudinal analyses were performed using MPlus version 7.2 multilevel modeling (Muthén & Muthén, 1998–2012) and utilized a MLR estimator. Mixed effects models estimate how differences in the baseline level of an outcome and its rate of change over time relate to variables of interest (fixed effects) that differ between subjects (e.g., education, monolingual-bilingual status). Mixed effects models allow for heterogeneity in the number of assessment time points and in the lags between assessments across persons.

Maximum likelihood estimation provides unbiased estimation of model parameters if the missing data can be considered to be missing completely at random or missing at random

(Schafer & Graham, 2002). In studies of cognitive aging, increasing cognitive impairment leading to inability to complete subsequent evaluations is a concern that could result in non-ignorable missing data. This could result in underestimation of rate of cognitive decline in those who drop out, which would decrease statistical power for identifying predictors of cognitive decline. Missing at random is satisfied if patterns of missing data can be explained by observed variables in the model. Longitudinal observation provides information about declining cognition and so likely minimizes bias associated with missing observations due to increasing cognitive impairment.

Results

Sample Characteristics

Sample characteristics by country where education occurred are presented in Table 1. A total of 1789 participants were enrolled in SALSA and had baseline cognitive testing. Of those, 1499 completed at least one follow-up evaluation and were included in this study, 602 (40%) received all of their education in Mexico, and 809 (54%) received all of their education in the US – 39 (3%) received education in both countries, and migration age was not known for 49 (3%). Six follow-up evaluations were completed by 511 of the 1499, 266 completed five follow-ups, 170 had four follow-ups, 192 had three, 173 had two follow-ups, and 187 had one follow-up. About half were born in Mexico and half in the US. Individuals were allowed to decide which language they preferred for testing; 88% of those born in Mexico were tested in Spanish compared to 24% of those born in the US. Language proficiency also substantially differed by country of education. Those born in Mexico were predominantly monolingual Spanish speakers, while those born in the US were more likely to be bilingual or monolingual English speakers. About two-thirds of bilinguals were tested in English. The overall mean level of education was low (mean = 7.5, S.D. = 5.3), with more than 50% of the sample having less than an 8th grade education. However, the education level spanned a very wide range from zero years of formal education to graduate degrees for both those born in Mexico and the US. Attained education was substantially lower in those educated in Mexico.

Language proficiency ratings were available for 799 (409 monolingual Spanish, 342 bilingual, 48 monolingual English). Three hundred six were randomly selected from the overall SALSA sample (146 monolingual Spanish, 139 bilingual, 21 monolingual English), and 493 were selected for full cognitive/clinical evaluations on the basis of scoring below the 20th percentile on either the 3MS or VM.

Base Model Development

Figure 1 shows 3MS and VM trajectories for 30 randomly selected participants. 3MS showed significant average improvement (estimate = 0.145 (SE = 0.050) points/year, p<.004) in an unconditional model without independent variables or covariates, but VM declined on average (−0.263 (0.058), p<.001); there was significant variability of intercepts and slopes for both cognitive outcomes (p's < .001). The variable coding missing data for the next evaluation was associated with both the 3MS and VM, and consequently was retained in subsequent models. VM scores were 1.43 points lower (on the recoded scale with a S.D. of 15, S.E. = 0.37, $p<0.001$), and 3MS scores were 1.43 points lower (S.E. = 0.35, $p<0.001$) if the next evaluation was missing.

In preliminary longitudinal models that included just covariates, being tested in Spanish and being older were associated with lower 3MS baseline scores. Older age was associated with a faster rate of 3MS decline. Males showed a slower rate of decline compared to females. Language of test administration was not related to 3MS decline. For VM, being tested in Spanish, male, and older age were associated with lower baseline scores. Older age was associated with faster rate of decline but males declined at a slower rate.

Education Effects

The next step of data analysis added continuous years of education to the base model and covariates. Higher education was associated with higher 3MS baseline scores (about 0.36 S.D. per four years of education), but education was not related to rate of change in 3MS. Similarly, higher education was associated with higher baseline VM but was not related to change in VM.

