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Original Contribution

Contribution of Socioeconomic Status at 3 Life-Course Periods to Late-Life Memory Function and Decline: Early and Late Predictors of Dementia Risk

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Both early life and adult socioeconomic status (SES) predict late-life level of memory; however, evidence is mixed on the relationship between SES and rate of memory decline. Further, the relative importance of different life-course periods for rate of late-life memory decline has not been evaluated. We examined associations between life-course SES and late-life memory function and decline. Health and Retirement Study participants (n = 10,781) were interviewed biennially from 1998–2012 (United States). SES measurements for childhood (composite score including parents' educational attainment), early adulthood (high-school or college completion), and older adulthood (income, mean age 66 years) were all dichotomized. Word-list memory was modeled via inverse-probability weighted longitudinal models accounting for differential attrition, survival, and time-varying confounding, with nonrespondents retained via proxy assessments. Compared to low SES at all 3 points (referent), stable, high SES predicted the best memory function and slowest decline. High-school completion had the largest estimated effect on memory (β = 0.19; 95% confidence interval: 0.15, 0.22), but high late-life income had the largest estimated benefit for slowing declines (for 10-year memory change, β = 0.35; 95% confidence interval: 0.24, 0.46). Both early and late-life interventions are potentially relevant for reducing dementia risk by improving memory function or slowing decline.

cognition; cognitive decline; decline; education; income; memory; memory decline; socioeconomic status

Abbreviations: CDE, controlled direct effect; HRS, Health and Retirement Study; IPW, inverse probability weight; SES, socioeconomic status.

Dementia incidence is influenced by both midlife level of cognitive function and rate of cognitive decline in late life (1–3). Level is interpreted as "premorbid cognition," whereas rate of decline is considered more closely aligned with diseases common at older ages, such as Alzheimer disease or cerebrovascular pathology (4). Low socioeconomic status (SES) is associated with incident dementia and decreased level of cognitive function in late life (5–8). Emerging data indicate that both early-life and adult SES predict late-life level of cognitive function (5, 9–11), but whether there is a relationship between either childhood or adult SES and rate of cognitive decline remains uncertain (12). Evaluating the timing of exposure is important for targeting prevention strategies, (10, 13), and the social determinants and the timing of sensitive periods may differ for cognitive level and cognitive decline.

Although Whalley et al. (11) argued for a life-course framework for understanding dementia, little prior work has formally integrated life-course theories or made an attempt to empirically evaluate alternative life-course models for cognitive aging (9, 14–20). Most studies on SES and cognitive outcomes have focused on educational attainment as the measure of SES (21). Higher levels of education consistently predict lower risk of cognitive impairment or dementia in late life (7, 14, 20, 22–31). However, the evidence for education and rate of cognitive decline is less conclusive (12, 20, 32). Earlier studies reported slower decline among more highly educated individuals (33–39), but recent studies have not replicated these findings (20, 40–50). Even fewer studies have focused on childhood SES, which may be key for establishing cognitive or brain reserve (5, 10, 31, 51–58). Some evidence also suggests that cognitive reserve might also be affected by cognitive activities later in life (54). If so, interventions in adulthood could offset some of the adverse consequences of low early-life SES.

As the field moves to more explicit examination of distinct life-course periods, we also need to adopt methods that allow appropriate identification. Such methods include selection of covariates based on the hypothesized causal model, accounting for time-varying confounders, and specifying models so that the effects of each model might plausibly correspond with the impact of a potential intervention targeting a life-course period. In the present study, we compared the association between measures of SES at 3 different time points (childhood, early adulthood, and older adulthood) and late-life memory function and memory decline in the Health and Retirement Study (HRS), using inverse probability weights (IPWs) to appropriately account for time-varying confounding.

METHODS

Study population

HRS is a nationally representative cohort drawing from a target population of all noninstitutionalized adults in the contiguous United States. Participants aged ≥50 years in 1998 were eligible for inclusion in our study (59). Biennial interviews (or proxy interviews for deceased participants) were available through 2012. Study details have been provided elsewhere (60–62).

