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Demographic Predictors of Cognitive Change in Ethnically Diverse Older Persons

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Abstract

The purpose of this study was to evaluate how demographic variables relate to cognitive change and address whether cross-sectional demographic effects on cognitive tests are mirrored in differences in longitudinal trajectories of cognitive decline. We hypothesized that race and ethnicity, education, and language of test administration would relate to cross-sectional status and that the rate of cognitive decline would differ among African Americans, Hispanics, and Caucasians, across levels of educational attainment, and according to linguistic background. Participants were 404 educationally, ethnically, and cognitively diverse older adults enrolled in an ongoing longitudinal study of cognition. Mixed-effects regression analysis was used to measure baseline status and longitudinal change in episodic memory, executive functioning, and semantic memory. Results showed that ethnicity and education were strongly associated with baseline scores, but were, at most, weakly associated with change in cognition over time after accounting for confounding variables. There was evidence that the episodic-memory scores of Spanish-speaking Hispanic participants with limited education underestimated their true abilities in the initial evaluation, which may reflect lack of familiarity with the testing environment. These results —consistent with other reports in the literature—suggest that cross-sectional effects of

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demographic variables on cognitive-test scores result from differences in life experiences that directly influence test performance and do not indicate greater disease effects on cognition in minorities and those with limited education.

Keywords

cognitive change; African Americans; Hispanics; ethnic differences; dementia

As the minority population continues to grow in the United States, studies of diverse populations are imperative for the field of aging research. Current figures estimate that minorities represent one third of the United States population and will grow by 2050 to represent the majority of the United States' population (U.S. Census Bureau, 2008). Cognitive decline in older persons is a major public-health problem. Coupled with the rapid increases in demographic diversity, this underlies a pressing need to understand cognitive decline in diverse groups.

Research has documented great heterogeneity in cognitive trajectories among older individuals (Mungas et al., 2010; Hayden et al., 2011), including members of diverse communities (Glymour & Manly, 2008). A number of reports suggest that minority populations and those with limited educational experience are at a greater risk for dementia (Chin, Negash, & Hamilton, 2011; Tang et al., 2001; Evans et al., 1997). Development of dementia is a gradual process, so these findings suggest that education and race/ethnicity might influence the rate of cognitive decline preceding dementia and associated disability. Studies of trajectories of continuous measures of cognition across the full range of cognitive function are particularly relevant to the question of how demographic differences might contribute to cognitive decline because they allow for sensitive characterization of trajectories in normal individuals, as well as in individuals who are declining due to diseases of aging like Alzheimer's disease.

A substantial body of literature has shown that test scores from a single, cross-sectional cognitive evaluation are strongly associated with race/ethnicity (Manly et al., 1998; Sloan & Wang, 2005; Zsembik & Peek, 2001; Schwartz et al., 2004) and education (Manly, Byrd, Touradji, & Stern, 2004; Mungas, Reed, Marshall, & González, 2000; Mungas, Reed, Haan, & Gonzalez, 2005; Masel & Peek, 2009; Alley, Suthers, & Crimmins, 2007). Alternate interpretations of cross-sectional associations of race/ethnicity and education with cognition have important implications for understanding cognitive decline in older persons. Such associations might reflect health disparities in minorities and those with less education, resulting in higher rates of disease, and consequently, cognitive impairment. In contrast, nondisease factors might also influence test scores, for example, life experiences that build knowledge bases, cognitive skills, and familiarity with cognitive testing (Glymour & Manly, 2008).

Measurement artifacts might also contribute to cross-sectional differences. A significant literature suggests that test retaking or practice effects can impact test performance, and these outcomes have been found to differ by race/ethnicity (Reeve & Lam, 2007; Schleicher, Van Iddekinge, Morgeson, & Campion, 2010; Van Iddekinge, Morgeson, Schleicher, & Campion, 2011). In a study of older persons, Karlamangla et al. (2009) found that individuals with low education (<8 years) showed greater improvement from initial to second assessment, suggesting that scores from the initial time of testing underestimated true ability levels. Measurement bias, addressed in studies of differential item functioning (DIF; Pedraza & Mungas, 2008; Gibbons et al., 2011), also may contribute to education and race/ethnicity differences in cognitive-test outcomes.

Longitudinal studies have important implications for understanding cross-sectional differences and for critically testing alternative explanations of these differences. For example, if cross-sectional differences are due to differential onset and progression of diseases of aging in persons from ethnic minorities or lower education levels, one would expect greater decline in test scores over time for these groups. Under this scenario, race/ethnicity and education effects on longitudinal declines would mimic, at least to some degree, cross-sectional differences associated with these factors, and one would expect that baseline differences would be amplified over time. Alternatively, differential cognitive decline would be less likely if factors that account for cross-sectional race/ethnicity and education differences on test scores are not related to disease processes. That is, if life experiences that help build cognitive knowledge structures and skills underlie race/ ethnic and educational differences on cognitive tests, these differences would be exhibited at each time of measurement for middle-aged and older persons in disadvantaged groups. In this case, we would expect to see consistent race/ethnic and education effects at each time of measurement, and therefore negligible differential race/ethnic or education effects on longitudinal outcomes. Longitudinal studies also help to sort out methodological contributions to cross-sectional differences. Differential practice effects can be directly modeled in longitudinal studies (Karlamangla et al., 2009), and DIF presumably would affect all evaluations in a similar manner, and consequently, would not introduce bias in terms of estimating rate of change.

Studies examining trajectories of continuous measures of cognition in different racial/ethnic groups composed of individuals representing the full range of cognitive function from normal cognition to dementia are particularly relevant to understanding variables that influence cognitive outcomes in older populations. A number of studies have addressed the question of race/ethnicity effects on cognitive decline. Several have been based on the Study of Assets and Health Dynamics Among the Oldest Old (AHEAD). This is a nationally representative panel survey of older adults, with oversampling of minority ethnic groups and five waves of assessment between 1993 and 2002. More than 7,000 individuals were enrolled in this study, and more than 2,300 completed five assessments. A brief telephone-based assessment of cognitive function was used that included items measuring mental status, verbal learning, and memory, as well as questions that assessed working memory and general knowledge. Results consistently showed robust cross-sectional differences, such that African Americans and Hispanics had lower cognitive-test scores than Caucasians (Sloan & Wang, 2005; Karlamangla et al., 2009; Wolinsky et al., 2011). Race/ethnicity differences in cognitive decline, however, varied both within and across these studies. Karlamangla et al. applied mixed-effects modeling to characterize longitudinal change across the five assessment waves and reported that African Americans showed slower decline on average in global cognition than Caucasians, whereas Hispanics and Caucasians did not differ in rate of decline. Sloan and Wang (2005) showed that both African Americans and Hispanics had better cognitive outcomes than Caucasians across four assessments. Wolinsky et al. (2011) utilized only the first and last assessments in AHEAD data; in analyses of simple change scores, Caucasians showed declines that were equal to or greater than African Americans and Hispanics, but in analyses in which scores from the last assessment were the outcome and first assessment scores were entered as a covariate, Caucasians had better outcomes. We note that researchers (e.g., Glymour, Weuve, Berkman, Kawachi, & Robins, 2005) have argued that adjusting for baseline test scores in this manner introduces a bias toward overestimating the effect of a demographic variable on cognitive change.

