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RESEARCH ARTICLE

High school quality is associated with cognition 58 years later

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Abstract

We leveraged a unique school-based longitudinal cohort—the Project Talent Aging Study—to examine whether attending higher quality schools is associated with cognitive performance among older adults in the United States (mean age = 74.8). Participants (n = 2,289) completed telephone neurocognitive testing. Six indicators of high school quality, reported by principals at the time of schooling, were predictors of respondents' cognitive function 58 years later. To account for school-clustering, multilevel linear and logistic models were applied. We found that attending schools with a higher number of teachers with graduate training was the clearest predictor of later-life cognition, and school quality mattered especially for language abilities. Importantly, Black respondents (n = 239; 10.5 percentage) were disproportionately exposed to low quality high schools. Therefore, increased investment in schools, especially those that serve Black children, could be a powerful strategy to improve later life cognitive health among older adults in the United States.

1 | INTRODUCTION

Education is an important predictor of later-life cognition and Alzheimer's disease and related dementias (ADRD).[1–3] Because many aspects of education are amenable to policy change, its potential to impact later-life brain health has been elevated, even though educational systems and experiences are complex and may affect health in multitude of ways.[4]

During the 20th century, U.S. educational policies focused on duration of schooling with introduction of laws regulating minimum entry age, minimum drop-out age, or mandatory length of enrollment. But it is unclear if such policies causally affect dementia.[5,6] Current educational policy has increased focus on quality of education with legislation such as Every Student Succeeds Act[7]. However, the extant literature on school quality and later life brain health is sparse.[8,9] Several studies leveraged the stark differences in quality between schools serving Black and White children prior to Brown vs. Board of Education. Most indicate that attending segregated schools predicts lower later-life cognition among Black people.[10–13] School quality was also shown to contribute to racial disparities in cognition.[8] Despite the landmark ruling of Brown vs. Board of Education in 1954 for school desegregation, the U.S. educational system continues to be racially segregated and schools serving Black children continue to receive fewer resources[14] that contribute to provision of high quality schooling.[9] Subsequently, racial inequalities in school quality may contribute to persistent disparities in late-life cognitive outcomes for future generations.

There is no agreement on how to operationalize school quality in health research. Resource-driven school characteristics, such as teacher's compensation or student-teacher ratios, predict students' abilities and achievement in the short run[9] especially for those from disadvantaged backgrounds.[15] Historical administrative records of school characteristics have been linked to cognition in later-life.[16,17] However, the extant literature on school quality and later-life brain health draws samples from schools in a single state with mostly White respondents[17] or uses national samples with characterization of school quality that is limited to the state level.[18]

The aim of this study was to examine the relationship of six indicators of school quality and cognitive performance 58 years after high school. Studying multiple indicators may be important for understanding the best targets for possible policy interventions. Studies proposed that having the opportunity to attend higher quality schools is especially beneficial for people from disadvantaged backgrounds, such as racial and ethnic groups that were historically denied educational opportunities[8], people with fewer years of school[16], and people who obtain lower scores on tests of academic achievement.[17] Therefore, we also examined if the studied associations differed by factors that may influence who is positioned to benefit from investments in schools: sex/gender, race and ethnicity, and region of residence at the time of schooling.[13,17,19] We hypothesized that higher school quality would be associated with better cognitive performance, and that non-Hispanic (NH) Black older adults and those living in the southern region of the United States would especially benefit from high quality education because they are less likely to have access to other structural resources[20] throughout the life course that may compensate for lack of investment in schools.

Research in Context

1. **Systematic review**: Education is an important predictor of cognitive performance during the life-course. Few studies examined the role of educational quality, and none that measure school quality at a local level, at the time of schooling and include diverse population. Studies examining educational quality at the state level using historical administrative records were used to inform hypotheses and selection of indicators.
2. **Interpretation**: Our findings are the first to show association between several indicators of school quality with cognitive ability almost 6 decades later. Racial and ethnic differences in school quality (e.g., investment in teachers, term length) may contribute to disparities in later-life cognition.
3. **Future Directions**: Studies are warranted to (a) corroborate our findings among later-born cohorts, since our participants attended high school in 1960; (b) examine the mediating role of adult financial resources and later-life health; (c) obtain longitudinal follow-up to understand potential links to cognitive trajectory and incident dementia.