Of 20,556 possible age-eligible respondents in the 1998 wave, we excluded participants without a memory assessment at our first outcome wave of 2002 ($n = 5,840$). In addition, we excluded those missing data on childhood SES ($n = 1,692$), educational attainment ($n = 30$), or income in 2000 ($n = 290$), as well as anyone with missing covariate information ($n = 2,056$), for a final analytical sample of 10,781. For sensitivity analyses based on multiple imputation of missing covariates, we retained 12,720 respondents.

HRS was approved by the University of Michigan Health Sciences Human Subjects Committee; all participants are read a confidentiality statement when first contacted, and the participants give oral or implied consent by agreeing to do the interview. The Harvard School of Public Health Human Subjects Committee determined that the current analyses were exempt.

Memory function and decline outcomes

Memory was assessed by immediate and delayed recall of a 10-word list and the Informant Questionnaire for Cognitive Decline (IQCODE) (63). For individuals too impaired to participate directly in memory assessments, proxy informants, typically spouses, were asked to assess the participants' memory on a 5-item Likert scale and completed a 16-item IQCODE (64, 65), which has been previously validated (66). We used a previously developed memory composite score combining proxy and direct memory assessments for longitudinal analyses (67). The composite score algorithm was developed in an 856-subject subsample who participated in a comprehensive neuropsychological battery as part of the Aging, Demographics, and Memory Study (68, 69). We standardized the memory score by its 1995 standard deviation so that every unit change in memory score corresponds to approximately 1 standard deviation in that year's population.

Childhood SES

A composite childhood SES score, previously developed and validated (A. Vable et al., Stanford University, unpublished manuscript, 2016), assessed the domains of father's educational attainment, mother's educational attainment, father's occupation, and financial capital. These measures were assessed retrospectively at baseline, except father's occupation, which was assessed in 1998 (the third or fourth interview for some respondents). This score was dichotomized at the median.

Early adult SES

We used educational attainment as a proxy for early adult SES. We created 2 indicator variables: high-school completion (≥12 years) and college completion (≥16 years), so the college variable can be interpreted as the estimated effect of college over and above the estimated effect of high school.

Late-life SES

Our primary measure of late-life SES was self-reported household income in 2000, dichotomized at the median. In sensitivity analyses, we considered an alternative measure of late-life SES—self-reported household wealth in 2000—also median-dichotomized. Finally, we considered a dichotomous measure of respondent's current labor-force status (works full-time, part-time, or retired vs. unemployed, disabled, or not in labor force) as our third marker of late-life SES.

Other covariates

Analyses accounted for confounders of the association between each SES measure and memory function/decline (i.e., for each life-course SES measure, we considered as potential confounders variables that may have influenced both the SES measure and memory function or decline). Confounders were deemed relevant to each life-course measure of SES if they came temporally prior to it (e.g., all confounders of early-life SES were also included as confounders of early or mid-adulthood and late-life SES) (Figure 1). For early-life SES, potential confounders included birth year (as a linear spline with knots at the following years: 1926, 1934, 1940), race/ethnicity (white, black, or other), sex (male or female), and southern birthplace (yes/no). Additional potential confounders for early/mid-adulthood SES included baseline marital status (married/partnered, separated/divorced, widowed, and never married), age at first child's birth (cutpoint at 18 years of age), initiated smoking before age 18 years (yes/no), childhood social capital composite scale (created via factor analysis using measures of maternal investment, dichotomized at the median), father absent during childhood (yes/no), rural childhood (yes/no), childhood and baseline self-rated health (low, good, high). Baseline health measures were added as potential confounders for late-adulthood SES, including smoking (yes/no), drinking (drinks per day: 0, 1–2, ≥3), body mass index by category (normal weight, overweight, obese),