Masel and Peek (2009), in a related study based on the Health and Retirement Study (HRS), a successor to AHEAD that shared methodology and data, extended the entry age of participants downward to age 51, again found strong baseline differences associated with race/ethnicity, and found mixed results with continuous measures, such that African

Americans declined more rapidly than Caucasians on a continuous measure of memory and Hispanics declined more rapidly on a mental-status measure. When the outcome was a decline greater than one standard deviation from first to last evaluation, however, there were no differences among these three ethnic groups. Using data from the Chicago Health and Aging Project (CHAP), a longitudinal cohort study, Wilson et al. (2010) found that, over the course of 11 years, the annual rate of decline on a factor-based composite measure of global cognition did not differ for African American and Caucasian individuals diagnosed as cognitively normal, mildly cognitively impaired, or having dementia.

These studies collectively show inconsistent results in terms of which groups declined more. Minority groups declined more in some studies (and analyses), but Caucasians declined more in others. This is even more noteworthy when one considers that several of these studies were secondary analyses of the same parent study, and that different results were obtained from different analyses within the same publication. All of these studies used population-based samples, had relatively large sample sizes, and consequently were able to detect relatively small effect sizes. In general, effect sizes for significant group differences in rate of decline were quite small, and effect sizes for baseline differences were large. For example, in Masel and Peek (2009), the effect size for memory decline in African Americans (compared with Caucasians) was less than −0.01 (−.03/3.39), whereas the cross-sectional effect size for this comparison was .08 (−0.26/3.39). Rate of decline was generally larger, as would be expected, when younger individuals (51–70) were not included. In Karlamangla et al. (2009) for example, cross-sectional scores were about 25% lower than Caucasians for Hispanics and about 50% lower for African Americans, but the only significant difference in rate of change favored African Americans. Another relevant consideration is that the cognitive assessment in the AHEAD and HRS studies was a brief telephone assessment, and this may present an important limitation. Although cognitive assessment in the CHAP study was more comprehensive, the outcome measure nevertheless assessed global cognition, and none of these studies evaluated domain-specific cognitive outcomes.

Research examining the association of education to the progression of cognitive impairment over time has been similarly mixed. Some studies have shown that higher levels of education slow cognitive decline in older adults (Bosma et al., 2003; Butler, Ashford, & Snowdon, 1996; Lyketsos, Chen, & Anthony, 1999). Other studies have shown that individuals with higher levels of education perform better on cognitive tests compared with less educated individuals of similar age, but decline cognitively at a similar rate (Glymour et al., 2005; Karlamangla et al., 2009; Tucker-Drob, Johnson, & Jones, 2009; Zahodne et al., 2011; Wilson et al., 2009). Given that higher education has been associated with decreased risk for dementia in a number of studies (Evans et al., 1997; Gatz et al., 2001; Räihä, Kaprio, Koskenvuo, Rajala, & Sourander, 1998), further studies to clarify education effects on continuous measures of cognitive change are important.

The purpose of the current study was to evaluate how ethnicity and educational attainment relate to cognitive trajectories in a diverse sample of older persons. Linguistic background also was of central interest, given its direct relevance to the growing population of non-English-speaking and bilingual older persons and specifically, to the growing populations of Spanish-speaking Hispanics. We hypothesized that race/ethnicity, education, and language background would relate to cross-sectional test scores, consistent with previous literature, but we were particularly interested in how these variables would be associated with longitudinal change. Thus, we tested our primary hypotheses: Rate of cognitive decline would differ among African Americans, Hispanics, and Caucasians, across levels of educational attainment, and according to linguistic background. This study was unique in that we used an ethnically, linguistically, and educationally diverse longitudinal sample of

older persons from three major racial/ethnic groups—African Americans, Hispanics, and Caucasians—to examine trajectories of cognitive change. Our sample included an unusually broad range of education, from no formal schooling to doctoral degrees, with broad educational diversity within each of the three racial/ethnic groups. Our sample was diverse not only in terms of the demographic variables of interest, but also in cognitive status across the full spectrum, i.e., from normal function to dementia and presumably, in the prevalence and degree of age-related diseases causing cognitive impairment. An important strength of our study was the use of psychometrically sophisticated, longitudinal cognitive-outcome measures that have been developed and validated for cross-cultural and multilingual use (Mungas, Reed, Crane, Haan, & González, 2004; Mungas, Reed, Haan, & González, 2005; Mungas, Reed, Farias, & DeCarli, 2005; Mungas, Widaman, Reed, & Farias, 2011), and this enabled sensitive tracking of change in three important cognitive domains using psychometrically matched measures of episodic memory, semantic memory, and executive function.

Method

Participants

This study included 404 participants in an ongoing longitudinal study of cognition in an educationally and ethnically diverse sample of older adults. These individuals were evaluated and followed within the research program of the University of California, Davis Alzheimer's Disease Center (UCD ADC). All participants had at least two evaluations, but a rolling enrollment design was used and consequently, the number of evaluations varied. Participants were recruited into the study through two routes: (a) Community outreach and (b) memory-clinic referrals. Approximately 67% of participants were recruited through community-based recruitment protocols designed to enhance both the racial and ethnic diversity and the spectrum of cognitive dysfunction of the sample, with an emphasis on normal cognition and mild cognitive impairment (MCI). Recruiters utilized various outreach methods, such as soliciting in a community-hospital lobby, administering a community survey, exhibiting at health fairs, or through word of mouth. Community-recruitment methods have been previously described (Hinton et al., 2010). The other 33% of the sample initially sought a clinical evaluation at the UCD ADC and subsequently were recruited for this study. These individuals predominantly had a clinical diagnosis of MCI. The overall sample included 116 African Americans, 104 Hispanics, and 184 Caucasians.

Regardless of recruitment source, inclusion criteria were age greater than 60 years and ability to speak English or Spanish. Exclusion criteria included unstable major medical illness, major primary psychiatric disorder (history of schizophrenia, bipolar disorder, or recurrent major depression), and substance abuse or dependence in the last five years. All participants signed informed consent, and all human subject involvement was overseen by institutional review boards at University of California, Davis, the Department of Veterans Affairs Northern California Health Care System, and San Joaquin General Hospital in Stockton, California.

Sample characteristics are presented in Table 1. Overall, the percentage of women in the African American sample (71.6%) was higher than in the other two groups. Hispanics had the lowest mean years of education, with 8.9 years and Caucasians had the highest mean years of education, with 14.7 years. More than half of the Hispanic population (54%) took their cognitive tests in Spanish. The average follow-up time for each ethnic group was similar across groups, as was the average number of evaluations for each individual.

Measures

Clinical evaluations—All participants received multidisciplinary diagnostic evaluations through the UCD ADC at baseline and at approximately annual intervals following the baseline evaluation. Baseline and follow-up evaluations followed the same protocol and included a detailed medical history and a physical and neurological exam. A physician fluent in Spanish examined subjects who spoke only Spanish. Family members or other informants with close contact with participants were interviewed to obtain information about levels of independent functioning for their corresponding participants. Information about change in the identified participant's cognitive and functional status prior to each evaluation was an important component of the clinical history and was assessed by independent interviews with the participant and the informant. Clinical neuropsychological evaluation using standard neuropsychological tests was performed at baseline and at each follow-up. These clinical tests are distinct from the outcome measures used in analyses examining longitudinal trajectories. Routine dementia work-up laboratory tests were obtained at the baseline evaluation for all participants and when clinically indicated at the time of follow-up evaluations. Diagnosis of cognitive syndrome (normal, MCI, dementia) and, for individuals with dementia, identification of underlying etiology, were made according to standardized criteria and methods. Clinical methods including diagnosis have been described in more detail previously (DeCarli et al., 2008).

