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RESEARCH ARTICLE

Education and midlife cognitive functioning: Evidence from the High School and Beyond cohort

Chandra Muller[1] | Eric Grodsky[2] | Adam M. Brickman[3] | Jennifer J. Manly[3] | Koit Hung[1] | Michael J. Culbertson[2] | John Robert Warren[4]

[1]Department of Sociology, University of Texas-Austin, Austin, Texas, USA

[2]Department of Sociology, University of Wisconsin-Madison, Madison, Wisconsin, USA

[3]Taub Institute for Research on Alzheimer's Disease and the Aging Brain, Department of Neurology — Vagelos College of Physicians and Surgeons, Columbia University, New York, New York, USA

[4]Institute for Social Research and Data Innovation, University of Minnesota, Minneapolis, Minnesota, USA

Correspondence
John Robert Warren, Institute for Social Research and Data Innovation — University of Minnesota, 909 Social Science, 267 19th Ave S. Minneapolis, MN 55455, USA.
Email: warre046@umn.edu

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Abstract

INTRODUCTION: Educational attainment is associated with midlife cognitive functioning. However, degree attainment is the culmination of complex and unequal processes involving students' backgrounds, the opportunities that schools provide them, and their performance within those schools—all of which may *also* shape midlife cognition. What do educational gradients in midlife cognition look like using a richer conceptualization and measures of "education?"

METHODS: We use data from High School and Beyond (HS&B:80)—a large, nationally representative sample of Americans followed from high school through age ∼60—to assess the role of education in stratifying midlife cognition.

RESULTS: High schools' academic and socioeconomic environments predict midlife cognition primarily through their associations with their students' academic performance. Student academic performance strongly predicts midlife cognition, partially through its association with degree attainment.

DISCUSSION: Inequalities in educational opportunities and in students' performance in schools shape midlife cognition—even among students with the same attained degrees.

KEYWORDS
cognitive functioning, education, life course, schools

Highlights

- Degree attainment predicts midlife cognitive functioning, but a large portion of that association is accounted for by students' high school academic performance as measured by test scores, grades, and course completion.
- High school contexts and learning opportunities predict midlife cognition mainly because they play a role in shaping students' academic performance.
- Understanding the potential benefits of education for later-life cognitive functioning requires attention to broader schooling processes and to students' academic performance beyond degree attainment.

1 | BACKGROUND

The risk of Alzheimer's disease and related dementias (ADRD) may be profoundly shaped by socioeconomic processes that begin in early life and operate in part through the education system.[1] Educational gradients in ADRD risk are well-documented; their sources are poorly understood.[2] In research in this area, education is almost always measured as "years of schooling completed" or "highest degree earned." However, measures of attainment may not capture important dimensions of education that matter for ADRD risk. This study focuses on high school contexts, opportunities, and outcomes that characterize the crucial period of schooling when most American adolescents are full-time students in highly stratified school settings.

As shown in Figure 1, the sociodemographic, spatial, and school contexts that precede degree attainment—from early childhood on—may shape cognitive functioning and its maintenance across adulthood.[3,4] We focus on high school, the last stage of compulsory schooling in the United States. As in the earlier stages, contexts and processes vary markedly across high schools; however, educational contexts and opportunities vary *within* high schools as well—across classrooms and curricular groupings.[1–3] These differential contexts and opportunities contribute to patterns of inequality in grades, achievement test scores, completion of college preparatory coursework, and other outcomes.[3,5] Advantageous social contexts and schooling opportunities certainly prepare students to succeed in college and the workforce, but they also equip those students with resources—such as higher-order thinking and non-cognitive skills—to continue to learn and adapt to challenges during adulthood.[6,7] Thus, the contexts, processes, and products of schooling—not just the degrees that ultimately result from them—may shape resilience and cognitive functioning even among people with the same terminal degrees.

Conceptualizing "education" as more than degree attainment (as per Figure 1) in research on educational gradients in cognition is warranted for several reasons. First, educational contexts and opportunities vary tremendously between and within high schools and among people who complete the same degrees. Second, there is limited but suggestive evidence that these processes and contexts of schooling are themselves associated with later-life cognitive functioning. Third, patterns of schooling inequalities—particularly related to race, ethnicity, family resources, and spatial location—may shed light on sources of disparities in ADRD risk. Fourth, educational processes and contexts are frequently modified through policy. A broader conceptualization and a more complete empirical operationalization of education can thus position the field to understand how education policy might improve long-term cognitive outcomes at the population level.

Previous research on educational gradients in cognition that conceives of education as more than just degree attainment has lacked

RESEARCH IN CONTEXT

1. **Systematic review**: The authors reviewed the literature using traditional sources and meeting abstracts. While there is a large literature relating educational degree attainment to later-life cognitive outcomes, there are much smaller literatures that consider other dimensions of education.
2. **Interpretation**: Our findings led us to conclude that midlife cognition is shaped by more than how far people go in school and what degrees they earn. Racism and classism influence the schools that students attend; the resulting inequities in educational contexts, resources, and opportunities to learn influence what students accomplish in their schools prior to graduation. All of these are related to midlife cognition.
3. **Future directions**: To understand how education shapes cognition in the long term, ADRD researchers should use data that include details about early life educational contexts, opportunities, and outcomes like those available in HS&B:80. Analysis of the effects of racism and classism on education and how they shape cognition in later life is essential.