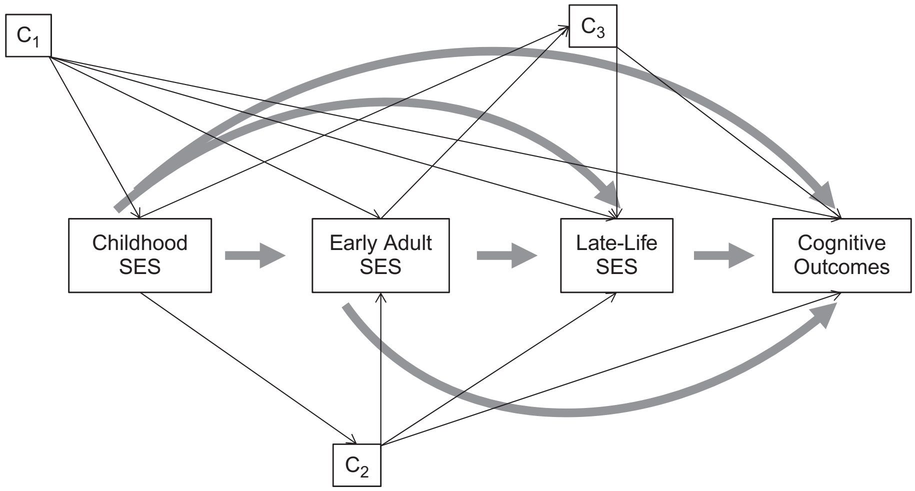

Figure 1. This model shows the hypothesized causal relationships between the different measures of socioeconomic status (SES), cognitive outcomes, and confounders.

physical activity level (vigorous physical activity ≥3 times per week: yes/no), diabetes diagnosis (yes/no), ever had hypertension (yes/no), stroke diagnosis (yes/no), elevated depressive symptoms (measured by the Center for Epidemiologic Studies Depression Scale (CES-D): depressive symptoms score >3), and heart-disease diagnosis (yes/no).

Statistical analysis

We assessed memory function and memory decline. Memory function was modeled longitudinally from 2002–2012 using marginal mean regression models for repeated outcomes, and memory decline was modeled for the same interview years using indicator variables for each wave and interaction terms with linear years-since-baseline (in decades) by SES at each time point. We included indicator variables for the interview year (instead of continuous years-since-baseline) because this both allows for average change over time and accounts for period differences. We included main effects for each measure of SES as well as terms for interaction between all 4 SES variables.

For both outcomes (memory function and decline) we adjusted for prechildhood confounders (C1) by direct inclusion in the outcome regression of substantive interest. Confounders from childhood and beyond cannot be included directly in the outcome model because they may also act as mediators, and such adjustment may induce collider stratification bias. In order to remove the confounding without blocking the possible mediated path between SES and memory, we used IPWs to adjust for postchildhood confounders (C2 and C3) (70). This identifies controlled direct effects (CDEs) of each SES measure on memory function and decline. CDEs correspond with the effect of each SES measure on memory, if all individuals were to take on a specified value of the mediator. In this case, the mediators are subsequent measurements of SES. For instance, we are estimating the CDE of childhood SES on memory not through education or late-life income. We specify interaction terms so that the CDE of childhood SES could differ based on whether someone completed high school or had high late-life income.

In addition, we used IPWs to account for differential attrition and selective survival (see Web Appendix 1 for a description of the IPWs, and Web Table 1 for weighting model results). Although we specified an independence working correlation structure for repeated outcomes (71), in order to accommodate time updated weights, we have reported robust standard errors, which appropriately account for the longitudinal design and all sources of variability.

In sensitivity analyses, we estimated identical models, using late-life wealth instead of income. We also estimated models regressing memory in 2002 on income in 2000 both with and without controlling for labor-force status in 2000, to ascertain whether labor-force participation partially explained the correlation between income and memory. Finally, we used multiple imputation to investigate evidence of bias from excluding participants who were missing covariate data. We generated 20 imputed samples and used linear regression to impute continuous variables and logistic regression for binary ones. Our final sample size for each imputation was 12,720. These results were nearly identical to the primary analysis, and they are presented in Web Appendix 2 along with a more detailed description of how these models were implemented.