Cognitive-outcome measures—The primary cognitive-outcome measures in this study were from the Spanish and English Neuropsychological Assessment Scales (SENAS). These measures were administered at all evaluations. The SENAS has undergone extensive development as a battery of cognitive tests relevant to diseases of aging (Mungas et al., 2004; Mungas, Reed, Farias, & DeCarli, 2005; Mungas et al., 2000; Mungas, Reed, Haan, & González, 2005). Modern psychometric methods based on item response theory were used to create psychometrically matched measures across different scales and across English and Spanish versions. This study used a subset of SENAS tests to measure three cognitive domains: episodic memory, semantic memory, and executive function. Episodic memory is a composite score derived from a multitrial word-list-learning test (Word List Learning 1, (Mungas et al., 2004). Semantic memory is a composite of highly correlated verbal (object-naming) and nonverbal (picture-association) tasks. Executive function is a composite measure constructed from component tasks of category fluency, phonemic (letter) fluency, and working memory (digit-span backward, visual-span backward, list sorting). Measure development and psychometric characteristics have been reported in previous publications (Crane et al., 2008; Mungas et al., 2004; Mungas, Reed, Haan et al., 2005).

Three alternate forms of the word-list-learning task were used for the episodic-memory measure. These forms were alternated in the longitudinal evaluations to control for practice effects. Form 1 was administered for the baseline evaluation, Form 2 for the second assessment, Form 3 for the third, and then the same sequence was repeated for subsequent evaluations. Forms were matched in terms of list structure, but the use of different forms in a longitudinal study raises questions about equivalence of forms, and consequently, form effects were evaluated in subsequent analyses.

Apolipoprotein E (ApoE) genotype—ApoE genotyping was carried out using the LightCycler ApoE mutation detection kit (Roche Diagnostics, Indianapolis, IN). Briefly, genomic DNA extracted from ethylenediaminetetraacetic acid (EDTA) blood is amplified by polymerase chain reaction. The 265 base pair product is hybridized with dual color probes specific for the detection of the mutations at Codons 112 and 158 of the human ApoE gene. Melt-curve analysis allows unambiguous genotyping of the six ApoE alleles.

Data Analysis

Mixed-model, random-effects regression analyses were used to estimate longitudinal trajectories of cognitive-outcome measures and to evaluate effects of the primary demographic variables of interest on cognitive trajectories, independent of relevant covariates. Mixed-effects models for longitudinal data provide estimates of predicted baseline level and rate of change in the outcome, and estimated effects (fixed effects) of the association between baseline level, rate of change, and predictors such as ethnicity that differ between subjects, and those such as word-list form that may vary from visit to visit within subjects. These models included random effects to quantify the between-person variation resulting from a person's tendency to be above or below the mean at baseline (random intercept) or to change more or less (random slope) than predicted by their characteristics included in the model. Mixed-effects models also allow for different frequency of assessments and different lags between assessments across persons.

The longitudinal cognitive measures of episodic memory, semantic memory, and executive function were the primary outcomes. The primary demographic independent variables included race/ethnicity (African American, Hispanic, Caucasian), language of test administration (English, Spanish), and years of formal education, and we also examined effects of gender and age at baseline evaluation. Covariates included clinical diagnosis at baseline evaluation (normal, MCI, dementia), ApoE genotype (ε4 positive, ε4 negative), and recruitment source (community vs. clinic). Previous studies from our group have shown that individuals recruited into our longitudinal cohort from clinics decline at a much faster rate than those recruited from the community (Farias, Mungas, Reed, Harvey, & DeCarli, 2009; Carmichael et al., 2012; Mungas et al., 2010), making this a potentially important confounding variable to include in explanatory models. Finally, we also included practice and form effects as covariates. Previous studies have shown practice effects for continuous cognitive outcomes (Ferrer, Salthouse, McArdle, Stewart, & Schwartz, 2005; Ferrer, Salthouse, Stewart, & Schwartz, 2004; Wilson et al., 2006), including an earlier study from our group based on this same longitudinal cohort (Mungas et al., 2010). Our earlier study showed significant effects on the episodic-memory measure related to word-list form, and therefore we explicitly modeled form effects.

We performed a planned sequence of analyses to incrementally explain variability in the estimated baseline score and rate of change of the three cognitive-outcome measures. For each of the three outcome measures, this involved a series of four mixed-effects models. Table 2 shows the sequence of analyses. We began with a baseline model (Model 1) focused on methodological effects (i.e., word-list form and practice effects) that previously have been shown to impact cognitive trajectories (Mungas et al., 2010). We also included language of test administration in this model because language is an additional major methodological and substantive factor, which might conceivably impact trajectories on its own and in conjunction with form and practice effects. Practice was coded, following Mungas et al., (2010) as previous test administration versus no previous administration and was modeled as a time-varying independent variable (0 for the initial evaluation, 1 for all subsequent evaluations). Word-list form effects were evaluated by including time-varying independent variables that coded for the form administered at each evaluation. We also included language of test administration and terms to account for interaction effects of Language × Practice and Language × Word-List Form. In Model 2, we added race/ethnicity to the core model to estimate its effects, conditional on the effects included in Model 1. We added education, gender, and age in Model 3, to address the question of the degree to which education might account for observed differences across race/ethnicity. Our final model further checked for possible confounds by recruitment source, baseline clinical diagnosis, and ApoE genotype.

We modeled effects of time in years from the baseline evaluation. Continuous independent variables of age and education were centered at 70 and 12 years, respectively. Categorical independent variables were dummy coded such that no previous evaluation, word-list learning form, English language administration, Caucasian race/ethnicity, female gender, community recruitment source, normal clinical diagnosis, and ε4 negative ApoE genotype were reference values.

Mixed-model regression analyses are sensitive to assumptions of linearity, normality, and constant variance. These assumptions were examined using graphical and statistical diagnostics. Residuals and random effects were examined to assure that they were normally distributed, and plots of residuals against predicted values and effects were examined to verify that nonlinear trends in the data or nonconstant variances were not present. Additional diagnostics included evaluation of variance components related to random effects and within-subject error variance to address adequacy of statistical estimation procedures associated with the random-effects modeling. Analyses were performed using the SAS "PROC MIXED" function and an unstructured covariance matrix for random effects was specified.

Results

Model 1: Methodology Effects

We performed a planned sequence of four models, with each model building upon the previous model. Model 1 evaluated effects of previous evaluation, language of test administration, and word-list form for the episodic-memory test. Estimated baseline scores were significantly lower in individuals tested in Spanish for all three outcomes (i.e., episodic memory: differences in baseline cognitive-test scores between Spanish and English test administration, $b = -0.56$, $SE = 0.13$; executive function: $b = -0.55$, $SE = 0.10$; semantic memory: $b = -1.29$, $SE = 0.11$), but language of administration was not associated with rate of change for any measure (all ps > 0.28). A significant main effect of previous evaluation was found for semantic memory ($b = 0.06$, $SE = 0.03$), and a significant interaction of language by previous evaluation was found for episodic memory ($p < .005$). Episodic-memory scores for individuals tested in Spanish were higher, on average, for follow-up evaluations than for initial evaluations (estimated difference = 0.27, $SE = 0.11$), but this effect was not observed for those tested in English (estimated difference = −0.06, $SE = 0.04$). No other significant effects related to previous administration or the Previous Administration × Spanish Interaction were found. Word-List Form 1 in episodic memory was associated with higher scores than Forms 2 and 3 (ps < 0.001), as in the previous study (Mungas et al., 2010), but the Spanish × List Form interactions were not significant (ps > 0.09). In summary, Spanish administration was associated with lower baseline scores for all three outcomes, semantic memory was slightly better for follow-up evaluations, and episodic memory was clearly better at follow-up evaluations for Spanish examinees, but not for those tested in English.