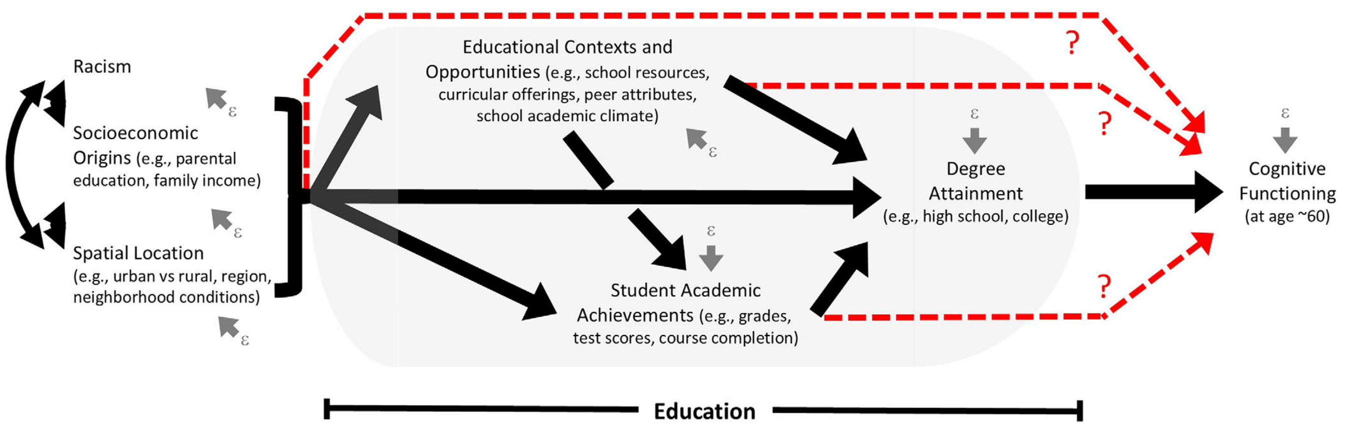

FIGURE 1 Conceptual model.

suitable nationally representative data. For instance, research has relied on *state*-level indicators of school quality such as student-teacher ratios, school term length, and attendance rates[8–10]; however, given local control of schooling systems and patterns of residential and school segregation, most of the variability in school quality is within (not between) states. Other researchers have used stronger measures but data from cohorts in specific regions of the United States or populations that have experienced high rates of selective mortality.[11,12]

Newly available nationally representative data—collected prospectively from high school students who were reinterviewed in midlife—provide valuable insights into the nature of the relationships between education and later life cognitive functioning. Specifically, we examine the possibility that advantageous educational contexts, learning opportunities, and academic outcomes at the end of high school contribute meaningfully to better cognitive functioning at age ~60—even among people with the same terminal degrees.

We address two main questions. First, do (a) high school contexts and learning opportunities and (b) student's academic performance within those schools predict midlife cognitive functioning, even after taking family background and demographic characteristics into account? Second, to what extent are associations between degree attainment and midlife cognition due to the school contexts and learning opportunities, student academic performance, and family background that are observed prior to degree attainment?

2 | METHODS

2.1 | Sample selection

High School and Beyond (HS&B:80) began in 1980 as a nationally representative probability sample of 30,030 high school sophomores and 28,240 high school seniors from a probability sample of 1,020 U.S. public and private high schools.[13] From the initial sample of 58,270 students, a random subset of 14,830 sophomores and 12,000 seniors have been re-interviewed multiple times. Panelists were almost all born between 1961 and 1965 and were thus between 56 and 60 when last contacted in 2021. Note that all reported sample sizes have been rounded to the nearest 10 in accordance with the requirements of restricted-use data licenses.

The 1980 student, parent, teacher, and school administrator questionnaires gathered data on students' educational experiences; school curricular offerings; school composition and resources; student-level outcomes (e.g., grades, coursework); and family socioeconomic background (e.g., parental education and occupation, family composition, siblings, parenting practices, and parents' educational and occupational expectations for their children). Both the sophomore and senior cohorts completed standardized multiple-choice achievement tests in reading, vocabulary, and math. Secondary and post-secondary transcripts have been appended to student records.

Senior and sophomore cohort panel members were re-surveyed in 1982, 1984, and 1986; sophomores were re-surveyed in 1992 and 2014; and seniors were re-surveyed in 2015. HS&B:80 surveys have had remarkably high response rates—ranging from ~90% in the 1980s to ~65% in the 2014 and 2015 follow-ups. In 2021, all surviving members of the HS&B:80 cohort were again recontacted. Fieldwork included a multimode survey that assessed neurocognitive functioning and asked about a variety of other topics. Sample members initially completed either a telephone or Web survey; they were offered the other mode if they did not initially respond. Some sample members were invited to complete the telephone survey after the Web survey; these were people who either (a) scored in the bottom quartile of the distribution of either of the cognitive tasks administered on the Web survey or (b) were among 25% of Web survey completers scoring above the bottom quartile and selected at random. Of surviving eligible HS&B:80/21 sample members, 13,980 completed surveys in 2021—a response rate of 58%.