2 | METHODS

2.1 | Study population

We leveraged a school-based longitudinal cohort called the Project Talent Aging Study (PTAS), which encompasses schools from 42 states. The cohort study builds on a 1960 Project Talent (PT60) data collection (n = 377,016) that included national probability sample of about 5% of U.S. high schools (n = 1,226).[21] Students in the selected high schools were enrolled in the 9-12th grade (∼13-18 years old) and completed a battery of tests and questionnaires over a 2-day period. In 2018-2019, 22,584 participants from 856 schools were invited to join the PTAS. Present analyses leverage the PTAS Stage 2 sample to which 2,353 individuals responded (eFigure 1). We excluded 64 observations without school identifier, leaving 2,289 observations from 599 schools. PTAS Stage 2 respondents had slightly higher abstract reasoning scores and higher parental socioeconomic status (SES) compared to the PT60 respondents and were more likely to attend desegregated schools (eTable 1).

2.2 | Indicators of school quality

Principals at each school responded to a survey of over 100 questions regarding school characteristics from which we selected six indicators of school quality based on the indicators currently used to measure school quality in the Unites States[22,23], previous literature[8,16,17], and internal validation (eTable 2). The six selected independent exposures were: (1) dropout among girls, (2) dropout among boys, (3) number of teachers with graduate training, (4) teacher salaries, (5) term length, and (6) school size. Original categories were collapsed in a data-driven manner due to small sample sizes. The dropout measures capture a percentage of boys/girls that entered 10th grade but dropped out before graduation. The original six categories were collapsed into four (0-9%, 10-19%, 20-29% and = > 30%) by combing the three highest categories. Ten categories corresponding to number of full-time teachers with some graduate training in their main area were collapsed into four (0-5, 6-14, 15-23 and = > 24). Three categories (< = $2999, $3000-3499, $4000 = >) were created from original ten to capture the annual starting salary for teacher with a bachelor's degree and no experience. Nearly 38% of schools reported having exactly 180 days in their school year, hence term length continuous variable was grouped in 3 categories (180 < , 180 days, > 180). School size may be a proxy for school quality since larger schools typically have more resources.[24] We created a school size indicator using the median number (341) of students in PT60 schools to categorize small versus larger schools. In our sample, 91% of the larger schools were in urban settings; thus, school size was not independent of the differences in resources that are afforded to schools in rural vs. urban settings. Polychoric correlations indicated a strong relationship between the two dropout measures (correlation coefficient = 0.88) and between school size and number of teachers with graduate training (correlation coefficient = 0.84) (eTable 3). Correlation among other school quality indicators were modest (range 0.02 to 0.5).

We conducted an internal validation of school quality indicators in which we examined the association of each indicator with post-high school educational attainment. We hypothesized that indicators of school quality would predict post-high school educational attainment, which was self-reported in PTAS. On average, the selected indicators were associated with 0.2 additional years (range: 0.01 to 0.61 years) of educational attainment (eTable 2).

2.3 | Cognitive measures

Performance on tests of language, memory, and attention was measured via telephone assessment. Immediate recall was measured by a CERAD 10-word list recall[25] across 3 trials and scores from each trial were summed (score range: 0-30). After at least 5-minutes, a delayed recall trial was conducted. We calculated a delayed recall savings score as the proportion of words recalled after the delay compared to the last immediate recall trial (score range: 0-1). Language ability was measured by animal (semantic)[25] and phonemic fluency[26], where participants were asked to name animals for 45 seconds and words starting with the letter F for 60 seconds. Immediate recall and language ability measures were normally distributed. For all abilities, we converted the raw scores to z-scores using the sample mean and standard deviation. In serial sevens, the participants were asked five times to subtract the number 7 starting at 100. The serial sevens scores had low variation with 60% of respondents correctly completing all five subtractions. We created a binary indicator of poor serial seven performance indicating at least one incorrect subtraction.