Model 2: Race/Ethnicity Differences

Table 3 shows effects of language, race/ethnicity, and education on baseline scores for all four models, and Table 4 shows the same results for longitudinal change in the cognitive scores. Model 2 included ethnicity in addition to the variables tested in Model 1. Ethnicity had a large effect on cognitive scores at baseline that is readily apparent in the Model 2 results in Table 3. African Americans and Hispanics displayed lower semantic-memory scores (difference in reference to Caucasians, $b = -0.69$, $SE = 0.08$; $b = -0.50$, $SE = 0.11$, respectively) and lower executive-function scores ($b = -0.30$, $SE = 0.08$, $b = -0.32$, $SE = 0.11$, respectively), compared with their Caucasian counterparts. Ethnicity had a small and

nonsignificant effect on episodic memory at baseline. In contrast to these baseline results for Model 2, African Americans and Hispanics did not decline more on cognitive tests over time than Caucasians. Indeed, Table 4 (Model 2) shows that minorities showed significantly slower declines than Caucasians on all three cognitive outcomes.

Figures 1–3 provide plots of estimated annual change from Models 2–4 for each ethnic group and each cognitive outcome. Model 2 results in Figures 1–3 show that the Caucasians, on average, declined significantly on all three measures. Considering first episodic memory, Hispanics showed significantly less decline than Caucasians (Table 4; $b = 0.10$, $SE = 0.03$), and average rate of change for Hispanics was not significantly different from zero (see Figure 1); annual change for episodic memory for African Americans was significantly less than zero (see Figure 1), and differed significantly from change shown by Caucasians (Table 4; $b = 0.06$, $SE = 0.02$). For semantic memory, both African Americans and Hispanics declined significantly on average over time (see Figure 2), but declined significantly less than Caucasians (Table 4; African Americans: $b = 0.10$, $SE = .02$, Hispanics: $b = 0.08$, $SE = 0.02$); this pattern of results was mirrored in the outcomes for executive function (see Figure 3).

Model 3: Education, Gender, and Age

The overall estimates and significance levels for language and ethnicity remained relatively unchanged with the addition of education, age, and gender in Model 3. Education was associated with higher baseline cognitive-test scores for episodic memory ($b = 0.04$, $SE = 0.01$), semantic memory ($b = 0.05$, $SE = 0.01$,), and executive function ($b = 0.06$, $SE = 0.01$,), but education had no significant impact on annual cognitive change for any of the three outcome measures (Table 4, Model 3).

Model 4: Additional Checks for Confounding Variables

The three ethnicity/language groups differed significantly with respect to recruitment source and baseline clinical diagnosis. Model 4 controlled for these effects and additionally controlled for ApoE genotype. Results for Model 4 in Table 3 show that language, ethnicity, and education had relatively robust effects on cognitive baseline scores that were not substantially altered when controlling for additional variables. In contrast, the significant ethnic group differences that were present in Model 2 diminished substantially when covariates were added in subsequent models as shown in Table 4. Table 5 shows effects of all independent variables included in Model 4 and illustrates this point. Thus, although language of test administration, ethnicity, and education were associated with differences in baseline cognitive scores, these variables did not predict change in cognitive-test scores over time. This is particularly noteworthy in the case of ethnicity. Figures 1–3 illustrate that, as potential confounders were added in succeeding models, ethnic differences in longitudinal change in cognition became nonsignificant.

Figure 4 demonstrates the effect of education on cognitive trajectories. This figure presents the average model-derived trajectory from Model 4 for three levels of education, corresponding to 9 years, 12 years, and 15 years. The effect of education on baseline scores is apparent in the separation of model-predicted scores at Time 0. But, the similarity of the slopes for the three levels of education for each outcome highlights the nonsignificant impact of education on cognitive change. Education was associated with clear differences in scores, but rate of change in scores was not related to education.

We performed secondary analyses that fit Model 4 for each cognitive outcome measure using just the community subsample. Results were essentially the same; strong effects of race/ethnicity and education were found on baseline scores, but none of the effects of race/

ethnicity or education on longitudinal change were significant. This provides evidence that recruitment source differences inherent in the overall sample did not bias either cross-sectional or longitudinal results.

We then performed a series of secondary analyses to investigate effects of additional variables. One set of analyses investigated potential nonlinearities in longitudinal trends. Here, we included the quadratic effect of time (i.e., the Time × Time power polynomial) and the quadratic interaction with other main effects (e.g., the Time × Time × Race/Ethnicity product term). No significant effects of nonlinearities were found. We also investigated whether mortality affected results. Mortality was related to baseline performance and to longitudinal decline, but effects of race/ethnicity and education were unchanged.

Discussion

The purpose of this study was to examine whether education and race/ethnicity are associated with different cognitive-change outcomes over time. Two primary findings are notable. First, consistent with previous cross-sectional studies of race/ethnicity and education effects on cognition in old age (Tang et al., 2001; Gurland et al., 1999; Fitzpatrick et al., 2004), we found ethnicity and education were each strongly associated with cognitive-baseline scores. The second major finding was that race/ethnicity and education were weakly-to-not-associated with *change* in cognition. We found no significant effects of education on slope of cognitive change, and the significant ethnic effects that were found indicated that African Americans had slightly better longitudinal outcomes than Caucasians, even when adjusting for baseline extent of cognitive impairment due to clinical disease such as MCI or dementia. Currently the role that race or ethnicity and education play in cognitive decline during old age is not well understood, but a growing body of literature shows that these variables are not strongly associated with differences in rate of cognitive change (Wilson et al., 2010; Wilson et al., 2009; Masel & Peek, 2009; Karlamangla et al., 2009).

It is important to note that significant race/ethnicity group differences in cognitive change were present prior to accounting for key confounding variables, but in all cases Caucasians showed the most rapid declines. For example, our Model 2 included effects for language and ethnicity and showed that African Americans and Hispanics had a significantly slower rate of decline across all three cognitive outcomes compared with Caucasians. However, once additional confounders were incorporated into the final model (Model 4), no significant differences were found across the three ethnicities in the rate of decline for episodic memory. African Americans continued to show slightly slower rates of decline for semantic memory and executive function than Caucasians, although this effect was small. In comparison, Hispanics exhibited rates of decline on all three outcomes that were similar to those shown by Caucasians. Overall, these findings highlight the critical need to control for confounding effects when investigating factors that explain decline in cognition.