Categorical education was then added to covariates, and these results are presented in Table 2. Progressively higher categorical levels of education were associated with progressively higher 3MS and VM scores, and these changes followed a relatively linear pattern. Figure 2 shows average 3MS and VM trajectories as a function of education level. Group differences in baseline levels were larger for the 3MS than VM. There were no significant group differences in rate of change for the 3MS or VM.

Education Effects by Country of Education

Multiple group analyses were used to test if education effects differed by country of education (808 educated in US, 601 in Mexico). The likelihood ratio test indicated that continuous education effects on 3MS intercept and linear slope components differed across groups (χ^2 [2]=12.0, $p=0.002$). Effects of education on intercepts significantly differed across groups (χ^2 [1]=10.9, $p=0.001$), with stronger effects for the Mexico group. Education was related to baseline scores in both groups, but baseline scores were 0.33 S.D. higher per four additional years of education in the US compared to 0.41 S.D. higher for four years of education in Mexico. Continuous education was not related to annual rate of 3MS decline in either Mexico or the US, and the education effect on 3MS decline did not differ across countries. Effects of continuous education on VM intercept and linear change components did not differ across groups (χ^2 [2]=5.2, $p=0.08$).

Mexico and US group means of cognitive trajectory components were generally similar after adjusting for continuous education: 3MS baseline – Mexico = 106.17 (S.E.=0.96), US = 105.01 (0.52); 3MS linear change – Mexico = 0.09 (0.16), US = −0.01 (0.09); VM baseline – Mexico = 106.79 (1.06), US = 104.09 (0.54), VM linear change – Mexico = −0.59 (0.20), US = −0.47 (0.11). VM baseline was significantly higher in the Mexico educated group ($p=0.004$) but other differences were not significant.

Monolingual – Bilingual Language Usage

Monolingual versus bilingual language usage was the primary independent variable in this analysis and age, gender, and education were covariates (N=1458). Results are shown in Table 3. Monolingual Spanish speakers had lower baseline 3MS scores after accounting for covariates, but bilinguals did not significantly differ from monolingual English speakers. VM baseline did not differ across language usage groups. Change in 3MS and VM was not related to monolingual - bilingual status. Figure 3 shows average 3MS and VM trajectories as a function of monolingual – bilingual status.

A secondary analysis dropped education as a covariate. Monolingual Spanish speakers had substantially lower baseline scores than monolingual English speakers for both the 3MS (estimate = −13.92, S.E. = 0.69, p=0.001) and VM (estimate = −6.69, S.E. = 0.70, p=0.001) and bilinguals also significantly differed from monolingual English speakers for 3MS (estimate = −3.27, S.E. = 0.69, p=0.001) and VM (estimate = −1.83, S.E. = 0.75, p=0.014). Monolingual-bilingual status was not related to change in the 3MS or VM. The combined results from the primary and secondary analyses indicate that monolingual – bilingual status did not affect rate of cognitive decline. Monolingual Spanish status was associated with lower baseline scores and bilinguals had somewhat lower baseline scores than monolingual English speakers in models not adjusting for education.

Additional secondary analyses used self-rated language proficiency to characterize bilingualism and effects were examined in the subsample with language proficiency ratings (n=799) and in the random subsample (n=306). Results were quite consistent with the primary analysis. Monolingual/bilingual status characterized by self-reported proficiency was not related to either 3MS or VM slopes, monolingual Spanish intercepts were lower, and bilingual-monolingual English intercept differences were relatively small or not present.

Finally, we also examined non-linear, quadratic models of cognitive decline. Adding a quadratic random effect component to the mixed effects longitudinal model for VM did not significantly improve model fit evaluated using the Sample Adjusted Bayes Information Criterion (Enders & Tofighi, 2008; Tofghi & Enders, 2007). A model with a quadratic component did fit better for the 3MS, but results related to overall change over the course of this study were nearly identical to those from the linear model, and the linear model was subsequently selected for parsimony and clarity of presentation.

Summary of Results

Education had robust effects on baseline 3MS and VM, with stronger effects on the 3MS. Groups defined by quartiles of the education distribution showed progressively higher baseline cognitive scores that followed a relatively linear pattern. Neither continuous nor categorical education was related to cognitive change. Education effects were very similar in subgroups educated in Mexico and in the US with the exception that baseline 3MS was related to continuous education in both groups but this association was stronger in the Mexico educated group. Monolingual-bilingual status was not related to cognitive decline. Monolingual Spanish speakers had lower baseline 3MS scores, but bilinguals did not significantly differ from monolingual English speakers on either 3MS or VM independent of education. Similar results were found when language usage and proficiency ratings were used to characterize monolingual-bilingual status.