2.4 | Covariates

Participant demographic characteristics included attained age (years and months), sex/gender and race/ethnicity. Self-reported sex (male/female) variable, collected in PT60, was used as an indicator for sex/gender. Race/ethnicity was self-reported in PTAS and categorized as: Non-Hispanic White, Non-Hispanic Black, Hispanic, Asian and all other racial groups (American Indian/Alaskan Native, Middle Eastern/North African, Native Hawaiian/Other Pacific Islander or other race/ethnicity). Early-life factors could confound the association of school quality and later-life cognitive ability. Thus, we included highest parental education, collected in PT60, as an indicator of childhood socioeconomic background. If mothers and fathers' education differed, the higher one was used. For examination of regional heterogeneity, we used an indicator of southern region using the U.S. Census Bureau definition. Our interest was to capture the total effect (i.e., both direct and indirect pathways) of school quality; hence, we chose not to include covariates that are downstream from school quality, such as length of education or midlife cardiovascular disease[4,27,28], and would mediate the studied relationship.[29] One exception was adolescent cognitive aptitude that we considered a confounder and a possible mediator. While adolescent cognitive aptitude can result from attending high quality schooling and influence the school a child attends, it also is an important predictor of later-life cognitive ability.[30] To operationalize adolescent cognitive aptitude (mean 0; SD 1), we used scores on abstract reasoning task (15 items) from 1960.[30] This non-verbal, multiple-choice test required examination of complex elements that have a logical relationship or pattern, and selection of an option that fits a missing piece of each pattern.

2.5 | Statistical analyses

First, we summarized baseline sample characteristics. Second, for our main analysis, we fit a multilevel linear or logistic model for every outcome and school quality indicator, adjusting for age, sex/gender, and parental education and included a random intercept at the school-level. Third, additional set of models added adolescent abstract reasoning scores[30]. To examine if the studied associations differed, we used models that included an interaction between school quality indicator and sex/gender, race and ethnicity, or region of residence at the time of schooling, respectively. When examining race/ethnicity differences, we included only NH White and NH Black people because few respondents identified with other racial/ethnic groups and these participants were clustered in few schools. We used multiple imputation

TABLE 1 Descriptive statistics for the overall sample in Stage 2 analyses, as well as across race/ethnicity, sex/gender, and region of schooling.

	Overall (n = 2,289)	NH Whites (n = 1,839)	NH Blacks (n = 242)	Men (n = 1,086)	Women (n = 1,203)	Non-Southern (n = 1,654)	Southern (n = 625)
Age, mean (SD), year	74.8 (1.2)	74.8 (1.2)	75.0 (1.3)	74.8 (1.2)	74.8 (1.2)	74.8 (1.2)	74.9 (1.9)
Adolescent abstract reasoning, mean (SD)	9.4 (2.9)	9.8 (2.7)	6.6 (3.0)	9.6 (2.8)	9.3 (2.9)	9.7 (2.8)	8.8 (3.1)
Cognitive tests scores							
Animal Fluency (n = 2,273)	16.7 (4.9)	17.0 (4.9)	14.7 (4.6)	17.0 (5.0)	16.4 (4.9)	16.8 (4.9)	16.4 (5.0)
Letter F Fluency (n = 2,265)	11.7 (5.0)	11.9 (5.0)	11.0 (5.3)	11.5 (5.1)	11.9 (5.0)	11.9 (5.0)	11.2 (5.0)
Immediate recall (n = 2,270)	20.5 (4.4)	20.6 (4.5)	20.0 (4.3)	19.2 (4.4)	21.5 (4.2)	20.5 (4.4)	20.5 (4.6)
Delayed Recall Savings (n = 2,236)	0.78 (0.19)	0.78 (0.18)	0.76 (0.21)	0.74 (0.2)	0.81 (0.17)	0.77 (0.18)	0.79 (0.19)
Poor Serial 7 (binary), no. (%)	933 (40.7%)	692 (37.6%)	139 (57.4%)	362 (33.3%)	571 (47.5%)	665 (40.0%)	268 (42.9%)
Women, no. (%)	1203 (52.6%)	942 (51.5%)	144 (60.3%)				
Parental education							
Unknown or less than grade school	514 (22.5%)	331 (18.0%)	92 (38.0%)	262 (24.1%)	252 (21.0%)	357 (21.45%)	157 (25.1%)
At least some high school	935 (40.9%)	759 (41.3%)	100 (41.3%)	437 (40.2%)	498 (41.4%)	674 (40.5%)	261 (41.8%)
Higher than high school	840 (36.7%)	749 (40.7%)	50 (20.7%)	387 (35.6%)	453 (37.7%)	633 (38.0%)	207 (33.1%)
Southern region, no. (%)	625 (27.3%)	492 (26.8%)	116 (47.9%)	278 (44.5%)	347 (55.5%)		
Race/ethnicity, no. (%)							
Non-Hispanic White	1839 (80.3%)			893 (82.2%)	946 (78.6%)	1347 (81.0%)	492 (78.7%)
Non-Hispanic Black	242 (10.6%)			96 (8.8%)	146 (12.2%)	126 (7.6%)	116 (18.6%)
Hispanic	75 (3.3%)			37 (3.4%)	38 (3.2%)	67 (4.0%)	8 (1.3%)
Asian	103 (4.5%)			49 (4.5%)	54 (4.5%)	100 (6.0%)	3 (0.5%)
Other	30 (1.3%)			11 (1.1%)	19 (1.6%)	24 (1.4%)	6 (1.0%)