Language also made a strong contribution to baseline cognitive-test scores, but not to longitudinal change in scores. More than half of the Hispanic individuals in our sample were evaluated in Spanish. These Spanish test takers had lower executive, semantic, and episodic memory baseline test scores than Hispanic individuals who took the tests in English. Lower scores in semantic memory most likely represent differential exposure to life experiences that contribute to broad acquisition of knowledge. Episodic memory by definition does not involve knowledge acquired over the lifetime, but might similarly be influenced by life experiences that contribute to development of the skills underlying episodic memory performance. However, the relative lack of familiarity with and exposure to test taking probably influenced results for Spanish speakers. Spanish test takers exhibited a large positive increase in episodic memory scores at the second time of measurement, showing

that they benefited disproportionately from previous testing on this measure. Karlamangla et al. (2009), using a similar approach to longitudinal modeling of data from the AHEAD study, showed that individuals with less than 8 years of education disproportionately benefited from repeated testing. The overall level of education of participants who took the test in Spanish in our study was quite low (Spanish administration $M = 6.6$ years, $SD = 5.4$; English administration $M = 11.7$ years, $SD = 3.9$) and it is likely that their exposure to testing was quite limited. The finding that their performance improved substantially after the initial assessment suggests that their episodic memory performance at the baseline evaluation underestimated their true ability. An important implication of this finding is that a single test result, especially for a relatively difficult test of memory and learning, may not accurately reflect true ability in Spanish-speaking Hispanics with low education.

This study was based on a sample that included a range of cognitive function from normal to demented as well as broad diversity in demographic characteristics. Overall averages in rates of change can be somewhat misleading because they represent aggregated effects of many different individual trajectories. For this reason, accounting for confounding variables that might distort results is critical. Specifically, clinic recruits were disproportionately Caucasians, and more Caucasians had a clinical diagnosis of MCI at baseline evaluation. Both of these factors are associated with greater cognitive decline (Mungas et al., 2010; Farias et al., 2009); thus, meaningful comparisons of Caucasians with African Americans and Hispanics must account for these differences. Of course, other variables not included in this study might be associated with cognitive decline, might be differentially distributed across demographically defined groups, and potentially might confound effects of demographic variables on cognitive change. For example, neuropsychiatric symptoms have been found to be associated with cognitive decline over time (Lee, Paddock, & Feeney, 2012). It is also possible that neuropsychiatric symptoms may not only be associated with cognitive decline, but will also differ across ethnic and/or education groups (Livney et al., 2011).

The major finding from this study was the lack of significant effects of language, race/ethnicity, and education on longitudinal change in cognitive function. Negative findings raise important questions about whether important effects are truly not present or whether there simply is inadequate statistical power to detect significant effects. This is a particular concern for ethnic-group differences, in which the overall sample is split into smaller comparison groups. Inadequate statistical power does not seem to be a viable explanation for the negative findings in the present study related to race/ethnicity. Significant ethnic-group differences were identified in earlier models, prior to introduction of covariates in the model. All longitudinal differences that were found favored minorities over Caucasians, as would be expected given that Caucasians were disproportionately recruits from clinics who had diagnoses of MCI. In subsequent models that controlled for these variables, the group differences in longitudinal cognitive change were quite small, were not significantly different from 0 in normals (Figures 1–3), but still favored African Americans over Caucasians. It is possible that other unmeasured confounders might have negatively biased the results for Caucasians, but a larger sample size and greater statistical power in this study would have made it more likely to show significantly less decline in African Americans and Hispanics compared with Caucasians.

Effect size is at least as important as statistical significance. Our sample was able to detect group differences in longitudinal change of about 0.04 SD per year. To place this into context, the baseline difference in episodic memory between normals and those with MCI was approximately 1.5 SD (see Table 5). The transition from normal to MCI at a rate of −0.04 per year (Caucasians, Table 5) would take about 37 years, while the same transition at a (detectably different) rate of −0.08 would still take 18 years. This difference is not

negligible, and indeed might represent the difference between a 60-year-old having little likelihood of progressing to MCI in his or her lifetime versus having a substantial likelihood of this change in clinical status. Careful studies with larger samples are needed to further refine our understanding of the determinants of cognitive decline, and are especially relevant to developing accurate estimates of public health consequences in a rapidly aging population.

The sample for this study was diverse, both in demographic characteristics and cognitive trajectories, but important limitations related to its representativeness should be noted. First, the majority of the Hispanic sample in this study was primarily of Mexican descent. Results may not generalize to other Hispanic or Latino groups from different regions. Similarly, African Americans were from a specific region (Northern California) that may not be representative of the broader population, and other ethnic minorities were not included in this study. In addition, the sample in this study was essentially a sample of convenience.

Although it is necessary to consider these limitations, results from population-based longitudinal studies broadly support our findings. Race/ethnicity and education were consistently related to baseline cognitive scores in these studies (Wilson et al., 2009; Masel & Peek, 2009; Karlamangla et al., 2009; Sloan & Wang, 2005; Wolinsky et al., 2011; Alley et al., 2007). Effects on longitudinal change were sporadically reported in these studies, and in a number of cases, favored ethnic minorities and individuals with lower education. When significant effects on change were found, effect sizes tended to be small. The large and representative samples of these studies have relative advantages over our study, but our psychometrically sophisticated, domain-specific cognitive-outcome measures were a relative strength in comparison to the brief, telephone-administered measures of cognition used in many of these studies. Some questions may remain about demographic contributions to longitudinal change in cognition, and such effects are inconsistently found. That is, at times they favor disadvantaged groups but are weak when they are found. But in contrast, effects on cross-sectional or baseline scores are consistently strong and favor more advantaged groups. This overall pattern of findings supports the basic hypothesis that cross-sectional differences are largely due to differences in life experiences but cognitive decline results from age-related diseases that transcend demographic differences.

This study highlights the importance of longitudinal assessment, and has implications both for research and clinical practice. Although cross-sectional studies provide beneficial information regarding the aging process, they provide only a partial picture of cognitive decline across ethnically diverse populations. In order to fully understand disease in the aging population, future research must not only include ethnically diverse groups in their samples, but must also measure and account for unique factors associated with these populations that likely would influence cognitive-test results. Clinically, our results highlight the importance of being cautious in interpreting test results from a single evaluation, especially for minority groups and those with lower education. Cognitive-test scores are influenced by many factors in addition to diseases of aging, and equating lower scores with presence of disease effects ignores the other, sometimes more substantial contributions of nondisease variables (Mungas, Reed, Farias, & De-Carli, 2009). Longitudinal evaluation can be particularly beneficial for disentangling static influences of life experiences on test scores from dynamic effects of diseases of aging.

