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The relationship between education level and Mini Mental State Examination domains among older Mexican Americans

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Abstract

To study the effect of education on the performance in the *Mini-Mental State Examination* (MMSE) domains, we included 2,861 Mexican Americans aged 65 and older from the Hispanic Established Populations for Epidemiologic Studies of the Elderly (EPESE) followed from 1993–1994 until 2004–2005. The MMSE was examined as total score (0–30) or divided in two global domains: 1) no-memory (score 0–24): Orientation, attention, and language; and 2) memory (score 0–6): working and delayed memory. Mean age and total MMSE were 72.7 and 24.6 at wave 1, and 81.7 and 20.5 at wave 5. Spanish speaking subjects had lower years of education (4.1 vs. 7.4, p<.0001), they had significantly higher adjusted (by age, education, and gender) mean scores for memory, no-memory and the total MMSE compared with English speaking subjects across the five waves of follow-up. In multivariate longitudinal analyses over 11 years of follow-up, subjects with more years of education performed better than those less educated, especially in no-memory and the total MMSE. Spanish speaking subjects with 4–6 years of education had higher memory scores than those speaking English (estimate 0.40, standard error [SE] = 0.14, p<.001), 7–11 (estimate 0.27, SE= 0.13, p<.01) or 12+ (estimate 0.44, SE= 0.13, p<.001). This suggests that cultural factors and factors related to preferred language use may determine variations in MMSE performance. Since the memory domain of the MMSE is less affected by education, it may be used along with other cognitive tests in older populations with low education.

Keywords

Education; Mini-Mental State Examination; culture; language use; memory; older Hispanics

INTRODUCTION

Previous research suggests that Hispanic and Mexican-American populations consistently score lower on the *Mini-Mental State Examination* (MMSE)[1] compared to non-Hispanic whites.[2] These findings have been explained in part by cognitive and non-cognitive or

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cultural factors.[3] When cultural differences in the MMSE between racial and ethnic groups have been found, education has been the main variable associated with such differences.[4–6] For instance, when the MMSE is used in minority populations (e.g., Hispanic, non-Hispanic Black, Africans or non European-American elders), its sensitivity and specificity are reduced,[7,8] and ethnic differences are nearly always attributed to the prevalence of low education among those populations.[2] Moreover, although age is an important variable when measuring cognitive abilities in healthy older Hispanics, educational level has been demonstrated to affect MMSE scores more than age.[7]

Education is closely related to cultural background, which is another possible reason for low MMSE scores in Hispanics and other minority populations.[9,10] For instance, studies indicate that cognitive assessments are often done using instruments developed and normed for populations of a high educational level or a different culture. Ethnic and racial differences found in MMSE performance may reflect differences in the cultural appropriateness of the items rather than differences in ability.[11] The issues of potential cultural bias or differences in education level are typically addressed by reducing the cut-off scores, withdrawing items or using a different test when studying Hispanic or minority populations.[10,12] Blesa et al.[12] found that adjusting scores for age and education could improve specificity and sensitivity. Others have set different cut-off points for defining who is impaired,[9] used different items to assess domains of cognitive ability, and adapted or developed new tests.[13,14]

The MMSE is a widely used measure to screen for cognitive status and dementia in population and community-based, medical, neurological and even neuropsychological research.[8,15,16] However, using the total score of the MMSE as a predictor of cognitive decline poses certain difficulties as described above. Researchers have reported that the MMSE has high sensitivity and specificity when diagnosing certain types of dementia.[16] Yet, when scores range from 17–30 or even from 25–30,[17] the instrument loses sensitivity. Since formal education affects cognitive performances in the MMSE, persons with low education could potentially be incorrectly identified as at risk for dementia due to their education. Even if education is controlled for, using the total MMSE score to screen for cognitive changes remains questionable in minority populations.[18]

Memory impairment is one of the earliest markers of cognitive decline;[19] therefore, analyzing the memory items may be useful in differentiating between low MMSE scores related to education versus low MMSE score due to cognitive decline or dementia.[20] The purpose of this study was to assess the cross-sectional and longitudinal effect of education on performance of the MMSE by global domains as well as its total score among older Mexican Americans. We hypothesized that the global memory domain of the MMSE would not be highly correlated with education, compared to the global no-memory domain and the total MMSE score overtime.