The resulting data and associated documentation are freely available to the research community to facilitate scholarship on cognitive functioning, cognitive aging, and inequalities in those outcomes. The 2021 (and earlier) HS&B:80 de-identified survey data are available via the US Department of Education's restricted-use data license program. All data collection, research procedures, and analyses were performed in compliance with relevant laws and institutional guidelines with the approval of institutional review boards. Informed consent was obtained prior to collecting data from HS&B:80 sample members. See Grodsky et al.[13] and www.edshareproject.org for more details about the HS&B:80 data.

2.2 | Measures

Descriptive statistics for all measures—separately by mode of response—are reported in Table 1.

2.3 | Cognitive outcomes

The 2021–2022 telephone survey included neurocognitive assessments of (1) auditory attention and working memory; (2) verbal learning and episodic memory; (3) letter fluency; and (4) semantic fluency. The Web survey included two assessments of episodic memory via (5) a verbal paired associates task and (6) a visual paired associates task. Each task on the phone survey was evaluated by a team of trained scorers; for most tasks, independent re-scoring allowed us to identify and correct problems in scoring.

2.3.1 | Auditory attention and working memory

In a "forward number span" task, participants heard increasingly longer lists of digits, one digit per second, and were immediately asked to repeat the digits in the same order. Each item provided two chances to repeat a certain length of digits; the task was discontinued if participants incorrectly recalled two sequences of the same length of digits in a row. Then, in a "backward number span" task, sample members

TABLE 1 Descriptive statistics.

Parameter	Telephone responders			Internet responders			All responders		
	ȳ or %	(SD)	*N*	ȳ or %	(SD)	*N*	ȳ or %	(SD)	*N*
Cognitive outcomes									
Auditory attention and working memory	0.04	(0.83)	5560		—			—	
Verbal learning episodic memory	0.01	(0.86)	5560		—			—	
Letter fluency	0.04	(0.84)	5560		—			—	
Semantic fluency	0.06	(0.80)	5560		—			—	
Verbal paired associates		—		–0.08	(0.92)	8660		—	
Visual paired associates		—		–0.06	(0.89)	8660		—	
Global cognitive functioning		—			—		–0.09	(0.83)	12,530
Educational attainment									
No high school degree	1.6%		5560	2.2%		8660	2.1%		12,530
High school only	19.4%			19.0%			20.5%		
Some college	41.2%			42.5%			41.0%		
Bachelor's degree	22.3%			21.4%			21.8%		
Graduate degree	15.6%			14.8%			14.6%		
School social, spatial, and academic context									
Schools' students: percent White	77.97	(26.61)	5260	79.27	(25.75)	8200	78.89	(26.24)	11,870
Schools' students: mean socioecon. status	–0.02	(0.39)	5560	–0.02	(0.38)	8660	–0.02	(0.38)	12,530
School: Northeast region	22.5%		5560	22.6%		8660	22.3%		12,530
School: South region	29.1%			31.3%			30.7%		
School: Midwest region	27.4%			27.4%			27.9%		
School: West region	21.0%			18.6%			19.1%		
School: academic press	0.04	(0.88)	5480	0.01	(0.81)	8540	0.01	(0.83)	12,350
School: math value added	0.01	(0.76)	5390	0.03	(0.74)	8410	0.02	(0.75)	12,160
Student-level academic outcomes									
Highest math: < algebra 1	17.8%		4890	17.3%		7840	17.8%		11,200
Highest math: algebra 1 or geometry	29.1%			31.6%			31.4%		
Highest math: algebra 2 or above	53.1%			51.1%			50.8%		
Grade point average	2.85	(0.73)	4930	2.83	(0.74)	7890	2.83	(0.73)	11,270
Math achievement test score	0.13	(0.99)	5160	0.08	(0.99)	8110	0.07	(0.97)	11,690
Vocabulary achievement test score	0.14	(1.00)	5200	0.07	(0.98)	8150	0.06	(0.98)	11,760
Reading achievement test score	0.12	(1.00)	5190	0.07	(0.99)	8140	0.06	(0.97)	11,740
Curricular track: general	35.5%		4910	36.5%		7850	35.6%		11,220
Curricular track: academic	39.8%			40.5%			40.3%		
Curricular track: vocational	24.6%			23.0%			24.1%		
Sociodemographic background									
Male	48.1%		5560	47.5%		8 660	47.9%		12,530
Female	51.9%			52.5%			52.1%		
White	72.0%		5560	73.6%		8660	73.9%		12,530
Black	11.3%			11.4%			11.2%		
Latinx	12.1%			10.4%			10.4%		
Other race/ethnicity	4.6%			4.6%			4.6%		
Senior in 1980	45.5%		5560	44.8%		8660	44.5%		12,530
Disabled (grade 12)	9.2%		5150	7.0%		8050	8.6%		11,620
Parent: less than high school	13.9%		5350	12.0%		8340	11.7%		12,060