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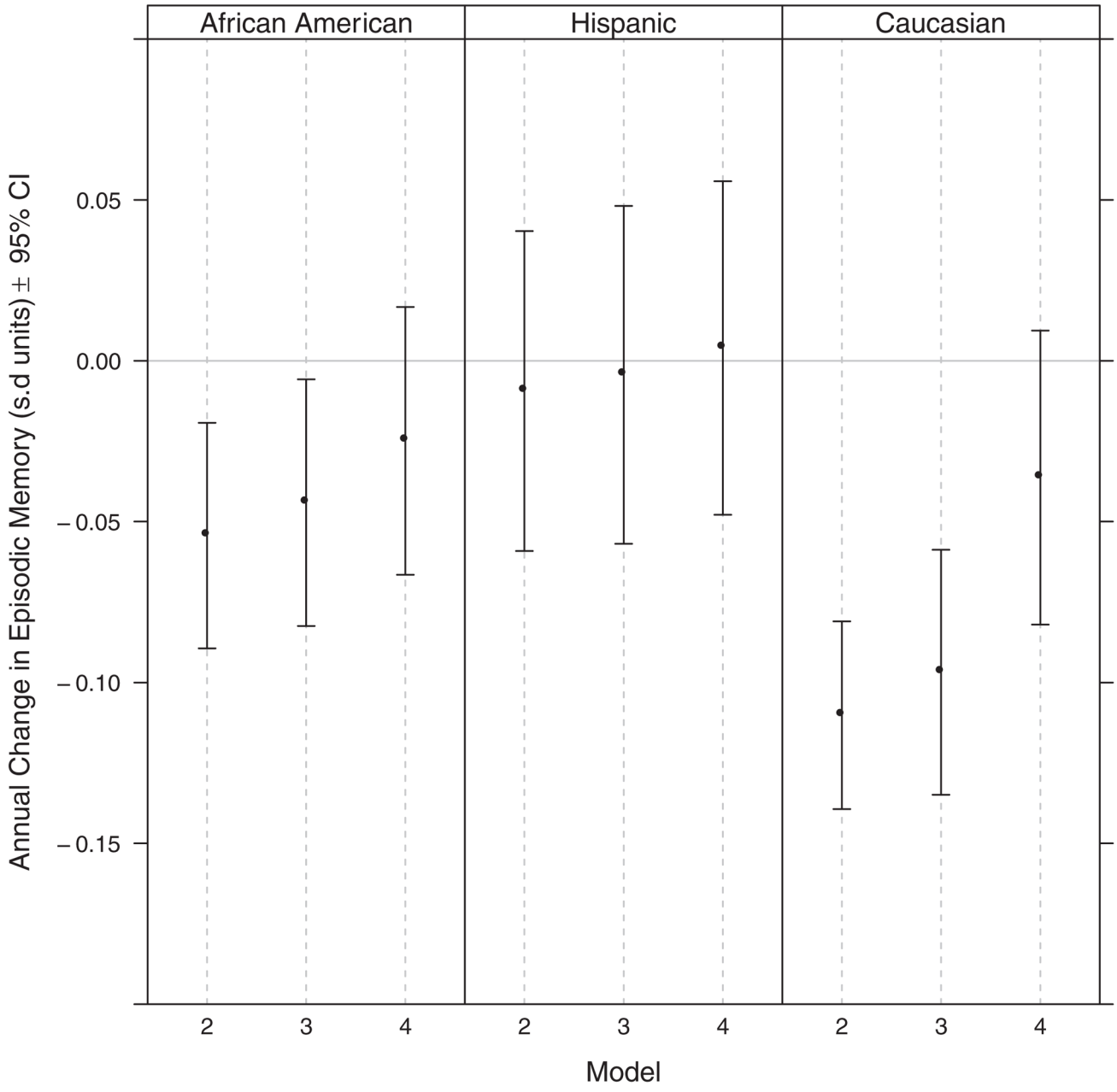

Figure 1.
Annual change in episodic memory in African Americans, Hispanics, and Caucasians estimated in mixed-effect regression Models 2–4. Scores shown are for a 70-year-old woman with 12 years of education taking the test in English, administered Form 1, recruited from the community, and diagnosed as normal and ApoE$_{\varepsilon}$4 negative.

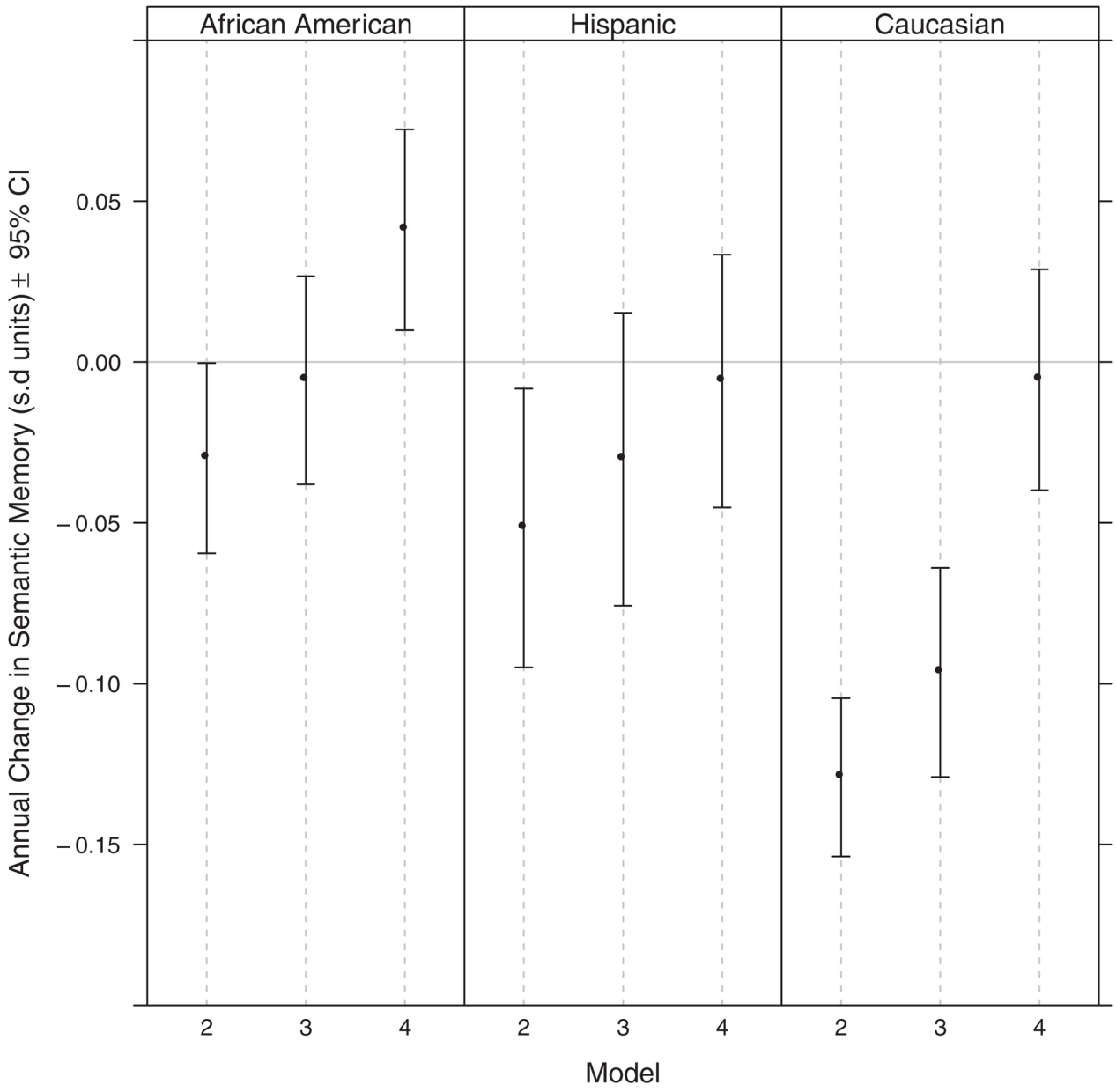

Figure 2.

Annual change in semantic memory in African Americans, Hispanics, and Caucasians estimated in mixed-effect regression Models 2–4. Scores shown are for a 70-year-old woman with 12 years of education taking the test in English, administered Form 1, recruited from the community, and diagnosed as normal and ApoE$_{\varepsilon}$4 negative.