Discussion

The primary goal of this study was to evaluate whether higher levels of education and ability to speak more than one language are associated with slower cognitive decline in a large and diverse sample of older Hispanics. We found strong effects of education on baseline cognitive test scores and lower baseline scores in monolingual Spanish speakers, but education and language usage were not related to rate of cognitive decline. Consequently, results of this study do not support the hypothesis that education and bilingualism promote resilience to cognitive decline. These negative findings are not likely explained by a lack of statistical power, since the sample was quite large and conferred high statistical power to detect even very small effects of these variables.

Education had a substantial effect on baseline global cognition and verbal memory scores, consistent with previous studies of education and baseline/cross-sectional cognitive test scores (Early et al., 2013; Glymour, Weuve, Berkman, Kawachi, & Robins, 2005; Karlamangla et al., 2009; Tucker-Drob, Johnson, & Jones, 2009; Wilson et al., 2009; Zahodne et al., 2011). In contrast, we found no association between education and cognitive change. While our results apply to two specific measures of global cognition and verbal memory, the pattern of strong education effects on baseline scores coupled with no effect on longitudinal change is quite consistent with other studies using broader measures of cognition in different populations (Early et al., 2013; Gross et al., 2015, Masel & Peek, 2009, Zahodne et al., 2011). As illustrated in Figure 2, while there were large education related differences in baseline 3MS, there were no education related differences in change from the initial to the final assessment. Education similarly was not related to change in verbal memory.

We also examined whether bilingualism was associated with slower cognitive decline. Monolingual Spanish speakers had lower baseline cognitive scores on average, but language usage/proficiency was not related to cognitive decline. Previous studies have shown that bilingualism is associated with better cross-sectional cognitive test performance (Bialystok et al., 2008; Bialystok et al., 2004; Bialystok, Poarch, et al., 2014), and several studies have found later age of onset in bilinguals or multilinguals (Alladi et al., 2013; Bialystok, Craik, Binns, Ossher, & Freedman, 2014; Chertkow et al., 2010; Freedman et al., 2014; Gollan, Salmon, et al., 2011). These results have been interpreted to suggest a protective effect of bilingualism on cognitive decline. However, previous studies have not been entirely consistent in showing such effects and bias against publication of negative results might influence what is reported in the literature (de Bruin et al., 2015). Many of the studies examining the effects of bilingualism in older populations are cross sectional, based on small samples, and age of onset studies often involve retrospective comparisons of estimated age of onset of monolinguals and bilinguals in clinical samples. Prospective studies examining effects of bilingualism on cognitive decline are particularly relevant to the question of whether bilingualism promotes cognitive resilience.

A recent study by Zahodne et al (2014) failed to show either an effect of bilingualism on continuous cognitive decline or on incidence of dementia. Their results are especially noteworthy since a large and representative sample was used, conversion to dementia was evaluated prospectively in individuals who were not demented at baseline evaluation, and both self-ratings and objective language proficiency measures were used to characterize bilingualism. A recent prospective study using the SALSA sample did not show bilingualism effects on age of dementia onset (Lawton et al., 2014). As addressed in Lawton et al., issues involving use of clinical versus community samples and retrospective self-report versus prospective clinical diagnosis of dementia may contribute substantially to different findings in the literature.

Our study utilized a large and representative, but very different sample of Hispanic older adults from that in Zahodne et al (2014) (primarily Mexican versus primarily Caribbean), and results replicate the lack of a bilingualism effect on cognitive decline reported by Zahodne et al. The biggest difference we showed in baseline cognitive outcomes was between monolingual Spanish speakers and monolingual English speakers. While monolingual Spanish speakers had lower baseline global cognitive test scores, they declined at the same rate as bilinguals and monolingual English speakers. Differences in baseline scores that were related to monolingual-bilingual status were largely explained by associated differences in amount of education.