(Continues)

TABLE 1 (Continued)

	Telephone responders			Internet responders			All responders		
Parameter	ȳ or %	(SD)	*N*	ȳ or %	(SD)	*N*	ȳ or %	(SD)	*N*
Parent: high school graduate	27.5%			32.9%			31.7%		
Parent: some college	31.8%			29.6%			30.6%		
Parent: bachelor's degree or more	26.9%			25.6%			26.0%		
Parent: occupational prestige	48.17	(13.28)	4100	47.76	(12.65)	6720	47.50	(12.64)	9510
Family income (log $)	9.92	(0.67)	4500	9.93	(0.66)	7210	9.93	(0.66)	10,290
Number of siblings	2.92	(1.69)	4970	2.93	(1.71)	7830	2.91	(1.72)	11,250
School: urban area	24.4%		5560	20.9%		8660	21.8%		12,530
School: suburban area	47.0%			50.0%			49.4%		
School: rural area	28.6%			29.1%			28.8%		

Note: The sample is restricted to High School and Beyond sample members who responded by phone or Internet to the 2021–2022 survey. All sample sizes are rounded to the nearest 10 in accordance with the requirements of restricted data access protocols.

completed the same task except that numbers were to be read back in reverse order.

2.3.2 | Verbal learning and episodic memory

Respondents were read a list of 10 words from the CERAD word list[14] approximately 2 s apart. Once the list was read, they were asked to recall the words in any order; this "immediate recall" task reflects the ability to learn new verbal information and to retrieve that information from short-term storage. After a delay of about 20 min, participants were again asked to recall as many of the list of 10 words as they could. This "delayed recall" task reflects the ability to retain verbal information over time and to retrieve that information from longer-term storage.

2.3.3 | Letter fluency

Respondents were asked to generate as many words as possible that begin with the letter "F" within 60 s, without using proper nouns, and without using the same word with a different ending. This task assesses phonemic processing and lexical access speed.[15]

2.3.4 | Semantic fluency

Respondents were given 60 s to generate the names of as many animals as possible. This task measures semantic processing and lexical access speed.[15]

2.3.5 | Verbal paired associates[16]

Participants were visually presented with 25 pairs of words (e.g., CITY | VIOLIN) and informed they would later be tested on which words were paired together. Word pairs are presented sequentially for 3000 ms each, with a 500 ms interstimulus interval between pairs. After a delay of a few minutes, participants were sequentially presented with one word from each of the studied word pairs and were asked to identify which word was previously paired with it by selecting the correct word from a list of four response options.

2.3.6 | Visual paired associates[16–18]

Participants were presented with 24 pairs of images and informed they would later be tested on which images were paired together. The two images within each image pair were unique examples of the same type of object or scene (e.g., two images of cars). Image pairs were presented sequentially for 5000 ms each, with a 1500 ms interstimulus interval between pairs. After a few minutes, participants were sequentially presented with one image from each of the studied image pairs and were asked to identify which image was previously paired with the probe image by selecting the correct image from five response options.

In analyses of the preceding six sets of task scores, we used dependent variables derived via Item Response Theory (IRT). A detailed description of the construction of these variables is provided in the Appendix.

2.3.7 | Global cognitive functioning

Finally, to provide a measure of cognition across respondents who participated by telephone and Web, we developed a measure of general cognitive functioning. We derive this measure from a hierarchical IRT model[19] that combines information from—and accounts for shared variance across-all six of the above tasks. To enhance comparability across survey modes and improve measurement precision, we incorporated a broad set of covariates from high school and midlife as an explanatory component of the higher-order latent variable;[20] the latter captures the common variation in cognition expressed in the six specific cognitive tasks and can be interpreted as an index of general cognitive functioning across memory and fluency domains. A detailed description of the construction of this measure also appears in the Appendix.

2.3.8 | Educational attainment

We rely on a self-reported measure of the highest degree completed that was obtained in the 2021 survey. Analyses based on alternative measures of educational attainment—for example, a measure that reflects the highest level of attainment ever reported across any survey or transcript source—yield substantive results that are quite like those we present below; those alternative results are available upon request.

2.3.9 | School contexts

We measure three dimensions of the contexts of high schools that sample members attended in 1980: (1) social context; (2) academic context; and (3) spatial context. Note that some measures are derived from school administrator reports in 1980 while others use design elements—a two-stage probability sample of schools and students nested in them, and large within school samples in the 1980 base year—to characterize the school contexts all sample members experienced. These measures pertain to entire schools and, thus, have the same value for all students within them.

School social context

We include two dimensions of school social contex: the *percentage of students who are white* (as reported by school administrators) and each *school's mean student socioeconomic background* (which reflects an index that is aggregated up to the school level and based on full base-year sample students' responses to questions about their father's educational attainment, their father's occupation, their mother's educational attainment, their family's income, and whether their family had possessions like an encyclopedia, a typewriter, more than two vehicles, and more than 50 books).