employing Markov chain Monte Carlo method with 10 imputations to account for missing values (range 0.7%–4.3%). We also examined percent variance at the school-level (eMethods 1, eTable4 and 5). All analyses were conducted using the SAS/STAT software, version 9.4.

3 | RESULTS

Table 1 lists sample characteristics. Most of the respondents (n = 2,289; mean age 74.8) described themselves as NH White (80.4%), followed by NH Black (10.5%). NH Black people had parents with lower education, lower adolescent and later-life cognitive scores, and were more likely to attend school in the U.S. South (Table 1). Exposure to lower quality schools was unequally distributed. A higher proportion of NH Black people and those living in the South attended smaller schools and schools with higher dropout rates, fewer teachers with graduate training, and lower teacher compensation (Table 2).

3.1 | School level indicators and later-life cognitive abilities

The main models (Table 3), adjusted for age, sex/gender, and parental education, indicated that attending schools with fewer teachers with graduate training was associated with scores on two language tests and one memory test (β range across abilities: −0.3 to −0.08SD). Specifically, the models indicated that attending schools with only 0-5 or 6-14 teachers with graduate training compared to = > 24 teachers was associated with lower phonemic fluency scores (β = −0.24 [95% CI = −0.37, −0.11] & β = −0.30 [95% CI = −0.42; −0.18] respectively), animal fluency (β = −0.22 [95% CI = −0.35; −0.089] & β = −0.12 [95% CI = −0.24; −0.004] respectively), and immediate recall (β = −0.20 [95% CI = −0.32; −0.081] & β = −0.12 [95% CI = −0.23; −0.013]). For context, 1 year of age was associated with −0.1 SD lower cognitive scores; therefore, attending schools with fewer teachers with graduate training corresponds to 0.8 to 3 years (= −0.08/0.1 to −0.3/0.1) difference in cognitive test scores (Figure 1A). Adjusting for abstract reasoning scores in adolescence (eTable 6) attenuated the associations by 13-33% (calculated as: (β_{model2} - β_{model1}/ β_{model1})*100). Point estimates and their 95% confidence intervals for four out of the six highlighted associations did not include the null. Thus, attending schools with 0-5 teachers compared to schools with 24 or more teachers with graduate training, was associated with later-life phonemic fluency, animal fluency, and immediate recall even when adjusting for adolescent cognitive ability (β range across abilities: −0.15 to −0.18SD; eTable 6). Because of correlation between school size and number of teachers with graduate training, we conducted a post-hoc sensitivity analysis stratifying our models by school size (results upon

TABLE 2 Distribution of the school quality predictors overall and across race/ethnicity, sex/gender, and region of schooling.