METHODS

Sample

Data are from the Hispanic Established Populations for Epidemiologic Studies of the Elderly (EPESE), a population-based study of 3,050 non-institutionalized Mexican Americans aged 65 and over residing in five Southwestern states - Texas, California, New Mexico, Colorado, and Arizona. Participants in the Hispanic EPESE were selected using a population-based probability sampling plan based on census data. The sampling plan and data collection procedures are described elsewhere.[21] The present study used the baseline data (1993–1994, n=2861), and the data obtained from the follow-up at 2-years (1995–96, n=2258), 5-years (1998–99, n=1876), 7-years (2000–01, n=1674), and 11-years (2004–05, n=1167), using all subjects with complete MMSE scores. Over the 11-year follow-up, 472 participants refused or were lost to follow-up and 1411 were confirmed dead through the National death Index file and from reports from participants' relatives. The interviews were conducted in Spanish or English, depending on the respondents' preference. The study was approved by the University of Texas Medical Branch Institutional Review Board.

Measures

The outcomes were participants' MMSE[1] total and domains score at baseline and at follow-up. The English and Spanish versions of the MMSE were adopted from the Diagnostic Interview Scale (DIS) and have been used in prior community surveys.[22] The Spanish version was translated from the English version without any modification of the items. Subjects who were excluded due to incomplete MMSE data (n=189) tended to be male, older and illiterate compared to subjects remaining in the sample. Items more commonly missed were back-spelling of "WORLD", writing a full sentence, reading (doing what the paper says: close your eyes), and copying the diagram correctly. MMSE was used as a total score (range 0–30) or divided in the following sub-domains: orientation (score 0–10), working memory (score 0–3), attention (score 0–5), delayed memory (score 0–3), and language (score 0–9) as shown in Table 1. As we describe later, two global domains, memory and no-memory, replaced these initial five sub-domains.

Independent Variables

Socio demographic variables examined were age (years), gender (male, female), preferred language at interview (Spanish or English), and education (years, continuous or categorized as 0, 1–3, 4–6, 7–11, and 12+). We analyzed the education data distribution by histograms and later adapted the education categories from Cagney & Lauderdale.,[23] who used similar education categories across mean standardized scores of the total MMSE with its domains in a multiethnic US population, but because our population has a much lower educational attainment, we excluded higher education categories (13 to 15, 16+). We treated education as a categorical variable for the main analyses to allow for nonlinear (e.g., threshold) effects.

Statistical Analyses

To compare education across MMSE domains and total scores, we standardized the scores (mean=1, standard deviation=1)[23] using PROC STANDARD, a z-score transformation. Thus, a 1-unit change in the transformed score is equal to one standard deviation for each of the MMSE domains or total scales. We plotted the standardized MMSE scores for the five sub-domains of cognitive function (working memory, delayed memory orientation, attention, and language) by education level; this was further stratified by language used at interview (Spanish or English). Since we found that the influence of education on the scores was similar in working and delayed memory, we combined working and delayed memory sub-domains into one global "memory domain" (score 0–6). In addition, since we found that the influence of education on the scores was similar in orientation, attention, and language, we combined the remaining sub-domains (orientation, attention, and language) into another global "no-memory" domain (score 0–24). Figure 1 shows the standardized mean scores for the memory domain, the no-memory domain and the total MMSE by education, stratified by language used at interview. The effect of education on the standardized mean scores for the memory domain was less pronounced that it was in the no-memory domain and the total MMSE, particularly among subjects having ≥ 1 year of education. Subjects who spoke Spanish during the interview tended to have higher standardized mean scores for memory domain, no-memory domain and the total MMSE than those who spoke English. Figure 2 shows that the memory domain is slightly affected by education, while the no-memory domain and the total MMSE are strongly affected by education.

To describe the relationship between MMSE domains or the total MMSE and variables of interest at baseline, Pearson or Spearman correlations were used (Table 1). To describe the study population and the MMSE domains and total MMSE scores across all five waves, we used descriptive statistics (% or means ± SD). To see whether the correlation between memory domain and the no-memory domain varied overtime, we also included Pearson correlations across all five waves (Table 2). To report adjusted mean scores (by age, education, gender, and language at interview) for the memory and no-memory domains and the total MMSE score across all five waves we used cross-sectional ANOVA calculations across either education or language at interview categories (Table 3). We conducted multivariate analyses for each MMSE global domain and the total score as a function of education, adjusted for age, gender, and preferred language at interview (Table 4). We used multivariate general linear mixed models using the MIXED procedure.[24] This longitudinal analytic approach over 11 years of follow-up accounts for unbalanced data (e.g., missing; participants with at least one follow-up contribute to longitudinal calculations), and models the trajectory of cognitive change with the fixed effects (measured at baseline) of age, sex and education along with time-dependent covariates (e.g., language at interview, measured at all five waves). In model 1, we included all variables without interaction terms. In model 2, we included all variables and the interactions we found significant such as time*education (longitudinal effect of education on scores) and education*language at interview (Table 4). All analyses were performed using the SAS System for Windows, version 9.1 (SAS Institute, Inc., Cary, NC), and significance level was set at p<0.05, two-tailed.