An important limitation of our study was that we measured bilingualism with self-ratings, primarily of language usage and of language proficiency in a sub sample. These types of measures might introduce unknown biases and future studies in which bilingualism is carefully measured using a combination of self-rating and objective methods are needed (Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012). Another important limitation of our study was that neither of our cognitive outcomes directly measured executive control processes that have been identified as being particularly relevant to bilingual advantages (Bialystok et al., 2008; Bialystok, Poarch, et al., 2014). Consequently, our study may not have been optimally sensitive to bilingualism effects. While the possibility remains that bilingualism would be associated with slower decline of specific executive function measures, our results nevertheless fail to show significant effects for global cognition and episodic function measures that are highly relevant to monitoring cognitive decline in older populations.

Our results showed only limited evidence that country of education influenced the association of education with late life cognition. Education had a stronger association with baseline 3MS in the Mexico educated group; otherwise, education effects did not differ by country. However, an important limitation of this study is that country of education was very broadly defined, and it is quite likely that there was considerable heterogeneity of educational experiences within Mexico and within the US. We were not able to examine more specific indices of resources devoted to education or of quality of education, which have been shown to have important influence on late life cognition (Glymour et al., 2008; Manly, Byrd, Touradji, & Stern, 2004). Further research is needed to evaluate possible disparities between the educational experiences within and across the US and Mexico subgroups and how they influence late life cognition. The Hispanics in this study are a mix of individuals who have migrated to the US at various ages and thus have experienced varying portions of their education in their country of origin; quantifying these varied experiences and their effects on late life cognition presents a major challenge for this line of research.

Country of education effects are especially complicated by individual differences between migrants and non-migrants. Mexican migrants to the US differ from non-migrants and native-born US individuals in a number of ways: they are healthier (Crimmins, Kim, Alley, Karlamangla, & Seeman, 2007; Thomson, Nuru-Jeter, Richardson, Raza, & Minkler, 2013), and they have been shown to have better health behaviors (Tong et al., 2012). These findings have been referred to as the "Hispanic paradox", and a prominent explanation is that individuals who chose to migrate are more robust or healthy than their Mexican peers who stay in Mexico and Mexican Americans who have lived in the US all of their life. The important point is that the subgroup in this study that was educated in Mexico were also immigrants, and it is not possible in this study to separate effects of differences in country of education from differences associated with migration.

There are additional limitations that should be noted. This current study examined a fairly homogeneous group of older adults of primarily Mexican descent. Because Hispanics are a heterogeneous group including individuals from various countries and origins findings from this study may not generalize to other Hispanic/Latino groups. The similarity of our results to the Zahodne et al (2014) results partially addresses this limitation. Additionally, there may be other covariates that were not included that may contribute to cognitive outcomes. For instance, neuropsychiatric symptoms such as depression have been shown to be associated with cognitive change over time (Lee, Paddock, & Feeney, 2012) and health status, diabetes specifically, has been shown to relate to cognitive outcomes in this sample (Mayeda, Haan, Kanaya, Yaffe, & Neuhaus, 2013; Mayeda et al., 2015). This study has many strengths as well. It takes advantage of the nearly 1,500 participants who are linguistically and educationally diverse. Although the homogeneous make-up of our sample can be viewed as a limitation, it is also a strength in that additional, unmeasured cultural confounders are less likely to influence results.

Findings from this study have important practical implications. Clinicians often use cross-sectional measures to diagnose underlying neurodegenerative diseases. Results of this study are consistent with a growing body of literature involving Hispanics and other groups that shows that failing to account for education effects on cross-sectional test scores can obscure true disease effects and lead to erroneous conclusions about presence, absence, and magnitude of disease effects (Early et al., 2013; Mungas et al., 2009). That is, cross-sectional differences do not appear to be explained by those with lower education declining more rapidly due to diseases of aging. When testing within the Hispanic community, findings from this study similarly highlight the importance of accounting for language usage as well as education, and specifically suggest that different norms for non-English and English speakers would be advisable. This study also converges with other literature that shows the importance of longitudinal assessment for identifying clinically significant cognitive decline (Early et al., 2013; Mungas et al., 2010). Differences in life experiences that underlie much of the heterogeneity in cross-sectional test scores should equally impact baseline and follow-up assessment scores, making it possible to measure longitudinal change independent of these influences. Ultimately, declining cognition is the clinical outcome of interest, and longitudinal assessment provides a more direct measure of this outcome.