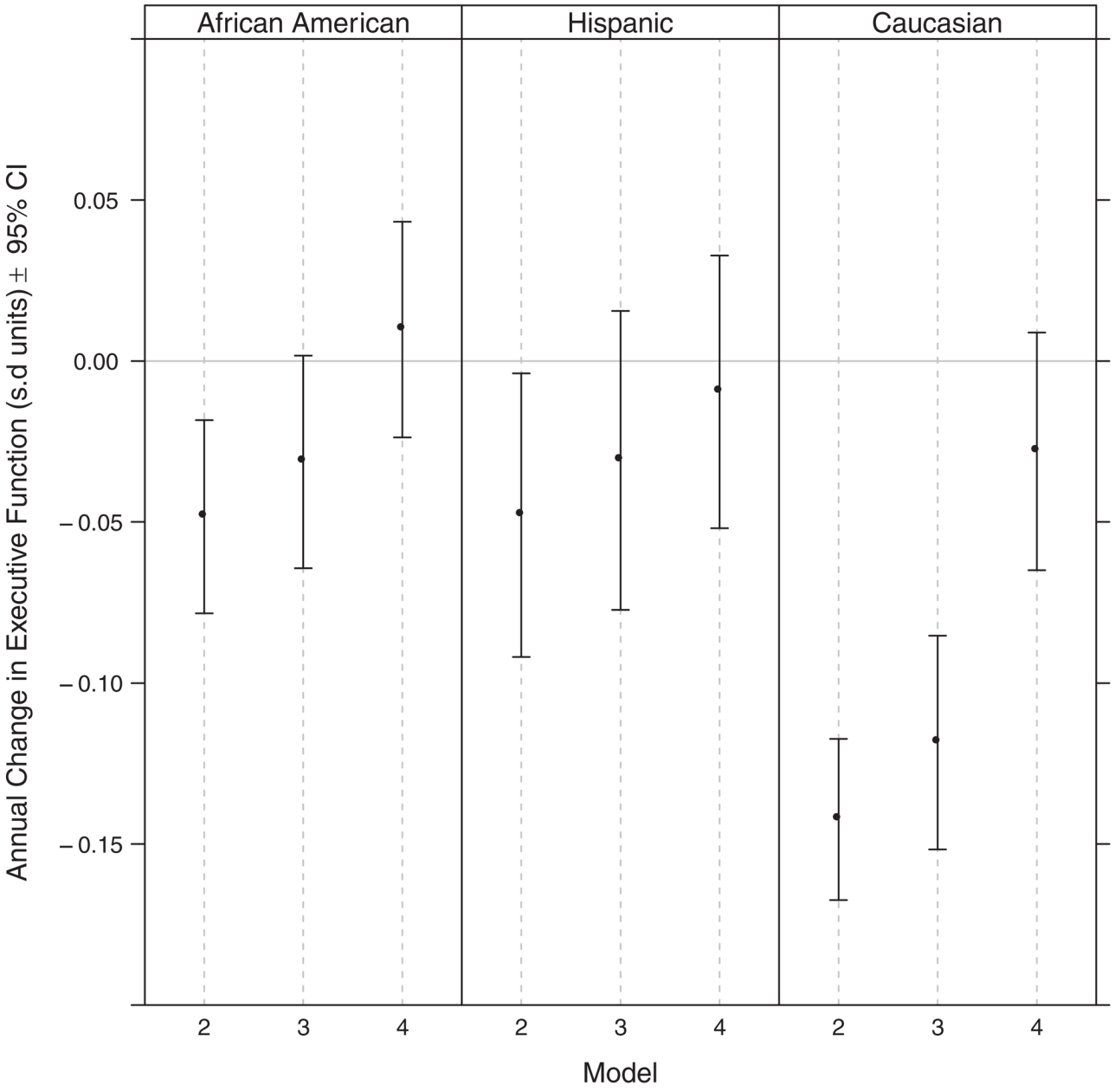

Figure 3.

Annual change in executive function in African Americans, Hispanics, and Caucasians estimated in mixed-effect regression Models 2–4. Scores shown are for a 70-year-old woman with 12 years of education taking the test in English, administered Form 1, recruited from the community. and diagnosed as normal and ApoE$_{\varepsilon}$4 negative.

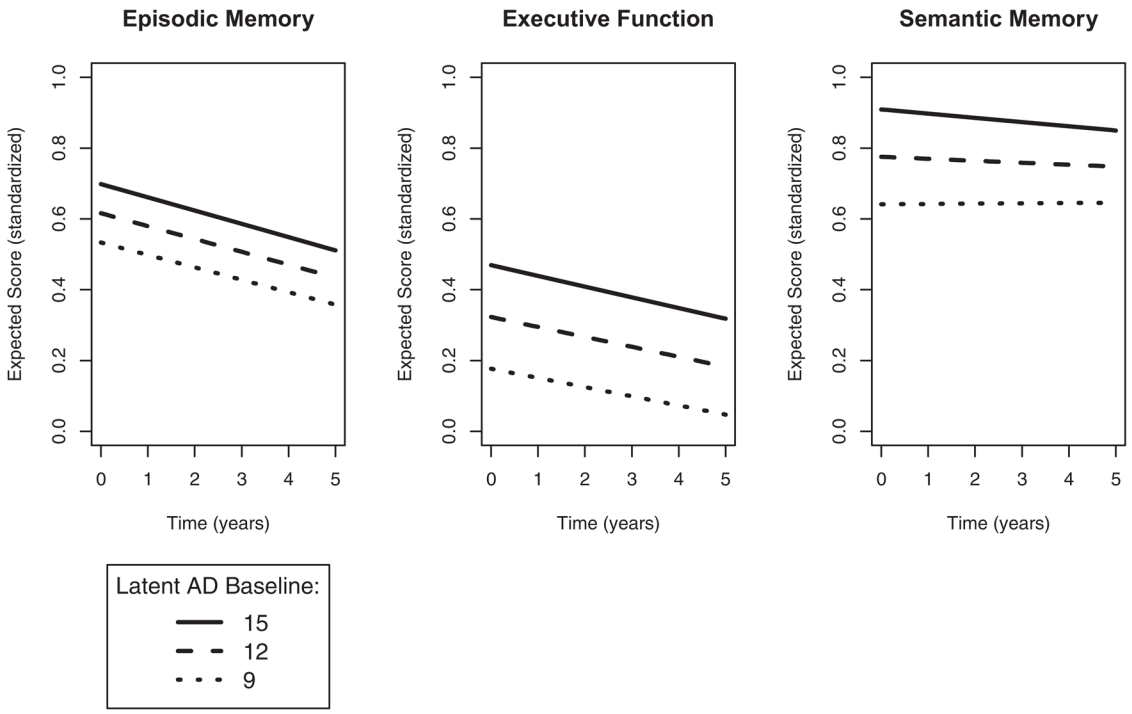

Figure 4.

Model-derived education trajectories for three specific education levels: 9 years, 12 years, and 15 years. Results describe education effects from Model 6 that included all independent variables and are adjusted for all other independent variables. The graphed results indicate the expected scores for a cognitively normal Caucasian woman, 70 years of age at the baseline evaluation, recruited from the community, tested in English with Form 1 of the episodic memory test, and with no ApoE e4 alleles.