School spatial context

To place our findings in the context of prior research that hypothesized that regional differences in social structural inequality that partly underly effects of Southern birth,[3,21,22] we include *region* as a contributor to school context.

School academic context

We draw on extensive research—much of it based on HS&B:80 data—showing the effects of schools on students' academic outcomes.[23] We include an index of *academic press*[23]—a composite school-level measure that includes measures of students' self-reported hours per week spent on homework; students' attitudes toward getting good grades; students' interest in school, math, and English; students' reports of their school's academic rigor; students' mean number of math and science courses taken; and students' distribution across academic, general, and remedial curricular tracks. Building on ideas from organizational theory, the concept of "academic press" refers to the degree to which schools' organizational structures and academic climate "press" students toward higher academic performance. Finally, we include *mathematics value-added*, a measure of the average gains in mathematics test scores that students in each HS&B:80 school achieved between their sophomore and senior years conditional on their initial baseline test scores. Based on a school random-effects model, this measure aggregates the total contribution of attending a school between 10th and 12th grade—including the influence of school organization, resources allocation, teachers' skill and effectiveness, academic climate, and peer attributes, and so forth—to test score gains, net of student achievement in 10th grade.

Academic outcomes in high school

Student-level academic outcomes (besides attainment) include three measures at the end of 12th grade: the *highest mathematics course taken*, *grade point average*, and standardized scores on *achievement tests in mathematics, vocabulary, and reading*. The achievement tests measured concepts taught in the high school curriculum; for example, the mathematics test focused on concepts in algebra, geometry, and trigonometry.[24] Finally, we include an indicator of student enrollment in the general, academic, or vocational *curriculum track*.

Sociodemographic background

The availability of individual-level data from early life positions us to assess conditional associations between education and later-life cognitive functioning. Of particular interest are patterns of structural inequality related to students' self-reported *race, ethnicity, gender*, and *family socioeconomic background* (*highest level of parents' education, highest of parents' occupational prestige, logged family income, and number of siblings*). We also adjust for control variables measuring students' self-reported *disability status in 12th grade*, their *graduation cohort* (i.e., sophomore or senior in 1980), and the *urbanicity* (i.e., urban, rural, suburban) of their high school.

2.4 | Statistical analyses

We estimate a series of ordinary least squares (OLS) regression models separately for each cognitive outcome. In Model 1, we regress the outcome on (a) measures of schools' social, regional, and academic contexts and (b) race and ethnicity, gender, sociodemographic background, and adolescent urbanicity of residence—all of which are covariates ascribed between birth and adolescence. Model 2 begins with Model 1 but adds measures of student-level academic outcomes. Next, Model 3 adds educational attainment. Finally, in Model 4 we regress the outcome on race and ethnicity, gender, sociodemographic background, adolescent urbanicity of residence, and educational attainment; this model approximates prior research, which typically can only characterize education in terms of degree attainment.

All models use sampling weights that cause the samples of HS&B:80 panelists who (a) responded to the 2021 telephone survey, (b) responded to the 2021 Internet survey, and (c) responded to either or both surveys in 2021 to be representative of the population from which these samples were drawn. We report coefficients and 95%

confidence intervals based on standard errors that are adjusted for the school-based cluster sampling design.

Finally, missing values of all variables are multiply imputed using Stata's mi commands for chained equations;[25,26] all reported results are based on five multiply imputed data sets. Logistic regression models were used for binary variables; ordinal logistic regression models were used for variables with more than two ordered categories; OLS linear regression models were used for individual-level continuous variables; and predictive mean matching (with draws from 20 nearest neighbors) was used for school-level continuous variables. All variables used in the analysis were included as covariates in each chained regression model. See Table A1 for information about the percentage of cases missing values for each variable and for more details on how missing values were imputed. Rates of missing values are generally low, are higher (~10%) for some self-reported educational outcomes, and are highest (~20%) for students' reports of parental income and occupation.

3 | RESULTS

3.1 | Descriptive results

Table 1 reports descriptive statistics for cognitive outcomes in 2021 (at about age 60); educational attainment; school social, spatial, and academic contexts; sociodemographic variables; and student-level academic outcomes. The table makes clear that the HS&B:80 sample is highly diverse with respect to socioeconomic origins, race, ethnicity, region and place of residence, educational performance in high school, and degree attainment. The table also shows that there are only minor differences in student- and school-level attributes across sample members who responded via different modes.

3.2 | Multivariate results

In Table 2, we report results for multivariable models predicting global cognitive functioning. In online appendices, we present results from parallel models predicting attention and verbal working memory (Table A2); verbal episodic memory (Table A3); letter fluency (Table A4); semantic fluency (Table A5); episodic memory as assessed using verbal (Table A6) and visual (Table A7) paired associates tasks. Results are broadly similar. However, (a) only the global cognitive functioning measure pertains to the entire cohort and (b) the global measure is more reliable than its component measures.