RESULTS

Correlations were computed in order to determine the relationship between global domains of the MMSE and education, age, language preference and gender. Table 1 shows that years of education (continuous variable) was highly correlated with no-memory domain (r=0.50), and the total MMSE scores (r=0.48), and only weakly correlated with memory domain scores (r=0.04) scores. Memory was not correlated with the lowest educational categories (0 or 1–3 years) and weakly correlated with the highest educational categories (4–6, 7–11 and 12+). Spanish preference at interview was negatively correlated with no-memory domain (r= −0.13), and the total MMSE scores (r= −0.12). It is important to notice that the relationship between Spanish preference and cognitive scores changed after controlling for education (Table 3). Age was negatively correlated with the global domains and the total MMSE scores. Gender was not associated with global domains or total MMSE score.

At baseline, Spanish spoken subjects had significantly lower years of education (4.1 ± 3.5 vs. 7.4 ± 4.0, p<.0001), and lower unadjusted scores for no-memory domain and total MMSE than English spoken subjects; however, after adjusting for education, Spanish spoken subjects had higher scores than English spoken subjects (Table 3). Illiterate subjects were older compared with those having 12 and more years of education (75.7 ± 7.7 vs. 71.8 ± 5.8, p<.0001). Table 2 shows the study population from wave 1 to wave 5. About four fifths of subjects preferred speaking Spanish at the interviews. The mean years of education remained equal overtime. As expected, scores on the global domains and total MMSE decreased overtime. The correlation between the global domains increased overtime, from 0.36 at wave 1 to 0.77 at wave 5.

Adjusted mean scores for the memory and no-memory domains and the total MMSE score across all five waves are reported in Table 3. Subjects with low education had lower scores than those with more years of education, and Spanish speaking subjects had higher scores than those English speaking in global domains and total MMSE across all waves.

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Finally, multivariate longitudinal analyses were done to establish the effects of education on global domains and the total MMSE in Table 4. In model 1, subjects with more than 12 years of education performed better than those with less than 3 years of education, especially in no-memory and the total MMSE, and subjects who responded in Spaish performed better than those who responded in English. In model 2, subjects with 4–6, 7–11 and 12+ years of education had significant higher longitudinal scores (over 11 years of follow-up) of memory, no-memory and total MMSE compared with those with less than 3 years of education. In addition, Spanish speaking subjects with 4–6 years of education (estimate 0.40, standard error [SE] = 0.14, p<.001) and 7–11 (estimate 0.27, SE= 0.13, p<.01) or 12+ (estimate 0.44, SE= 0.13, p<.001) had higher memory scores than the English speaking counterparts. Also, Spanish speaking subjects with 12+ years of education had higher no-memory and total MMSE scores than the English speaking counterparts (estimate 1.28, SE = 0.47, p<.01; estimate 1.73, SE = 0.56, p<.01, respectively).

DISCUSSION

In this study we assessed the cross-sectional and longitudinal effect of education on performance of the MMSE by global domains as well as its total score among older Mexican Americans. Our findings can be summarized as follows. Although, there was at baseline a low correlation between education and memory domain, along with a lesser or no effect of education on memory domain compared to no-memory domain and total MMSE (Table 1, Figures 1 & 2), multi-wave cross-sectional (Table 3) and longitudinal data (Table 4) showed that education had effect on the scores for memory domain but particularly for the no-memory domain and the total MMSE. On the other hand, preferred language at the interview, where Spanish speaking subjects had better performance than English speaking subjects, showed a consistent cross-sectional and longitudinal influence on the performance of global domains and total MMSE.