	Overall (n = 2,289)	NH Whites (n = 1,839)	NH Blacks (n = 239)	Men (n = 1,086)	Women (n = 1,203)	Non-Southern (n = 1,654)	Southern (n = 625)
Dropout boys							
0-9%	1264 (57.4%)	1028 (58.1%)	86 (36.1%)	592 (56.2%)	671 (58.5%)	989 (62.6%)	275 (44.%)
10-19%	525 (23.8%)	443 (25.1%)	69 (29.6%)	234 (22.2%)	291 (15.3%)	282 (17.9%)	243 (38.9%)
20-29%	201 (9.1%)	152 (8.6%)	35 (14.8%)	113 (10.7%)	88 (7.7%)	116 (7.4%)	85 (13.6%)
= > 30%	213 (9.7%)	145 (8.2%)	46 (19.5%)	115 (10.9%)	98 (8.5%)	192 (12.2%)	21 (3.4%)
Dropout girls							
0-9%	1393 (63.4%)	1170 (66.2%)	74 (32.0%)	658 (65.0%)	735 (62.0%)	1068 (67.8%)	325 (52.3%)
10-19%	469 (21.4%)	384 (21.7%)	71 (30.7%)	210 (20.8%)	259 (21.9%)	258 (16.4%)	211 (34.0%)
20-29%	205 (9.3%)	132 (7.5%)	52 (22.5%)	92 (9.1%)	113 (9.5%)	139 (8.8%)	66 (10.6%)
= > 30%	130 (5.9%)	82 (4.6%)	34 (14.7%)	52 (5.1%)	78 (6.6%)	111 (7.0%)	19 (3.1%)
No. of teachers with graduate training							
0-5	345 (15.1%)	286 (15.6%)	50 (20.7%)	151 (13.9%)	194 (16.1%)	163 (9.8%)	182 (29.1%)
6-14	451 (19.7%)	386 (20.9%)	53 (22.9%)	216 (19.9%)	235 (19.5%)	315 (18.9%)	136 (21.8%)
15-23	290 (12.6%)	237 (12.9%)	31 (12.8%)	135 (12.4%)	155 (12.9%)	194 (11.7%)	96 (15.4%)
= > 24	1203 (52.6%)	930 (50.6%)	108 (44.6%)	584 (53.8%)	619 (51.5%)	992 (59.6%)	211 (33.8%)
Teacher's salary							
< = 2999$	11 (7.3%)	93 (5.3%)	63 (26.7%)	61 (5.9%)	100 (8.7%)	43 (2.7%)	118 (19.4%)
$3000-3499	626 (28.6%)	540 (30.8%)	66 (28.0%)	295 (28.3%)	331 (28.7%)	188 (11.9%)	438 (72.0%)
= > $4000	1406 (64.1%)	1118 (63.9%)	107 (45.3%)	685 (65.8%)	721 (62.6%)	1354 (85.4%)	51 (8.6%)
Term length							
< 180 days	627 (27.4%)	535 (29.1%)	50 (20.7%)	274 (25.2%)	353 (29.3%)	349 (21.0%)	278 (44.5%)
180 days	793 (34.6%)	634 (34.5%)	89 (36.8%)	377 (34.7%)	416 (34.6%)	502 (30.2%)	291 (46.6%)
> 180 days	869 (38.0%)	670 (36.4%)	103 (42.6%)	435 (40.1%)	434 (36.1%)	813 (48.9%)	56 (9.0%)
School size							
< = median size	675 (29.5%)	545 (29.6%)	109 (45.0%)	310 (28.5%)	365 (30.3%)	398 (23.9%)	277 (44.3%)
> median size	1614 (70.5%)	1294 (70.4%)	133 (55.0%)	776 (71.5%)	838 (69.7%)	1266 (76.1%)	348 (55.7%)

request). The association between number of teachers with graduate training and animal fluency was larger for those attending smaller schools (< = median size = 341 students) and reliable for all contrasts (range: 0.5 to 0.6SD higher scores). The association between teacher training and immediate word recall was driven by those attending smaller schools. Phonemic fluency results did not vary by school size.

Attending schools that had lower teachers' salaries (< = $2999 vs. = > $4000) was reliably associated with lower letter animal fluency ($\beta = -0.23$ [95% CI: −0.40; −0.057]) and phonemic fluency (Figure 1B, Table 3). Post-hoc analyses showed that these result remained unaltered after controlling for educational attainment. Attending smaller schools was associated with lower phonemic fluency and immediate recall ($\beta = -0.15$ [95% CI = −0.24; −0.0478] & $\beta = -0.10$ [95% CI = −0.19; −0.013], respectively). Attending schools with high dropout rates for boys (30% = > vs. 0-9%) was associated with lower cognitive scores on all abilities and these associations were reliable for animal fluency ($\beta = -0.18$ [95% CI = −0.34; −0.024]), delayed recall savings ($\beta = -0.18$ [95% CI = −0.33; −0.024]), and poor serial sevens (OR = 1.43 [95% CI = 1.04; 1.97]. Term length indicator displayed mixed results. Attending schools with term length of less than ($\beta = -0.15$ [95% CI = −0.27; −0.036]) or exactly equal to ($\beta = -0.15$ [95% CI = −0.26; −0.045]) 180 days was associated with lower scores on phonemic fluency but higher delayed recall savings ($\beta = 0.092$ [95% CI = −0.015; 0.20] & $\beta = 0.13$ [95% CI: 0.030; 0.23]). After adjusting for adolescent abstract reasoning scores, the highlighted associations were attenuated by 7-67% (eTable 6). The largest attenuation occurred for the teacher salary indicator. The point estimates and 95% confidence intervals for association of term length with phonemic fluency, school size with phonemic fluency and delayed recall, and boys dropout with delayed recall did not include the null even after adjustment for abstract reasoning.