RESULTS

Baseline characteristics from 1998 are shown for the 10,781 individuals in our analyses (Table 1). Average follow-up was 8.2 years (out of a possible 10) and the average number of memory assessments was 5.1 (out of a possible 6). The mean age was 69 years at the first cognitive assessment in 2002. Distributions of the primary predictors—childhood SES, years of education, income, and wealth—are presented in Table 2.

Table 1. Baseline Characteristics of Participants Included in the Analyses, Health and Retirement Study, United States, 1998

Characteristic	No. of Participants (n = 10,781)	%
Potential confounders of childhood SES		
Male	4,205	39.0
Race/ethnicity (referent: white)		
Black	1,379	12.8
Other	204	1.9
Birth year		
Before 1929	2,679	24.9
1929–1932	2,419	22.4
1933–1935	2,662	24.7
After 1935	3,021	28.0
Southern birthplace	1,727	16.0
Additional potential confounders of education		
Age <18 years at birth of first child	918	8.5
Started smoking before age 18 years	3,042	28.2
Childhood self-rated health (referent: good)		
Low	639	5.9
High	8,284	76.8
Rural childhood	5,750	53.3
Father absent	864	8.0
Childhood social capital	0.04	0.97
Additional potential confounders of late-life SES		
Not physically active	5,486	50.9
Drinks per day (referent: 0)		
1–2 drinks	9,785	90.8
≥3 drink	232	2.2
Current smoker	1,637	15.2
Body mass index (referent: normal)		
Overweight	4,307	40.0
Obese	2,619	24.3
Current diabetes	1,088	10.1
Current hypertension	4,337	40.2
Current stroke	470	4.4
Current heart disease	1,717	15.9
Current depression	1,347	12.5
Current self-rated health (referent: good)		
Low	2,322	21.5
High	5,006	46.4
Current marital status (referent: married)		
Divorced/separated	1,070	9.9
Widowed	1,776	16.5
Never married	297	2.8

Abbreviation: SES, socioeconomic status.

Table 2. Distributions of the Primary Predictors Among the Study Sample, Health and Retirement Study, United States, 2000

Characteristic	Mean (SD)
Childhood SES	0.05 (0.99)
Years of education	12.69 (2.80)
Income in 2000	$58,443.78 ($109,107.82)
Wealth in 2000	$419,762.00 ($1,114,719.50)

Abbreviations: SD, standard deviation; SES, socioeconomic status.

Level of memory function

Point estimates for the association between each SES indicator and memory function were similar for all models: 1) including only childhood SES; 2) including childhood SES and both education variables; and 3) including childhood SES, education, and late-life income (Table 3). Thus we interpreted the CDEs from the model including all SES measures. High childhood SES, high-school completion, college completion, and high income in late life were each associated with better memory function. High childhood SES was associated with a 0.08-unit increase in memory score; completing high school was associated with 0.19 units' higher memory score, and college completion with an additional 0.08-unit difference. High late-life income was associated with a 0.13-unit increase. The estimated effect of high-school completion was significantly larger than both the childhood-SES estimate ($P < 0.001$) and the income estimate ($P = 0.003$). The term for interaction between high school and income was −0.10, meaning that if someone completed high school, the potential benefit of high late-life income was smaller. More specifically, compared with those who had low SES at all time points, someone who completed high school experienced only a 0.19-unit increase in memory score on average; someone who had high late-life income experienced only a 0.13-unit increase in average memory score, and someone who both completed high school and had high late-life income experienced a 0.22-unit increase in average memory score (Table 4). Finally, our results suggest that the worst life-course SES pattern for memory function was to have low SES at each time point (i.e., low childhood SES, no high-school or college completion, and low late-life income). Conversely, the best pattern was to have high SES at each point. Estimated effects of each life-course pathway (compared to having low SES at each time point) are reported in Table 4.