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Public Significance

Education and bilingualism have been identified as life experience variables that might protect against late life cognitive decline. This study failed to show a protective effect of these variables in a large sample of older Hispanics with diverse education and linguistic backgrounds. Further research is required to understand complex relations of education and bilingualism with late life cognitive decline.

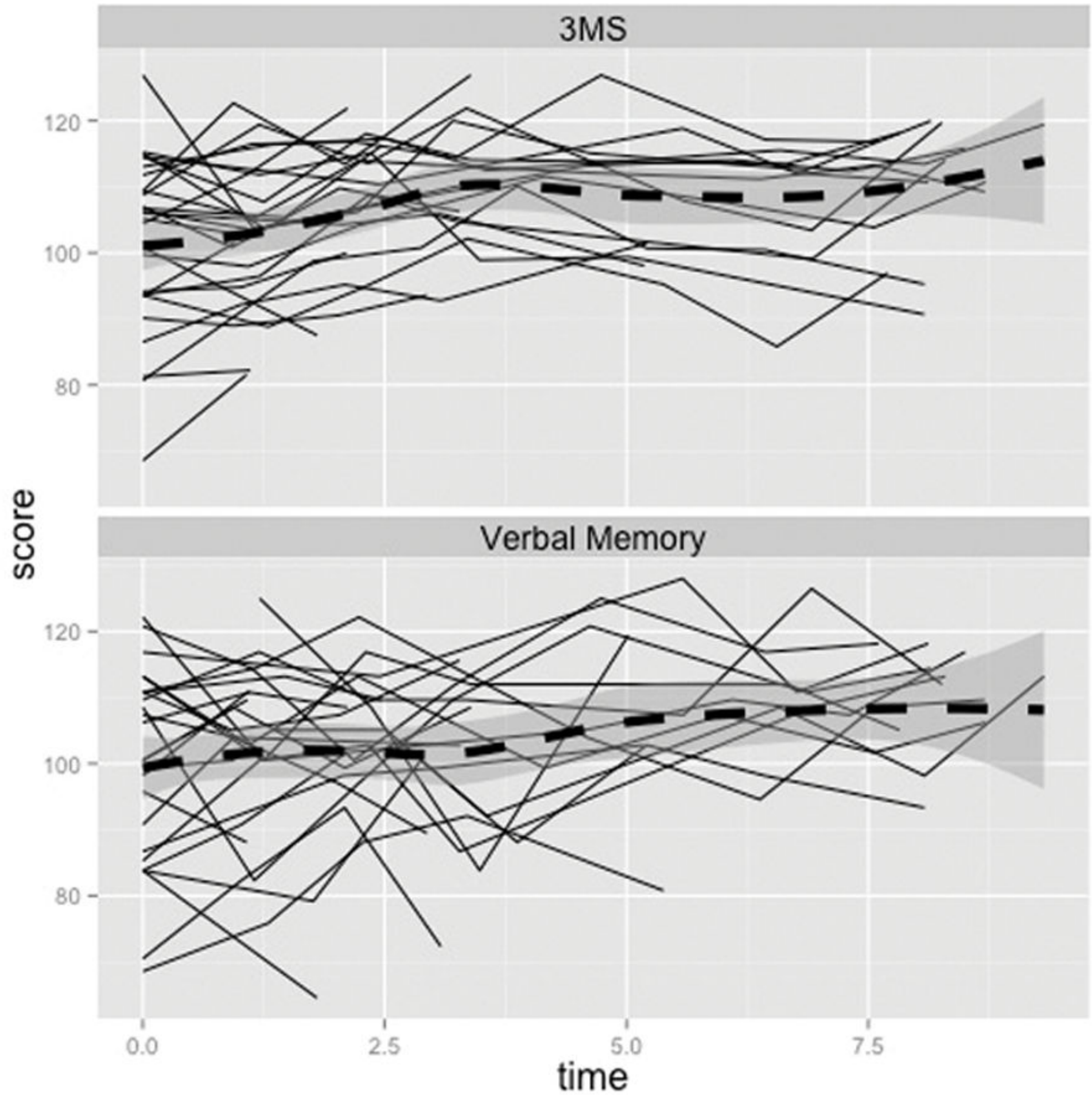

Figure 1.