3.2 | Exploratory differences across sex/gender, race and ethnicity, and region of schooling

Examination of heterogeneity of estimates were imprecise, and for most of the associations we did not see clear differences

TABLE 3 Pooled estimates from multiple imputation models examining association of individual school measures with level of cognitive functioning for language and memory domains (continuous) and indicator of impaired serial 7 score (binary), adjusted for age, sex, and parental education.

	Letter F fluency β (95%CI)	Animal Fluency β (95%CI)	Immediate recall β (95%CI)	Delayed Recall Savings β (95%CI)	Poor serial 7 OR (95%CI)
Dropout boys					
0-9%	Ref.	Ref.	Ref.	Ref.	Ref.
10-19%	−0.036 (−0.15; 0.076)	−0.001 (−0.11; 0.11)	0.097 (−0.003; 0.20)	0.093 (−0.013; 0.20)	1.33 (1.06; 1.66)
20-29%	−0.15 (−0.32; 0.017)	−0.10 (−0.27; 0.064)	0.047 (−0.10; 0.19)	−0.024 (−0.18; 0.13)	1.23 (0.88; 1.71)
=> 30%	−0.12 (−0.28; 0.043)	−0.18 (−0.34; −0.024)	−0.077 (−0.22; 0.066)	−0.18 (−0.33; −0.024)	1.43 (1.04; 1.97)
Dropout girls					
0-9%	Ref.	Ref.	Ref.	Ref.	Ref.
10-19%	−0.070 (−0.19; 0.046)	−0.081 (−0.20; 0.034)	0.032 (−0.071; 0.14)	0.10 (−0.009; 0.21)	1.30 (1.03; 1.63)
20-29%	−0.038 (−0.20; 0.13)	−0.069 (−0.23; 0.093)	−0.070 (−0.22; 0.076)	−0.064 (−0.22; 0.089)	1.10 (0.80; 1.52)
=> 30%	−0.032 (−0.23; 0.17)	−0.004 (−0.20; 0.20)	0.032 (−0.15; 0.21)	−0.19 (−0.38; 0.005)	1.35 (0.91; 2.01)
No. of teachers with graduate training					
0-5	−0.24 (−0.37; −0.11)	−0.22 (−0.35; −0.089)	−0.20 (−0.32; −0.081)	−0.010 (−0.14; 0.12)	1.22 (0.94; 1.58)
6-14	−0.30 (−0.42; −0.18)	−0.12 (−0.24; −0.004)	−0.12 (−0.23; −0.013)	−0.064 (−0.18; 0.048)	1.48 (1.17; 1.88)
15-23	−0.099 (−0.24; 0.043)	−0.076 (−0.21; 0.063)	−0.088 (−0.21; 0.037)	0.036 (−0.098; 0.17)	1.29 (0.97; 1.70)
=> 24	Ref.	Ref.	Ref.	Ref.	Ref.
Teacher's salary					
<= $2999	−0.16 (−0.33; 0.014)	−0.23 (−0.40; −0.057)	0.006 (−0.15; 0.17)	−0.058 (−0.23; 0.11)	1.21 (0.85; 1.72)
$3000-3999	−0.084 (−0.19; 0.020)	0.006 (−0.096; 0.11)	0.078 (−0.014; 0.17)	0.059 (−0.039; 0.16)	1.16 (0.94; 1.43)
=> $4000	Ref.	Ref.	Ref.	Ref.	Ref.
Term length					
< 180 days	−0.15 (−0.27; −0.036)	0.015 (−0.10; 0.13)	−0.076 (−0.18; 0.026)	0.092 (−0.015; 0.20)	1.12 (0.89; 1.41)
180 days	−0.15 (−0.26; −0.045)	−0.042 (−0.15; 0.066)	−0.026 (−0.12; 0.071)	0.13 (0.030; 0.23)	1.20 (0.96; 1.49)
> 180 days	Ref.	Ref.	Ref.	Ref.	Ref.
School size					
<= median size	−0.15 (−0.24; −0.048)	−0.073 (−0.17; 0.024)	−0.10 (−0.19; −0.013)	−0.072 (−0.16; 0.020)	1.17 (0.96; 1.42)
> median size	Ref.	Ref.	Ref.	Ref.	Ref.