Rate of memory decline

A corresponding set of 3 models was estimated for memory decline, with the exception of adding in years-since-baseline terms for interaction with the SES variables to estimate associations of each SES measure with rate of memory decline (Table 5). Because the estimated effects of SES on both baseline memory and rate of decline remained qualitatively similar across models, we focus on interpreting model 3, which estimated CDEs of all SES measures.

Table 3. Estimated Effects of Life-Course SES on Memory Function, Health and Retirement Study, United States, 1998–2012[a]

Characteristic	Model 1		Model 2		Model 3	
	β	95% CI	β	95% CI	β	95% CI
Childhood SES	0.07	0.05, 0.08	0.07	0.02, 0.12	0.08	0.01, 0.15
High-school completion			0.17	0.14, 0.19	0.19	0.15, 0.22
College completion			0.08	0.06, 0.11	0.08	0.03, 0.12
Late-life income					0.13	0.08, 0.18
Childhood SES × high-school completion			−0.05	0.09, 0.00	−0.05	0.12, 0.02
Childhood SES × college completion			−0.01	0.04, 0.02	0.02	0.04, 0.08
Childhood SES × late-life income					−0.03	0.11, 0.06
High-school completion × late-life income					−0.10	0.15, −0.05
College completion × late-life income					−0.00	0.06, 0.05
Childhood SES × high-school completion × late-life income					0.02	0.07, 0.12
Childhood SES × high-school completion × college completion × late-life income					−0.04	0.11, 0.03

Abbreviations: CI, confidence interval; SES, socioeconomic status.

[a] All models were weighted to adjust for survival, participation, and exposure to high SES at each time point. The following variables were controlled for through direct inclusion in the outcome regression: birth year, southern birthplace, sex, and race/ethnicity.

Each measure of SES was associated with rate of memory decline, with higher SES generally predicting slower decline (plotted in Figure 2). Compared with individuals with stable, low SES at all time points, completing high school predicted a 22% slower rate of memory decline, whereas the estimated effect of having high late-life income was to slow memory decline by 42%. The high school × years interaction term was significantly smaller than the income × years interaction term ($P < 0.001$). Figure 2 illustrates that the "high income only" curve (i.e., low childhood SES and no high-school or college completion) has a rate, or slope, of memory decline similar to that of the stable, high-SES group (high SES at every time point). At baseline, in comparison with the stable-low group, we found that the stable-high, high-school-only, and high-school-and-college groups had higher levels of memory function. However, the curves for the high-school-only and

Table 4. Effect Estimates for Each Life-Course SES Pathway on Memory Function in the Health and Retirement Study, United States of America, 1998–2012[a]

Childhood SES	High-School Completion	College Completion	Late-Life Income	β	95% CI
Low	Low	Low	Low	0	Referent
High	Low	Low	Low	0.08	0.01, 0.15
Low	High	Low	Low	0.19	0.15, 0.22
Low	High	High	Low	0.26	0.21, 0.32
Low	Low	Low	High	0.13	0.08, 0.17
High	High	Low	Low	0.22	0.18, 0.25
High	High	High	Low	0.31	0.26, 0.36
Low	High	Low	High	0.22	0.18, 0.26
Low	High	High	High	0.29	0.25, 0.33
High	Low	Low	High	0.18	0.13, 0.23
High	High	Low	High	0.24	0.21, 0.28
High	High	High	High	0.29	0.26, 0.33

Abbreviations: CI, confidence interval; SES, socioeconomic status.

[a] All models were weighted to adjust for survival, participation, and exposure to high SES at each time point. The following variables were controlled for through direct inclusion in the regression: birth year, southern birthplace, sex, and race/ethnicity.