Table 1

Sample Characteristics

Variable	African American (*n* = 116)	Hispanic (*n* = 104)	Caucasian (*n* = 184)	All (*n* = 404)
Gender				
N (%) Female	83 (71.6)	64 (61.5)	91 (49.5)	238 (58.9)
Education (years)				
M (*SD*)	13.1 (3.1)	8.9 (5.4)	14.7 (3.3)	12.7 (4.5)
Age				
M (*SD*)	74.8 (6.9)	76.8 (6.5)	79.0 (7.6)	78.4 (7.1)
Language				
N (%) English	115 (99)	48 (46)	183 (99)	346 (85.6)
Clinical diagnosis				
N (%) Normal	66 (56.9)	68 (65.4)	73 (39.7)	207 (51.2)
N (%) MCI	35 (30.2)	18 (17.3)	82 (44.6)	135 (33.4)
N (%) Dementia	15 (12.9)	18 (17.3)	29 (15.8)	62 (15.4)
Follow-up time				
M (*SD*)	4.0 (1.8)	4.1 (2.1)	3.9 (2.2)	3.9 (2.1)
Number of evaluations				
N (%) 2 evals	24 (20.7)	22 (21.2)	45 (24.5)	91 (22.5)
N (%) 3 evals	20 (17.2)	18 (17.3)	28 (15.2)	66 (16.3)
N (%) 4 evals	27 (23.3)	18 (17.3)	27 (14.7)	72 (17.8)
N (%) ≥5	45 (38.8)	46 (44.2)	84 (45.7)	175 (43.3)

Note. MCI = mild cognitive impairment; evals = evaluations.

Table 2

Sequence of Analysis Models

Model	Independent variables
1	Previous evaluations, language (Spanish), verbal-memory form
2	Model 1 + ethnicity
3	Model 2 + age, gender, education
4	Model 3 + recruitment source + baseline diagnosis + $ApoE_4$ genotype

Table 3

Baseline Cognitive Test Score Coefficients for Language, Ethnicity, and Education for Four Alternative Models

		Spanish[1]		African American[2]		Hispanic[2]		Education	
Cognitive measure	**Model**	**Estimate**	***SE***	**Estimate**	***SE***	**Estimate**	***SE***	**Estimate**	***SE***
Episodic memory	1	***−.56***	.13						
	2	***−.54***	.17	.17	.11	.05	.14		
	3	***−.41***	.17	.12	.10	.05	.14	***.04***	.01
	4	***−.30***	.13	−.06	.08	***−.29***	.11	***.03***	.01
Semantic memory	1	***−1.29***	.11						
	2	***−1.09***	.14	***−.69***	.08	***−.50***	.11		
	3	***−.83***	.13	***−.59***	.08	***−.40***	.11	***.05***	.01
	4	***−.76***	.12	***−.69***	.08	***−.55***	.10	***.05***	.01
Executive function	1	***−.55***	.10						
	2	***−.38***	.13	***−.30***	.08	***−.32***	.11		
	3	−.13	.12	***−.26***	.07	***−.23***	.10	***.06***	.01
	4	−.08	.11	***−.30***	.07	***−.32***	.09	***.05***	.01

Note. Group *N*s: Caucasian = 184; African American = 116; Hispanic = 104. Results show model mean-cognitive baseline-coefficient scores as a function of categorical language and ethnicity variables, and indicate the average effect on test scores of one additional year of education. Effects that are significantly different from zero are bolded. Cognitive-test scores are in standard deviation units.

[1]Coefficients show effect of Spanish administration in comparison with English administration.

[2]Coefficients show effects of African American and Hispanic race/ethnicity in comparison with Caucasians.

Table 4

Cognitive Change Coefficients for Language, Ethnicity, and Education for Four Alternative Models

		Spanish[1]		African American[2]		Hispanic[2]		Education	
Cognitive measure	**Model**	**Estimate**	***SE***	**Estimate**	***SE***	**Estimate**	***SE***	**Estimate**	***SE***
Episodic memory	1	.02	.03						
	2	−.04	.04	**.06**	.02	***.10***	.03		
	3	−.05	.04	***.05***	.02	***.09***	.03	−.00	.00
	4	−.04	.04	.01	.03	.04	.03	−.00	.00
Semantic memory	1	.03	.03						
	2	−.01	.03	***.10***	.02	***.08***	.02		
	3	−.02	.03	***.09***	.02	***.07***	.03	−.00	.00
	4	−.01	.03	***.05***	.02	−.00	.02	−.00	.00
Executive function	1	.03	.03						
	2	−.02	.03	***.09***	.02	***.09***	.03		
	3	−.02	.03	***.09***	.02	***.09***	.03	−.00	.00
	4	−.01	.03	***.04***	.02	.02	.03	−.00	.00

Note. Group *N*s: Caucasian = 184; African American = 116; Hispanic = 104. Results show model mean annual change in cognitive test coefficients as a function of categorical language and ethnicity variables, and indicate the average effect on cognitive change of one additional year of education. Effects that are significantly different from zero are bolded. Cognitive test scores are in standard deviation units.

[1]Coefficients show effect of Spanish administration in comparison with English administration.

[2]Coefficients show effects of African American and Hispanic race/ethnicity in comparison with Caucasians.

Table 5

Effects of all Independent Variables Included in Model 4 on Estimated Cognitive Baseline and Annual Change

		Effects on baseline level		Effects on annual change	
Cognitive measure	**Effect**	**Estimate**	***SE***	**Estimate**	***SE***
Episodic memory	Intercept	***.62***	.08		
	Time			−.04	.02
	Previous eval	−.06	.04		
	Language (Spanish)	***−.30***	.13	−.04	.04
	Span × Prev Eval	***.33***	.12		
	Form 2	***−.16***	.03		
	Form 3	***−.31***	.04		
	Hispanic	***−.29***	.11	.04	.03
	African American	−.06	.08	.01	.02
	Age	−.02	.00	−.00	.00
	Gender (male)	***−.39***	.06	.02	.02
	Education	***.03***	.01	−.00	.00
	Clinic	−.04	.08	***−.08***	.02
	MCI	***−.91***	.07	.00	.02
	Dementia	***−1.4***	.10	−.04	.03
	APOE4	−.10	.06	−.03	.02
Semantic memory	Intercept	***.78***	.08		
	Time			−.01	.02
	Previous Eval	.05	.03		
	Language (Spanish)	***−.76***	.12	−.01	.03
	Span × Prev Eval	.10	.07		
	Hispanic	***−.55***	.10	−.00	.02
	African American	***−.69***	.07	***.05***	.02
	Age	***−.02***	.00	−.00	.00
	Gender (male)	***.19***	.06	−.02	.01
	Education	***.05***	.01	−.00	.00
	Clinic	−.03	.07	***−.07***	.02

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		Effects on baseline level		Effects on annual change	
Cognitive measure	**Effect**	**Estimate**	***SE***	**Estimate**	***SE***
	MCI	***−.50***	.07	***−.05***	.02
	Dementia	***−.84***	.09	***−.16***	.02
	APOE4	.09	.06	***−.03***	.01
Executive function	Intercept	***.32***	.07		
	Time			−.03	.02
	Previous Eval	.01	.03		
	Language (Spanish)	−.08	.11	−.01	.03
	Span × Prev Eval	.08	.07		
	Hispanic	***−.32***	.09	.02	.03
	African American	***−.30***	.07	***.04***	.02
	Age	***−.02***	.00	−.00	.00
	Gender (male)	***−.14***	.05	−.02	.02
	Education	***.05***	.01	−.00	.00
	Clinic	.11	.07	***−.09***	.02
	MCI	***−.45***	.06	***−.06***	.02
	Dementia	***−.80***	.08	***−.09***	.02
	ApoE4	.03	.06	−.03	.02

Note. $N = 404$. Results show model-estimated mean annual change in cognitive-test scores as a function of categorical independent variables, and indicate the average effect on cognitive change of one additional unit for continuous variables. Effects that are significantly different from zero are bolded. Cognitive-test scores are in standard deviation units.