Trajectories of cognitive outcome measures. Lines show changes in cognitive scores over longitudinal assessments for 30 randomly selected participants. Heavy dashed line shows average trajectory by time.

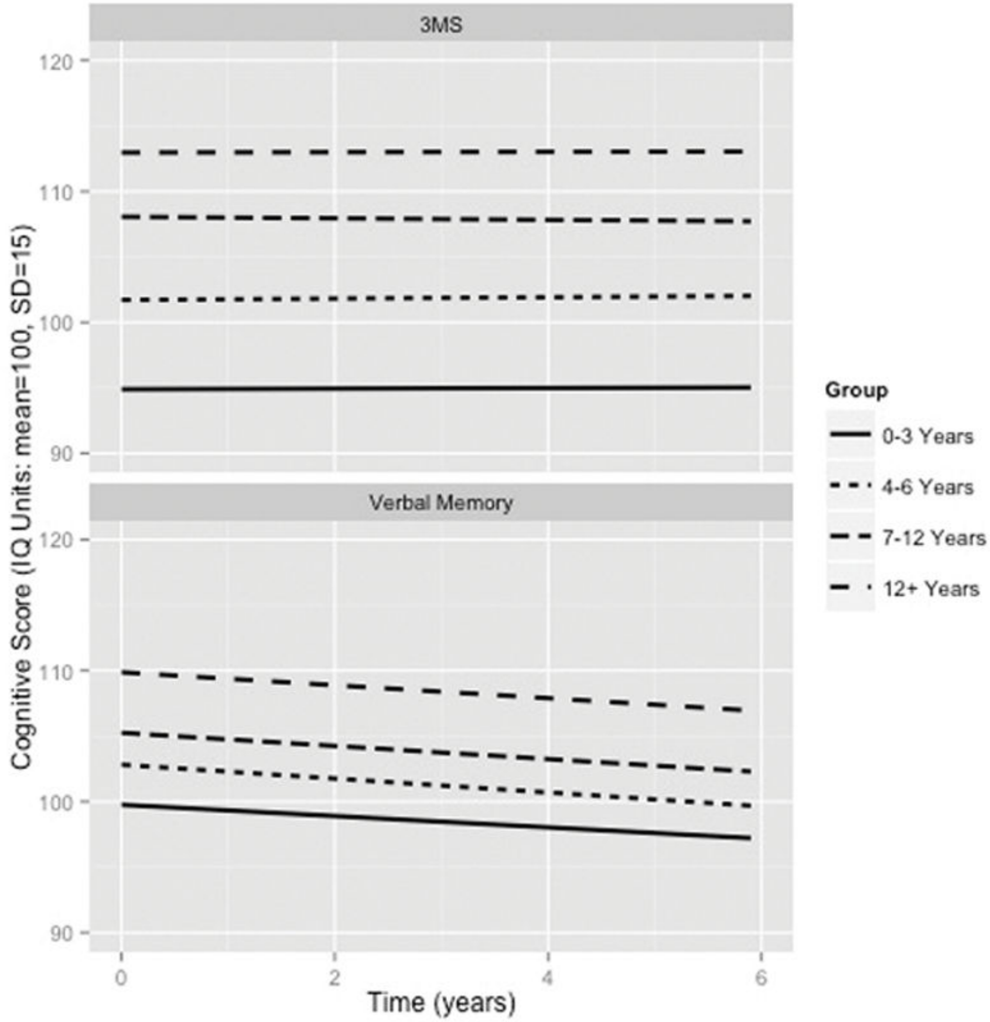

Figure 2.

3MS and VM trajectories by education group. Results show average linear trajectories for categorical education groups of 3MS and VM scores across assessments. Education groups represent quartiles of the distribution of continuous education. There are large average group differences for both variables at the baseline assessment but rates of change do not differ so that baseline differences are maintained across time. Covariates included age, gender, and language of test administration.