Education has been pointed out as a protective factor for cognitive decline in some studies[25,26] but not in others.[27,28] When population-based research compares cognitive outcomes in different cultures, education has also been an important variable,[2] as it was in our study. Particularly interesting in our study was the influence of education on the no-memory domain and the total MMSE. In fact, cognitive measures in Mexican-American population studies that have used the MMSE, report significant differences when comparing years of formal education with non-Hispanic white American samples.[2] In our study, just 10% of the subjects had more than 12 years of formal education. When trying to compare different ethnic groups regarding cognitive function, even if the MMSE is modified, education is a better predictor of memory decline in all subjects regardless of ethnicity.[2] Real differences due to cultural functioning cannot be identified since education is not balanced across such samples.

Language is another important variable to consider in future studies. A large percentage of subjects in our study (78% at baseline) chose to respond to the interview in Spanish. This may be an indicator of the low acculturation level they have despite living in the United States for several years. Indeed, the median number of years was 40 for Spanish spoken and 57 for English spoken subjects at baseline. Nonetheless, there are also subjects who were born in the U.S. but still preferred to respond in Spanish (68% of them). When analyzing results obtained in the MMSE for interviews in both languages, those that responded in English obtained consistently lower scores in all waves and the differences are even larger when level of education is taken into account (Figure 1, Table 3). Subjects that responded in English might have chosen this language because they thought this was expected from them by the interviewer, not necessarily because they were more fluent. Difficulty in understanding the questions asked in English could explain the low scores obtained by some subjects.

To study the role of education on the MMSE across various ethnic groups, some authors have grouped the MMSE by items[29–31] and others[32,33] by domains as were grouped in our study. In addition, previous studies have reported that certain items or domains of the MMSE may be influenced by education differently across ethnic groups or education categories.[34] For example, the items “season of the year”, “state recall” or “serial 7s” performed differently for Latinos or blacks than did for white subjects and for those with different levels of education.[30,31,35] As it was found in our study, spelling “WORLD” backwards has been found to be relatively more difficult for the low educational group and for Latino respondents. [30,31,35] On the other hand, MMSE domains have shown differences on stability and prediction of cognitive or affective outcomes in various studies. For example, among older adults diagnosed with generalized anxiety disorder, poor performance on the MMSE working memory domain was associated with increased baseline anxiety and depression, while baseline performance differences on the MMSE orientation domain predicted symptoms six months after cognitive behavior therapy intervention.[32] Also, the delayed recall domain was capable of predicting Alzheimer disease almost seven years before actual diagnosis, while the orientation domain was capable of predicting Alzheimer’s disease approximately three years before diagnosis.[33] Finally, the MMSE may be used to assess the cognitive stability of cognitive decline in psychiatric disorders because the test-retest reliability of this test is extremely good at different retest short-term and long-term intervals.[1,36,37]

Unlike immediate memory, writing or spatial orientation depend strongly on a subject’s education and occupation.[38] Writing is a skill that cultures with strong oral traditions, such as the Mexican one,[39,40] do not use, even if subjects know how to write and read. A construction worker may be very good at drawing a figure but not writing a sentence, even with little formal education, whereas memory function remains stable in cultures with robust oral based communications since knowledge is transmitted throug memory.[38,41] With this is mind, even in highly-educated subjects, writing could start to decline if computer writing overtakes handwriting.[38,41]

Information processing and knowledge acquisition vary between cultures. While in Europe, formal education and literacy is the rule, in Latin America, a region with strong oral tradition, formal schooling is not the only form of education available.[41,42] Indeed, important components of Latin American culture such as music, dance, songs, poetry, and story telling, myths and legends are transmitted orally across generations.[42] Therefore, memory is an important variable in cultures with oral tradition since knowledge and events have to be recalled and transmitted through language. Verbal communication also constitutes a main tool of cultural interaction in Hispanic populations including proverbs, folktales, jokes, folk prayers and others.[43] Since, culture is a complex multifactorial variable expressed in many forms (e.g., human relationships, lifestyle, beliefs, values, gastronomy),[42] some authors have pointed out the need for different methodologies, both quantitative and qualitative, in studying the role of culture on cognition.[44]

Since memory is a key cognitive domain involved in oral transmission, one can assume that a low score in the memory domain of the MMSE for members of cultures where oral tradition is common and important (i.e. populations of Mexican origin), might be a better and earlier marker of cognitive impairment compared to the total MMSE or even to education. We might then hypothesize that certain culture characteristics such as conversation, oral transmission of episodic memory of the Mexican population may be protective against cognitive decline since such cultural distinctiveness relies mainly in memory.[38,42] In other words, the cognitive procedure behind such processes, memorizing for later oral transmission, determines a specific cognitive profile.