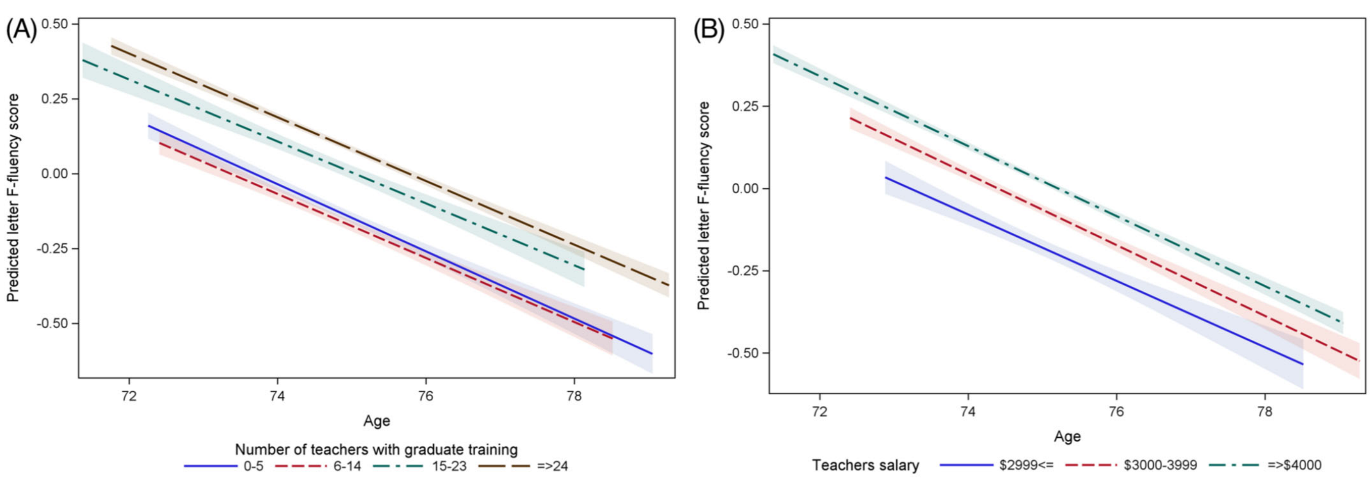

FIGURE 1 The predicted relationship of age and cognitive scores in older age when attending schools with (A) different number of teachers with graduate training in the main area, and (B) different levels of teachers' salaries. Figures were derived from one model, not multiple imputations.