Table 5. Estimated Effects of Life-Course SES on Memory Decline, Health and Retirement Study, United States, 1998–2012[a]

Characteristic	Model 1		Model 2		Model 3	
	β	95% CI	β	95% CI	β	95% CI
Childhood SES × years	0.145	0.118, 0.172	0.191	0.092, 0.291	0.222	0.076, 0.368
High-school completion × years			0.173	0.111, 0.234	0.177	0.093, 0.261
College completion × years			0.097	0.040, 0.155	0.120	0.001, 0.238
Late-life income × years					0.349	0.242, 0.457
Childhood SES × high-school completion × years			−0.047	0.154, 0.059	−0.091	0.250, 0.069
Childhood SES × college completion × years			−0.034	0.104, 0.036	−0.021	0.174, 0.133
Childhood SES × late-life income × years					−0.226	0.428, −0.023
High-school completion × late-life income × years					−0.155	0.278, −0.032
College completion × late-life income × years					−0.057	0.192, 0.078
Childhood SES × high-school completion × late-life income × years					0.227	0.009, 0.445
Childhood SES × high-school completion × college completion × late-life income × years					−0.003	0.174, 0.168
Wave: 2004	−0.105	0.112, −0.098	−0.139	0.152, −0.127	−0.159	0.175, −0.143
Wave: 2006	−0.209	0.219, −0.199	−0.275	0.297, −0.253	−0.315	0.344, −0.286
Wave: 2008	−0.303	0.316, −0.290	−0.407	0.440, −0.374	−0.467	0.511, −0.423
Wave: 2010	−0.452	0.469, −0.435	−0.593	0.638, −0.549	−0.678	0.736, −0.619
Wave: 2012	−0.549	0.569, −0.529	−0.732	0.787, −0.677	−0.840	0.913, −0.766

Abbreviations: CI, confidence interval; SES, socioeconomic status.

[a] All coefficients are for the interaction of the predictor variable and years since baseline (with years expressed in decades). Wave-to-wave (2-year) changes in memory averaged slightly over 0.1 units. For full model results, including level coefficients, see Web Table 4 in Web Appendix 3. All models were weighted to adjust for survival, participation, and exposure to high SES at each time point. The following variables were controlled for through direct inclusion in the regression: birth year, southern birthplace, sex, and race/ethnicity.

high-school-and-college groups declined at a more rapid pace than the curve for the stable, high group. The high-childhood-SES-only group, although similar at baseline to the stable-low group, had a rate of decline between that of the high-school-only and high-income-only groups. Finally, as expected, the stable, low-SES group had the steepest rate of decline.

In sensitivity analyses, we used household wealth instead of income as the measure of late-life SES. The estimated effects of wealth on memory decline were slightly smaller in magnitude than estimates for income. In these models, the estimated effect sizes of wealth and high-school completion on memory decline were similar. In our second sensitivity analysis, we found that the relationship between income in 2000 and memory in 2002 remained unchanged after adjustment for labor-force status in 2000.

Models using outcome regression covariate adjustment instead of IPWs to account for confounding (without further weighting for potential bias due to censoring or survival) found smaller estimated associations for each measure of SES for both memory function and decline. Finally, results from multiple imputation yielded qualitatively similar estimates and patterns of estimates (results in Web Tables 2 and 3 in Web Appendix 2).

DISCUSSION

Our results suggest that education is the most important socioeconomic contributor to level of memory function in older adults. An individual without a high-school education could, on average, partially compensate with high late-life income, but he or she would likely not attain the level of memory function of someone who completed high-school education. However, late-life income was the strongest determinant of rate of memory decline, although education was also associated. Thus, while our estimates indicate that high-school education has the biggest impact on level of functioning, late-life income appears more important for rate of memory decline.

There is consistent evidence of a large impact of education on level of cognitive function in late life (7, 14, 16, 18, 26–35), although less is known about the effects of other measures of SES (5, 10, 16–18, 31, 55, 56). This paper adds to prior literature by directly testing different measures of SES across 3 life-course stages and using IPWs to control for confounding, survival, and censoring. Only a few prior studies examined 3 distinct life-course measures in relation to late-life cognitive function (9, 16, 19, 20). Overall, our results are consistent with their results: Each measure of life-course SES contributes to memory function later in life, and it appears that upward mobility can somewhat offset the effects of low SES earlier in life.