Based on the previous discussion, we need to explore in further studies the memory domain of the MMSE (score 0–6) as an early screening method for cognitive impairment in multicultural populations. Some reports in the literature support this notion. For example, Kuslansky et al.[45] used part of the memory domain of the MMSE and found it to be less valid than the Memory Impairment Screen (MIS)[46] for Alzheimer's disease diagnosis; however, they only used the second part of the memory domain of the MMSE, the delay memory - three-word delay free recall, score 0–3- but no the working memory. Other investigators have found that the MIS,[46] a four-item delayed free- and cued-recall memory impairment test with high sensitivity and specificity for dementia, was not affected by education. In addition, our reports suggest that the memory domain of the MMSE is less dependent on education. This provides a new approach that can be used as a screening test, especially in primary care settings, along with other short cognitive tests like the clock drawing test (CDT).[47,48] Other alternatives we would suggest, with limited dependency on education that evaluate memory and other cognitive areas properly, are the Mini-Cog (a combination of the CDT and a simple 3-item delayed word recall test)[49] or the General Practitioner's Assessment of Cognition (GPCOG)[50] test (comprising a patient cognitive test and questions to an informant). Finally, a promising method for cognitive screening to deal with bias in education on test performance and education reporting is using reading abilities as a measure of educational quality.[51,52]

This study has several limitations. We do not have information about the comparability of education when persons included in our study sample were educated outside the US. This can account for some of the variation observed. Also, language used at the interview is an incomplete measure of acculturation. However, our results have shown that the variation between respondents using English and Spanish are not completely explained by the acculturation status. Our study also has several strengths. Our analyses were longitudinal and of a well studied and representative sample of older Mexican Americans. According to our findings, language at interview had a strong influence on the MMSE performance in this population. We also showed that the memory component of the MMSE plays an important role when analyzing cognitive function among older Mexican Americans.

In conclusion, education has a great influence on performance of the no-memory domain and the total MMSE, but less influence on the memory domain. Since education is still a concern for biased results when using the MMSE, clinicians may consider using the memory domain as a short version of the MMSE for cognitive screening of low educated Hispanic populations along with other short cognitive test such as the CDT. Preferred language at the interview had a longitudinal influence on the performance for global domains, and the total MMSE among older Mexican Americans, independent from education level, age and gender; suggesting that cultural identification has an influence on MMSE performance. Further research is necessary to determine strategies to reduce bias related to educational level in the cognitive assessment of Mexican Americans and other groups with strong oral traditions. Additional research is necessary to determine the best way to investigate cross-cultural data related to cognitive function and decline.

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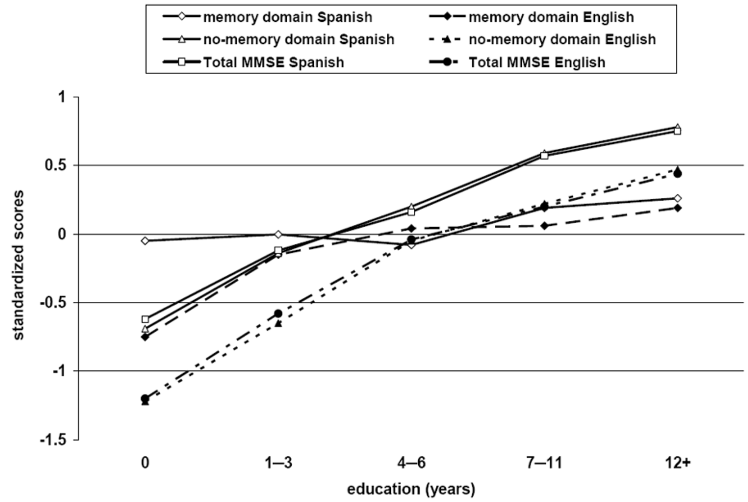

Figure 1.
Standardized mean scores for the memory, no-memory and the total MMSE by education, stratified by preferred language at interview.