3.2.1 | Model 1: School social, academic, and spatial contexts

Results for Model 1 show that—net of sociodemographic background factors—some school context measures are associated with midlife cognition. Students who attended schools with a higher percentages of White students and students who attended schools with greater levels of academic press scored higher on global cognitive functioning.

3.2.2 | Model 2: Student-level high school academic performance

A manifest purpose of schools is to boost students' knowledge and skills and their academic achievement; better schools generally do more to enhance student learning and academic success. In Model 2, we add measures of students' pre-degree attainment academic outcomes measured in high school. Many of the school context measures introduced in Model 1 that predicted midlife cognitive function are now, perhaps not surprisingly, no longer significant predictors of midlife cognitive functioning in Model 2. For example, the coefficient for academic press—which has been shown to promote students' learning and achievement—is attenuated and no longer statistically distinguishable from zero after considering students' high school academic performance.

Students' academic outcomes in high school are strong predictors of midlife cognitive functioning. There are sizable conditional associations between academic accomplishments in high school and midlife cognition; many of these associations are large in magnitude. For example, all else equal, a one-point increase in high school grade point average is associated with about one sixth of a standard deviation increase in global cognitive functioning.

The addition of student-level high school academic outcomes In Model 2 greatly attenuates many of the coefficients for student sociodemographic variables seen in Model 1. For example, adjusting for high school academic performance reduces by *more than half* the advantages of having a college-educated parent.

3.2.3 | Model 3: Educational degree attainment

In Model 3, we add a measure of sample members' highest degree attained. Not surprisingly, we see a sizable gradient in global cognitive functioning at midlife across levels of degree attainment (all else equal). For example, as compared to students who only completed high school, those who completed a bachelor's degree scored about half a standard deviation higher on our measure of global cognitive functioning, all else equal. Appendix Tables A2 through A7 show similar patterns across each individual measure of midlife cognitive functioning.

Of note, however: Adding educational attainment to the model does little to attenuate associations between measures of students' high school academic performance and midlife cognition. High school academic performance as measured by grades and achievement test scores predicts midlife cognitive functioning, but this is not primarily because students with better grades and test scores are more likely to complete high school and go on to college.

3.2.4 | Model 4: Approximating prior research

In Model 4, and for purposes of comparing our findings to those from prior studies that have *only* had access to degree attainment as a measure of education, we begin with Model 3 but exclude measures of

TABLE 2 OLS regressions of global cognitive functioning on education ($n = 12{,}530$).