Evidence for the association of SES with cognitive decline is less consistent (11, 36). Earlier research suggested that higher education predicted slower rates of decline (33–39). However, recently more methodologically sophisticated papers (e.g., based on longer follow-up periods and using analyses that do not induce bias by adjusting for baseline cognitive test scores

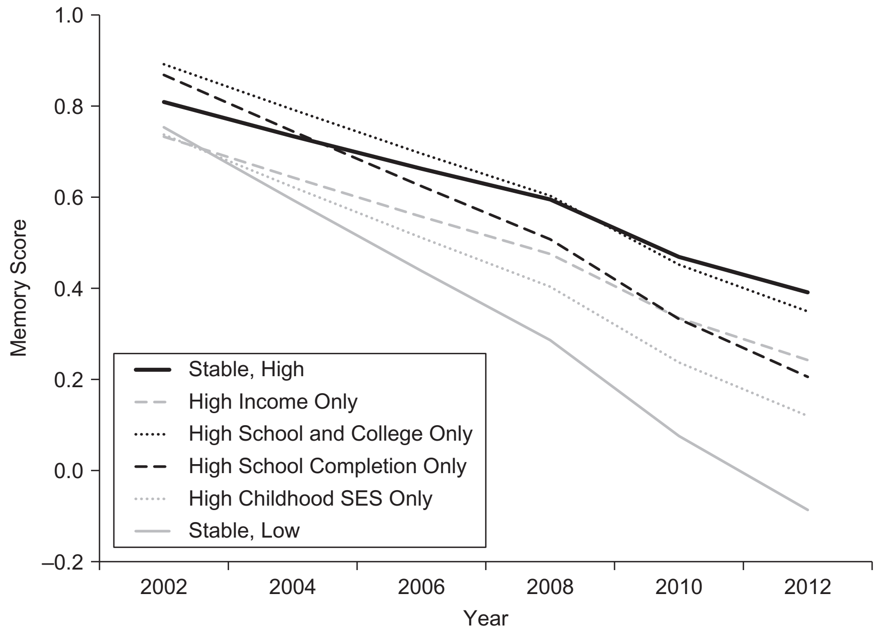

Figure 2. Predicted memory decline curves, Health and Retirement Study, United States, 2000–2012. Predictions were calculated from the memory decline model that included all 3 socioeconomic status (SES) measures and their interactions (Table 5, model 3).

(42)) have found no consistent association between education and rate of decline (20, 40–50). Little is known about the contribution of SES at different stages in the life course to rate of cognitive decline (9, 19, 20, 58, 72, 73). Most studies to date are either underpowered (i.e., null) or find that high SES at all time points is associated with slower rates of decline compared to low SES at all time points. Gonzalez et al. (20) also used HRS data, but their work differs from ours in several important ways that change the inferences their analyses can support. First, they included only participants aged ≥65 years, whereas we included all participants aged ≥50 years, increasing power and potentially allowing us to detect earliest memory changes. Gonzalez et al. (20) excluded proxy interviews (likely to represent the most impaired individuals) and participants in the bottom 5% of cognitive test scores at baseline. Therefore, their work addresses the question of whether rate of change in older adults is predicted by life-course SES when the older adults have no evidence of cognitive impairment. Our analyses did not exclude participants using criteria related to cognitive function, and we included study participants with proxy interviews, because we believe both exclusions would potentially lead to an underestimation of the total effect of SES on cognitive decline in the entire population (i.e., including persons with extreme cognitive test scores). More fundamentally, Gonzalez et al. (20) characterized social conditions quite differently, examining all measures of childhood SES in a single model (i.e., controlling each for the others) and all measures of adult SES in a single model. All of these distinctions may explain why Gonzalez et al. (20) found no evidence of an association between life-course SES and decline, while we did. Thus, our findings contribute in 2 ways: 1) we found that higher education was associated with slower rate of decline, and 2) we provide novel evidence on late-life SES and decline, finding that late-life income was a stronger determinant of rate of decline than education.