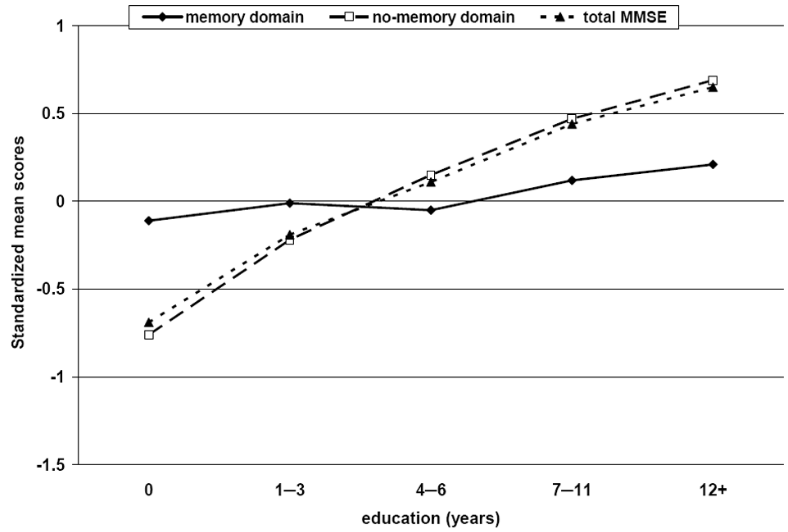

Figure 2.
Standardized mean scores for memory domain, non-memory domain and total MMSE by education.

Table 1

Pearson (r) or Spearman (rho) correlations between MMSE items and domains with education, age or gender, at baseline (Wave 1)

MMSE global domains	Education (years) continuous	Education 0 years	Education 1–3 years	Education 4–6 years	Education 7–11 years	Education 12+ years	Age (years) continuous	Female	Spanish at interview
Memory (score 0–6)	0.04 *	−0.01	0.01	−0.08‡	0.04*	0.08‡	−0.14 ‡	0.01	0.01
No-memory (score 0–24)	0.50‡	−0.37‡	−0.14‡	0.08‡	0.23‡	0.28‡	−0.21‡	−0.03	−0.13‡
Total MMSE (score=0–30)	0.48‡	−0.34‡	−0.13‡	0.06†	0.23‡	0.27‡	−0.23 ‡	−0.02	−0.12 ‡

MMSE=Mini-Mental State Examination (Folstein et al).

[1] P-values

* <0.05

† <0.01

‡ <0.0001

Memory= Sum of three items for working memory (registration of apple, table, penny) (score 0–3), and three items for delay memory (recall of apple, table, penny) (score 0–3)

No-memory= Sum of ten items for orientation (score 0–10), one item for attention (spelling WORLD backwards) (score 0–5), and nine items for language and praxis: naming (watch, pencil), repetition of a phrase, reading (doing what the paper says “close your eyes”), 3-stage command, writing a sentence, and coping a pentagon (score 0–9)

Table 2

Study population from Wave 1 through Wave 5

Variables	Baseline, Wave 1 (n=2,861)	Wave 2 (n=2,258)	Wave 3 (n=1,876)	Wave 4 (n=1,674)	Wave 5 (n=1,167)
Age (years)	72.7 ± 6.5	75.1 ± 6.6	77.2 ± 6.1	78.8 ± 5.6	81.7 ± 5.1
Female gender	58.3	59.0	60.3	62.6	64.1
Spanish speaking at interview	78.0	81.4	72.4	84.6	82.6
Education continuous (years)	4.9 ± 3.9	4.8 ± 3.9	4.9 ± 3.9	4.9 ± 3.9	4.9 ± 3.8
Education categories					
0 years	17.7	18.4	16.3	15.8	15.3
1–3 years	25.5	26.0	26.0	26.2	26.7
4–6 years	30.6	29.4	31.0	30.9	32.1
7–11 years	16.5	16.8	16.9	16.8	16.2
12+ years	9.7	9.4	9.8	10.3	9.7
MMSE domains					
- Memory (0–6)	5.2 ± 1.2	5.2 ± 1.1	4.8 ± 1.4	4.7 ± 1.6	4.4 ± 1.9
- No-memory (0–24)	19.4 ± 4.2	18.3 ± 4.4	17.1 ± 4.8	16.7 ± 5.2	16.1± 7.0
Correlation between memory & no-memory domains	[0.36] [a]	[0.40] [a]	[0.46] [a]	[0.57] [a]	[0.77] [a]
Total MMSE (0–30)	24.6 ± 4.9	23.5 ± 4.9	22.9 ± 5.6	21.6 ± 6.2	20.5 ± 8.6

MMSE=Mini-Mental State Examination. Data are presented as %, mean ± SD, or Pearson correlation [r].