	Model 1		Model 2		Model 3		Model 4	
	b	[95% CI]	b	[95% CI]	b	[95% CI]	b	[95% CI]
Educational attainment								
No high school degree					−0.03	[-0.18,0.12]	0.14	[-0.00,0.29]
High school only						*[Ref. Category]*		*[Ref. Category]*
Some college					0.21	***[0.07,0.35]***	0.57	***[0.42,0.71]***
Bachelor's degree					0.41	***[0.26,0.56]***	1.05	***[0.90,1.20]***
Graduate degree					0.55	***[0.41,0.70]***	1.29	[1.13,1.44]
School social, spatial, and academic context								
Schools' students: Percent white	0	***[0.00,0.00]***	0	[-0.00,0.00]	0	***[0.00,0.00]***		
Schools' average socioeconomic status	−0.01	[-0.10,0.08]	0.01	[-0.06,0.08]	0	[-0.07,0.07]		
School: Northeast region		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*		
School: South region	−0.03	[-0.09,0.03]	0.03	[-0.03,0.08]	0.01	[-0.04,0.05]		
School: Midwest region	0.03	[-0.02,0.09]	0.05	***[0.00,0.09]***	0.03	[-0.01,0.07]		
School: West region	0.07	***[0.00,0.14]***	0.12	***[0.07,0.18]***	0.11	***[0.06,0.16]***		
School: Academic press	0.11	***[0.08,0.15]***	0	[-0.02,0.03]	−0.01	[-0.04,0.02]		
School: Math value added	0.03	[-0.00,0.06]	−0.01	[-0.03,0.02]	−0.01	[-0.03,0.02]		
Student-Level academic outcomes								
Highest math: < algebra 1				*[Ref. Category]*		*[Ref. Category]*		
Highest math: Algebra 1 or geometry			0.07	***[0.02,0.12]***	0.05	***[0.00,0.10]***		
Highest math: Algebra 2 or above			0.08	***[0.03,0.14]***	0.04	[-0.01,0.10]		
Grade point average			0.15	***[0.12,0.18]***	0.11	***[0.08,0.14]***		
Math achievement test score			0.24	***[0.21,0.26]***	0.2	***[0.18,0.23]***		
Vocabulary achievement test score			0.12	***[0.09,0.15]***	0.1	***[0.08,0.13]***		
Reading achievement test score			0.19	***[0.16,0.21]***	0.17	***[0.15,0.20]***		
Curricular track: General				*[Ref. Category]*		*[Ref. Category]*		
Curricular track: Academic			0.06	***[0.02,0.10]***	0.01	[-0.02,0.05]		
Curricular track: Vocational			−0.05	***[-0.10,-0.01]***	−0.04	[-0.08,0.00]		
Sociodemographic background								
Female		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*
Male	−0.40	***[-0.44,-0.37]***	−0.41	***[-0.44,-0.38]***	−0.39	***[-0.42,-0.36]***	−0.34	***[-0.38,-0.31]***
White		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*
Black	−0.70	***[-0.78,-0.62]***	−0.35	***[-0.41,-0.29]***	−0.38	***[-0.44,-0.33]***	−0.75	***[-0.80,-0.69]***
Latinx	−0.42	***[-0.48,-0.35]***	−0.08	***[-0.13,-0.03]***	−0.09	***[-0.14,-0.04]***	−0.37	***[-0.42,-0.33]***
Other Race/Ethnicity	−0.25	***[-0.38,-0.11]***	−0.15	***[-0.26,-0.04]***	−0.15	***[-0.26,-0.04]***	−0.25	***[-0.38,-0.12]***
Senior in 1980	0.03	[-0.01,0.07]	−0.01	[-0.04,0.03]	−0.02	[-0.05,0.01]	−0.01	[-0.05,0.02]
Disabled (Grade 12)	−0.25	***[-0.33,-0.18]***	−0.09	***[-0.15,-0.03]***	−0.09	***[-0.15,-0.04]***	−0.21	***[-0.27,-0.15]***
Parent: Less than high school		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*
Parent: High school graduate	0.09	***[0.02,0.17]***	0.05	[-0.00,0.11]	0.05	[-0.01,0.10]	0.08	***[0.01,0.15]***
Parent: Some college	0.28	***[0.19,0.36]***	0.11	***[0.05,0.16]***	0.07	***[0.02,0.12]***	0.17	***[0.09,0.24]***
Parent: Bachelors degree or more	0.43	***[0.34,0.52]***	0.11	***[0.05,0.17]***	0.05	[-0.01,0.10]	0.22	***[0.14,0.30]***
Parent: Occupational prestige	0.01	***[0.00,0.01]***	0	***[0.00,0.00]***	0	***[0.00,0.00]***	0	***[0.00,0.01]***
Family income (log $)	0.09	***[0.05,0.12]***	0.05	***[0.02,0.07]***	0.04	***[0.02,0.07]***	0.07	***[0.04,0.10]***
Number of siblings	−0.03	***[-0.05,-0.02]***	−0.01	[-0.02,0.01]	0	[-0.01,0.01]	−0.01	***[-0.02,-0.00]***
School: Urban area		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*		*[Ref. Category]*

(Continues)

TABLE 2 (Continued)

	Model 1		Model 2		Model 3		Model 4	
	b	[95% CI]	b	[95% CI]	b	[95% CI]	b	[95% CI]
School: Suburban area	0.01	[-0.05,0.06]	0.03	[-0.02,0.08]	0.02	[-0.02,0.07]	0.03	[-0.02,0.08]
School: Rural area	0.03	[-0.03,0.09]	−0.01	[-0.06,0.03]	−0.01	[-0.06,0.03]	0.03	[-0.03,0.08]
Constant	−1.18	***[-1.59,-0.77]***	−1.15	***[-1.44,-0.86]***	−1.14	***[-1.43,-0.84]***	−1.44	***[-1.78,-1.10]***
R^2	0.36		0.69		0.72		0.53	

Note: Sample restricted to HS&B:80 sample members who responded to the 2021–2022 survey. Missing values have been imputed using chained equations. Analyses employ sampling weights and account for within-school clustering in 1980. All sample sizes are rounded to the nearest 10 in accordance with the requirements of restricted data access protocols. Bolded and italicized confidence intervals do not contain zero.
Abbreviations: CI, confidence interval; LOS, ordinary least squares.

schools' social and academic contexts and of students' high school academic performance. Several findings are notable.

First, the coefficients for degree attainment are roughly *twice* as large in Model 4 as compared to their counterparts in Model 3. This suggests that prior research may have dramatically *overstated* the role of educational attainment in shaping midlife cognition; it also highlights the extent to which school processes and students' academic performance prior to degree attainment may contribute to midlife cognitive functioning.

Second, the coefficients for many of the ascribed sociodemographic variables in Model 4 are roughly twice as large as their counterparts in Model 3. This suggests that prior research has dramatically *understated* the role of early life socioeconomic background in shaping school contexts, opportunities, and non–degree-attainment outcomes, which in turn influence midlife cognition.

Although we have featured results of models of global cognitive functioning, results for the six cognitive tasks that comprise that global measure are broadly similar. To the extent that school contexts predict the outcome, that association is largely attenuated by student-level school performance. Students' academic performance in high school is generally predictive of cognition, even net of degree attainment—and much of the association between degree attainment and cognition appears to be spurious owing to students' academic performance in high school. Although results are broadly similar across outcomes, we note that associations between all measures of education and (a) auditory attention and working memory and (b) verbal learning and episodic memory are weaker than for the other outcomes.