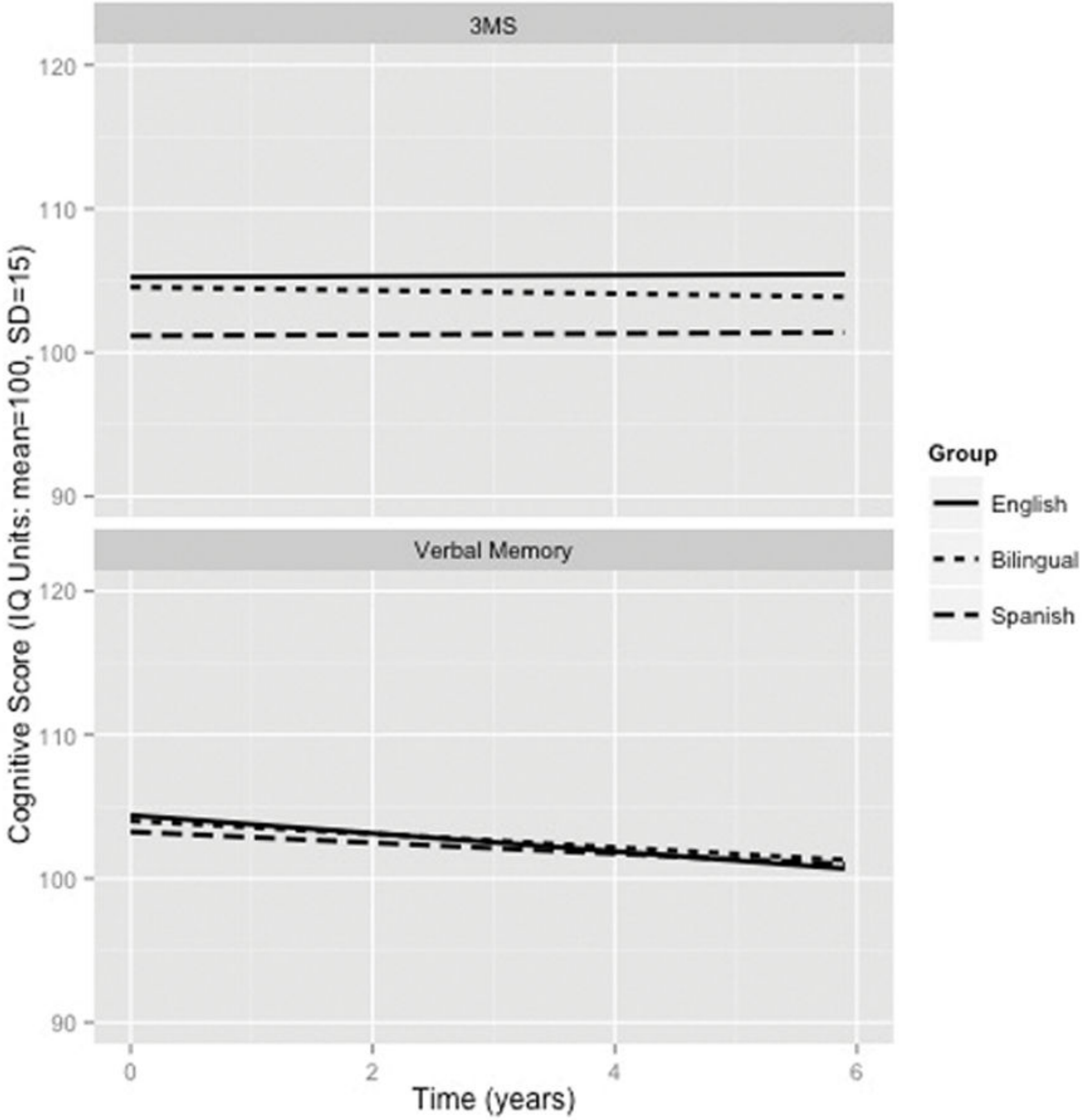

Figure 3.

3MS and VM trajectories by monolingual bilingual status. Results show average linear 3MS and VM trajectories of groups defined by patterns of language usage. Monolingual Spanish uses predominantly Spanish, Monolingual English primarily English, and Bilingual uses both English and Spanish in routine activities. Monolingual Spanish have lower baseline 3MS scores, but rates of change do not differ across groups. VM baseline scores and rate of change do not differ by monolingual bilingual status. Covariates included age, gender, and education (continuous).