[a] P <.0001

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Table 3

Adjusted means* by education or language at interview categories, Wave 1 through Wave 5

Variables	Baseline, Wave 1 (n=2,861)	Wave 2 (n=2,258)	Wave 3 (n=1, 1,876)	Wave 4 (n=1,674)	Wave 5 (n=1,167)
Memory scores (0–6)					
Education categories					
0 years	5.2 ± 0.1	5.2 ± 0.0	4.8 ± 0.1	4.6 ± 0.1	3.9 ± 0.1
1–3 years	5.2 ± 0.0	5.1 ± 0.0	4.7 ± 0.1	4.5 ± 0.1	4.2 ± 0.1
4–6 years	5.1 ± 0.0	5.1 ± 0.0	4.8 ± 0.0	4.6 ± 0.1	4.4 ± 0.1
7–11 years	5.4 ± 0.1	5.4 ± 0.1	4.9 ± 0.1	4.7 ± 0.1	4.6 ± 0.1
12+ years	5.5 ± 0.1	5.4 ± 0.1	5.0 ± 0.1	5.0 ± 0.1	4.8 ± 0.2
P-values	<.0001	0.0013	0.1439	0.0254	0.0001
Language at interview					
English	5.1 ± 0.0	5.0 ± 0.1	4.6 ± 0.1	4.2 ± 0.1	3.9 ± 0.1
Spanish	5.3 ± 0.0	5.2 ± 0.0	4.8 ± 0.0	4.7 ± 0.0	4.4 ± 0.1
P-values	0.0022	0.0023	0.0035	<.0001	0.0004
No-memory scores (0–24)					
Education categories					
0 years	16.4 ± 0.2	15.7 ± 0.2	15.0 ± 0.2	13.2 ± 0.4	11.9 ± 0.5
1–3 years	18.4 ± 0.1	17.2 ± 0.2	16.9 ± 0.2	14.5 ± 0.3	14.7 ± 0.4
4–6 years	19.9 ± 0.1	18.5 ± 0.1	18.5 ± 0.2	15.9 ± 0.3	16.8 ± 0.3
7–11 years	21.4 ± 0.2	20.2 ± 0.2	19.8 ± 0.2	17.3 ± 0.4	18.7 ± 0.5
12+ years	22.3 ± 0.2	21.5 ± 0.3	21.1 ± 0.3	18.4 ± 0.5	19.7 ± 0.6
P-values	<.0001	<.0001	<.0001	<.0001	0.0002
Language at interview					
English	19.0 ± 0.1	17.7 ± 0.2	15.8 ± 0.2	13.8 ± 0.4	14.4 ± 0.4
Spanish	19.5 ± 0.1	18.3 ± 0.1	17.3 ± 0.1	15.9 ± 0.2	16.4 ± 0.2
P-values	0.0020	0.0086	0.0038	<.0001	<.0001
Total MMSE scores (0–30)					
Education categories					
0 years	21.6 ± 0.2	20.9 ± 0.2	19.8 ± 0.3	17.4 ± 0.4	15.9 ± 0.6
1–3 years	23.6 ± 0.2	22.3 ± 0.2	21.6 ± 0.2	18.7 ± 0.4	18.9 ± 0.4

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Variables	Baseline, Wave 1 (n=2,861)	Wave 2 (n=2,258)	Wave 3 (n=1, 1,876)	Wave 4 (n=1,674)	Wave 5 (n=1,167)
4–6 years	25.1 ± 0.1	23.7 ± 0.2	23.3 ± 0.2	20.3 ± 0.3	21.2 ± 0.4
7–11 years	26.8 ± 0.2	25.6 ± 0.2	24.7 ± 0.3	21.7 ± 0.5	23.4 ± 0.6
12+ years	27.8 ± 0.3	26.9 ± 0.3	26.1 ± 0.4	23.0 ± 0.6	24.5 ± 0.7
P-values	<.0001	<.0001	<.0001	<.0001	0.0001
Language at interview					
English	24.1 ± 0.2	22.8 ± 0.2	20.1 ± 0.2	17.7 ± 0.5	18.3 ± 0.6
Spanish	24.8 ± 0.1	23.6 ± 0.1	21.4 ± 0.1	20.3 ± 0.2	20.8 ± 0.2
P-values	0.0005	0.0043	<.0001	<.0001	<.0001

* Adjusted for age, gender, education, and language at interview. Data are means ± standard error. P-values are testing differences on adjusted means of memory and no-memory domains and total MMSE across education or language at interview categories at each wave. MMSE=Mini-Mental State Examination.