4 | DISCUSSION

It is well established that educational degree attainment predicts midlife cognitive functioning. However, as depicted in Figure 1, degree attainment is the result of complex and unequal processes involving students' sociodemographic backgrounds, the contexts and opportunities that schools provide them, and their performance within those schools—all of which may also shape midlife cognition. What do educational gradients in midlife cognition look like using a richer conceptualization and measures of "education" from the last stage of American schooling that is compulsory, highly stratified, and precedes degree attainment for most people?

We use rich, newly available data from a large, nationally representative education cohort study that first interviewed young people as high school sophomores and seniors and has been repurposed as a cohort study of later life health and cognition to ask two basic research questions. First, do (a) high schools' social contexts and academic learning opportunities and (b) students' academic performance within those schools predict midlife cognitive functioning? We found that they do; however, high school contexts predict midlife cognitive functioning mainly because they influence what students achieve within them. Notably, those school contexts are also a function of family resources and of racial, ethnic, regional, and socioeconomic differences in distributions of school resources.

Second, to what extent are oft-observed associations between degree attainment and midlife cognition shaped by high school contexts and student academic performance observed prior to degree attainment? We found that prior research has likely *overstated* the role of degree attainment in stratifying midlife cognition while also *understating* the roles of early life socioeconomic and demographic inequities that shape access to school resources, school contexts, learning opportunities, and ultimately high school academic performance.

In Figure 1, we depicted a conceptual model of the ways in which historical and contemporary oppression and institutional inequalities experienced very early in life, educational contexts and opportunities, students' educational performance in school, and degree attainments combine to shape midlife cognitive functioning. Degree attainment—which is all that most research measures about education—matters for midlife cognition, but the independent association is not as strong as much prior research has claimed. School contexts and opportunities to learn matter because they shape students' academic performance as indexed by measures like grades, academic test scores, and course completion. Advantageous school contexts and opportunities influence students' academic performance, and students' academic performance is, in turn, strongly associated with midlife cognition.

Failing to account for school contexts, learning opportunities, and students' academic performance in high school leads to a substantial overstatement of the role of degree attainment, *per se*, in stratifying midlife cognition. At the same time, failing to account for school contexts, opportunities, and students' academic performance in school also leads to understatements of the role that education plays in producing early-life sociodemographic gradients in midlife cognition. Sociodemographic gradients in school contexts and especially in academic performance within schools puts young people on pathways toward unequal midlife cognitive functioning. This dynamic goes largely unobserved in research that only measures education in terms of degree attainment.

4.1 | Study limitations and future directions

Many of the limitations of our work stem from the basic fact that we use data from a large, population representative, community-based sample. First, following a cohort from adolescence to late midlife entails accepting that the educational and social contexts that HS&B:80 students experienced—in the early 1980s—may differ in important ways from the social and educational contexts that young people experience today.

Second, despite the wealth of information about education included in HS&B:80, we do not know anything about school contexts, opportunities to learn, or student-level achievements prior to high school. Our findings highlight the important role of high school performance as indexed by measures like grades and academic test scores; however, inequalities and inequities in such measures of school performance emerge long before high school, from early childhood education through middle school. Of course, studies of educational gradients in later life cogntion that only utilize measures of degree attainment *also* implicitly ignore variability in school contexts, opportunities, and student performance prior to high school.

Third, although HS&B:80 provides a unique opportunity to measure and model *between*-school differences in school contexts and opportunities, the data are weaker with respect to *within*-school differences in those same contexts and opportunities. Students within the same school may experience highly unequal educational environments and opportunities; for example, some teachers are more effective educators than others and some academic programs enhance student performance more than others. Nonetheless, our work represents a significant advance over previous research that has proxied between-school differences with county- or state-level indicators.

Education is more than how far people go in school and what degrees they earn. Racism and classism influence the schools that students attend; the resulting inequities in educational contexts, resources, and opportunities to learn influence what students accomplish in their schools prior to graduation. To understand how education shapes cognitive functioning in the long term—and perhaps to understand how school-based interventions could improve later life cognitive outcomes—ADRD researchers should use data that include details about early life educational contexts, opportunities, and outcomes like those available in HS&B:80, and should link educational exposures to historical and contemporary data on structural inequalities. Studying these aspects of education is essential because they can be modified by policy; however, we should not assume that policies improve education and its consequences for all groups of students. This will expand possibilities for understanding *how*, *why*, and *for whom* education impacts cognition and ADRD risk.

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CONFLICT OF INTEREST STATEMENT

The authors acknowledge no conflicts of interest. Author disclosures are available in the Supporting Information.

CONSENT STATEMENT

All authors have read and provided consent to be associated with this manuscript.

ORCID

Chandra Muller https://orcid.org/0000-0002-2216-7034
Eric Grodsky https://orcid.org/0000-0003-2178-0803
Adam M. Brickman https://orcid.org/0000-0002-5125-8226
Jennifer J. Manly https://orcid.org/0000-0002-9481-7497
John Robert Warren https://orcid.org/0000-0001-6079-5122

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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