Table 1

Sample characteristics by country of birth.

Variable	Born in Mexico	Born in US	p
N	745	754	
Number of evaluations – Mean (S.D.)	5.0 (1.8)	5.3 (1.8)	0.002
Time of follow-up (years) = Mean (S.D.)	6.1 (2.5)	6.2 (2.5)	0.22
Age (years) at baseline – Mean (S.D.)	70.9 (7.3)	69.8 (6.2)	0.002
Education (years) – Mean (S.D.)	5.2 (4.7)	9.8 (4.9)	0.001
Gender - % (N) Female	56 (422)	60 (449)	0.10
Spanish test administration - % (N)	88 (658)	24 (180)	0.001
Monolingual Spanish - % (N)*	76 (546)	11 (82)	0.001
Bilingual - % (N)*	20 (142)	52 (382)	0.001
Monolingual English - % (N)*	4 (31)	37 (276)	0.001
3MS baseline raw score – Mean (S.D.)	82.6 (13.9)	88.7 (10.5)	0.001

*Language status missing for 26 born in Mexico, 14 born in US.

Table 2

Incremental effects of categorical education on cognitive trajectory components in the overall sample (N=1499). Results are from models in which education was entered individually along with covariates age, gender, and language of test administration (covariate effects not shown). Reference values refer to females 70 years of age tested in English with more than 12 years of education. 3MS and VM have a mean of 100 and SD of 15.

Cognitive Trajectory Component	Independent Variable	Estimate	SE	p
3MS Baseline	Average - Reference	112.96	0.22	0.001
3MS Baseline	Education - 0–3 years *	−18.08	0.99	0.001
3MS Baseline	Education - 4–6 years *	−11.26	0.89	0.001
3MS Baseline	Education - 7–12 years *	−4.90	0.70	0.001
3MS Slope	Average - Reference	0.01	0.12	0.907
3MS Slope	Education - 0–3 years *	0.01	0.16	0.952
3MS Slope	Education - 4–6 years *	0.04	0.17	0.818
3MS Slope	Education - 7–12 years *	−0.07	0.13	0.568
VM Baseline	Average - Reference	109.92	0.74	0.001
VM Baseline	Education - 0–3 years *	−10.12	1.04	0.001
VM Baseline	Education - 4–6 years *	−7.06	1.04	0.001
VM Baseline	Education - 7–12 years *	−4.63	0.82	0.001
VM Slope	Average - Reference	−0.50	0.13	0.001
VM Slope	Education - 0–3 years *	−0.06	0.18	0.722
VM Slope	Education - 4–6 years *	−0.03	0.18	0.849
VM Slope	Education - 7–12 years *	−0.01	0.13	0.972

*Difference from reference mean.

Table 3

Incremental effects of monolingual versus bilingual status on cognitive trajectory components in the overall sample (N=1499/). Results are from models in which monolingual –bilingual status was entered along with age, gender, and education as covariates (covariate effects not shown). Reference values refer to females 70 years of age tested in English with 8 years of education who are monolingual English speakers. 3MS and VM have a mean of 100 and SD of 15.

Cognitive Trajectory Component	Independent Variable	Estimate	SE	p
3MS Baseline	Average - Reference	105.23	0.61	0.001
3MS Baseline	Monolingual Spanish Speaker *	−4.08	0.82	0.001
3MS Baseline	Bilingual *	−0.67	0.63	0.289
3MS Slope	Average - Reference	0.04	0.12	0.755
3MS Slope	Monolingual Spanish Speaker *	0.00	0.15	0.981
3MS Slope	Bilingual *	−0.15	0.12	0.213
VM Baseline	Average - Reference	104.46	0.65	0.001
VM Baseline	Monolingual Spanish Speaker *	−1.17	0.90	0.192
VM Baseline	Bilingual *	−0.39	0.73	0.592
VM Slope	Average - Reference	−0.63	0.13	0.001
VM Slope	Monolingual Spanish Speaker *	0.25	0.17	0.135
VM Slope	Bilingual *	0.17	0.13	0.213

*Difference from reference mean.