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Table 4

Multivariate longitudinal analyses (Mixed models) of scores for memory and no-memory domains and total MMSE as a function of education, language at interview and other demographics, from Wave 1 through Wave 5

	Memory (score 0–6)		**No-memory (score 0–24)**		**Total MMSE (score 0–30)**	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Predictor variable	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	8.62 (0.21) [a]	8.41 (0.23) [a]	28.76 (0.76) [a]	28.39 (0.83) [a]	37.20 (0.90) [a]	36.62 (0.97) [a]
Time (years)	−0.11 (0.00) [a]	−0.08 (0.01) [a]	−0.50 (0.01) [a]	−0.60 (0.04) [a]	−0.65 (0.02) [a]	−0.77 (0.04) [a]
Age (years)	−0.05 (0.00) [a]	−0.05 (0.00) [a]	−0.17 (0.00) [a]	−0.17 (0.01) [a]	−0.22 (0.01) [a]	−0.22 (0.01) [a]
Female gender (vs. male)	0.08 (0.03) [d]	0.08 (0.03) [d]	0.01 (0.13)	0.01 (0.13)	0.06 (0.15)	0.06 (0.15)
Education categories						
0 years	0.00	0.00	0.00	0.00	0.00	0.00
1–3 years	−0.05 (0.05)	0.16 (0.14)	1.72 (0.19) [a]	1.70 (0.46) [b]	1.67 (0.23) [a]	1.85 (0.55) [b]
4–6 years	0.01 (0.05)	0.29 (0.13) [d]	3.23 (0.19) [a]	3.76 (0.43) [a]	3.21 (0.22) [a]	4.04 (0.51) [a]
7–11 years	0.23 (0.06) [b]	0.39 (0.13) [c]	4.75 (0.22) [a]	5.07 (0.43) [a]	4.95 (0.26) [a]	5.42 (0.51) [a]
12+ years	0.32 (0.07) [a]	0.55 (0.11) [a]	5.82 (0.26) [a]	6.46 (0.45) [a]	6.13 (0.30) [a]	7.02 (0.54) [a]
Education categories*time						
0 years*time		0.00		0.00		0.00
1–3 years*time		0.02 (0.01)		0.09 (0.04)		0.11 (0.06)
4–6 years*time		0.06 (0.01) [a]		0.12 (0.04) [c]		0.18 (0.05) [c]
7–11 years*time		0.05 (0.01) [c]		0.12 (0.05) [d]		0.17 (0.06) [c]
12+ years*time		0.06 (0.02) [b]		0.16 (0.06) [c]		0.23 (0.07) [c]
Spanish (vs. English)	0.19 (0.04) [a]	0.51 (0.11) [a]	0.49 (0.12) [a]	1.07 (0.36) [a]	0.65 (0.14) [a]	1.52 (0.43) [b]
Spanish*education categories						
Spanish & 0 yr (vs. English & 0 yr)		0.00		0.00		0.00
Spanish & 1–3 yr (vs. English & 1–3 yr)		0.27 (0.14)		0.12 (0.46)		0.36 (0.54)
Spanish & 4–6 yr (vs. English & 4–6 yr)		0.44 (0.13) [b]		0.82 (0.43)		1.24 (0.50) [d]
Spanish & 7–11 yr (vs. English & 7–11 yr)		0.27 (0.13) [d]		0.56 (0.44)		0.75 (0.52)

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	Memory (score 0–6)		No-memory (score 0–24)		Total MMSE (score 0–30)	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Spanish & 12+ yr (vs. English & 12+ yr)		0.40 (0.14) [b]		1.28 (0.47) [c]		1.73 (0.56) [c]

MMSE=Mini-Mental State Examination. Variable time is testing the slope of decline on memory, no-memory and the Total MMSE scores over time. The term for the interaction between level of education and time represents the longitudinal effect of the baseline measure of level of education on the annual rate of decline in performance of the memory, no-memory and the Total MMSE scores. Estimate= estimate change in memory, no-memory or the Total MMSE scores; SE=standard error.

[a] $P < .0001$

[b] $P < .001$

[c] $P < .01$

[d] $P < .05$