These results have implications for the prevention of dementia-related outcomes, including mild cognitive impairment, amnestic mild cognitive impairment, and dementia. Preventing the onset of dementia is a high priority for public health, and 2 alternative approaches can be conceptualized: investing in improving cognitive reserve and slowing the rate of decline (4). We found that education was the main contributor to cognitive reserve (i.e., memory functioning, in our analyses), indicating that investing earlier in life is likely necessary in order to increase cognitive reserve. On the other hand, because we found that late-life income was the primary driver of decline, interventions later in life might be able to slow the rate of decline. Of course, because later-life SES is influenced by previous SES, interventions aimed at earlier life might also be effective at slowing decline. Therefore, given that both cognitive reserve and rate of decline influence the onset of dementia-related outcomes, interventions at both early and late stages of the life course may delay their onset.

Because we used different measures of SES at each time point, we cannot disentangle whether it is the timing of SES or the specific dimension of SES that matters. For example, our results are consistent with the idea that late-life level of memory function is influenced most by SES in early adulthood, when the most relevant measure of SES happens to be education. In this scenario, it is not actually anything specific about education that matters for memory, but rather it is something about this developmental stage and one's sensitivity to different social environments. Our results are also consistent with the alternative that it is the specific SES indicator that matters, as opposed to the timing of exposure to socioeconomic disadvantage. For example, there may be something about finishing high school—whether it is the actual acquisition of knowledge or the opportunities stemming from having the credential—that affects level of memory in late life (74). Similarly, having more income in late life may slow the rate of memory decline. However, we lack a measure of income in early life so we cannot tease out whether the effect of income on decline is specific to the age at which the high income is enjoyed. Several mechanisms plausibly link income and cognitive decline, including both material and psychosocial pathways (74). For example, higher income improves access to healthcare and healthy diets (material pathways) (75). Higher income also means more financial stability and lower financial stress (psychosocial pathways). Although in theory the effects of late-life income could also reflect the impact of continuing labor-force participation in older age, our sensitivity analyses showed similar estimated effects for wealth—which we would hypothesize to be less correlated with continuing labor-force participation—and we found no evidence that the relationship between income and memory was attenuated by labor-force status.

The available cognitive measures are an important limitation to this analysis; we lack assessment of many important domains of cognitive function. Unfortunately, we cannot distinguish the cause of memory decline (e.g., Alzheimer versus cerebrovascular disease), but this is a typical limitation of neuropsychological measures. For SES, having 2 measures in adulthood is a clear benefit, but the retrospective nature of the childhood and early adult measures is a limitation. Most important, this study is observational and therefore the possibility of unmeasured confounding remains. Specifically, we have little information on potential confounders in early and mid-life (because the study enrolled subjects after age 50 years), and the variables are reported retrospectively. Early-life cognitive function is an important potential confounder for which we have no measure. Evidence from natural experiments suggests the relationship between education and late-life memory is not entirely due to confounding (76, 77), but there is no comparable quasiexperimental evidence with respect to income.

Major strengths of this study are a focus on the social determinants of both late-life level and decline in memory; longitudinal follow-up on a large, diverse, and well-characterized cohort; and the incorporation of appropriate statistical methods to account for time-varying exposure history.

In conclusion, we found that education was the strongest predictor of level of memory function, whereas late-life income more strongly predicted rate of memory decline. This suggests that interventions in late life focused on SES or its downstream consequences—such as health behaviors—have the potential to slow cognitive decline. Future studies should attempt to more rigorously evaluate causality, tease out the potential mechanisms driving these associations, and assess whether these relationships differ by race/ethnicity, sex, or age.

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