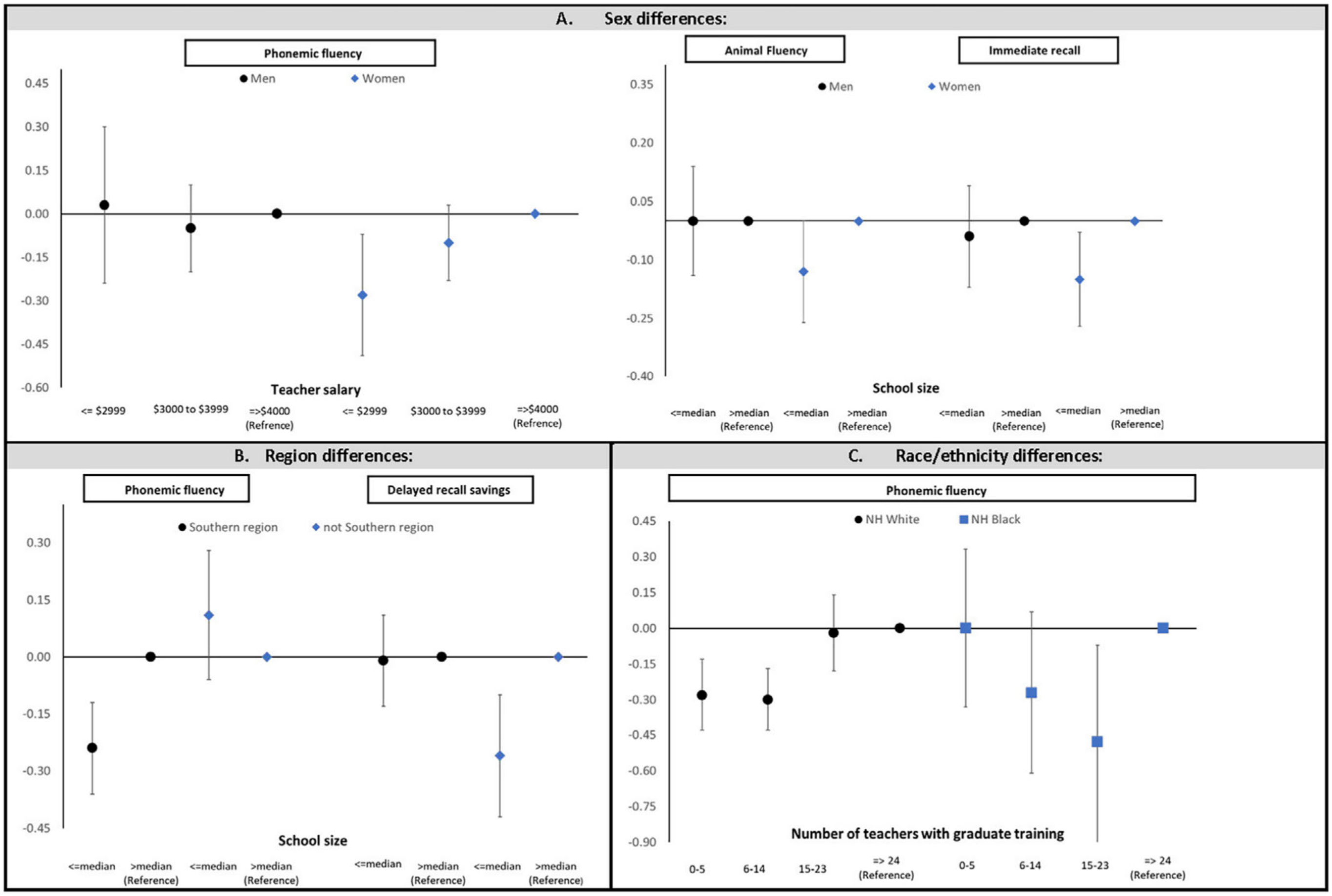

FIGURE 2 Estimates from models examining associations of various school factors with z-scores of cognitive abilities based on interaction of the school factor with: A. sex/gender; B. region; or C. race and ethnicity.

(Supplementary eTables 7-9). The association of teacher salary with fluency seemed to be driven by women. Among NH Black respondents, attending schools with a high number of teachers with graduate training (15-23 vs. = > 24) was associated with lower phonemic fluency scores, while among NH White respondents, attending schools with few teachers with graduate training predicted lower phonemic fluency scores (Figure 2C). The effect of attending small schools on lower animal fluency and immediate recall was also stronger among women than men (Figure 2A). Attending smaller schools was associated with higher phonemic fluency for those residing in the southern region of the United States but lower scores for those in other regions (Figure 2B). In contrast, the negative relationship of attending smaller schools on delayed recall savings was driven by those residing in the southern region of the United States (Figure 2B).

4 | DISCUSSION

We investigated the association of school quality with cognitive ability 58 years later. We found that attending schools with a higher number of teachers with graduate training was the most consistent predictor of later-life cognition (0.1 to 0.3SD higher scores) among six examined school indicators. High school quality mattered especially for performance on language tests, where findings remained robust to control for adolescent cognitive scores.

There are several reasons why access to well trained and well-paid teachers—the strongest predictors in our study—may affect later-life cognition. Instruction provided by more experienced and knowledgeable teachers might be more cognitively stimulating and, thus, may provide additional neural or cognitive benefits of time in the classroom. Those attending relatively smaller schools benefitted more from the presence of highly qualified teachers, where student-teacher interaction may be more intensive. Prior studies that observed that attending schools where teachers have graduate training in the subject matter predicted student achievement in the short run[31,32] align with our results. Attending higher quality schools may also impact students' life trajectory. Attending higher quality schools has been associated with obtaining further education in several studies[23,33,34], including ours (eTable 2). Continued schooling may confer benefits through obtaining important credentials, better occupation, and higher income.[33,34] In line with this mechanism, a previous study[17] found that the protective effect of school advantage was mediated via midlife SES, suggesting that attending higher quality school leads to cumulative advantages.

Like prior research examining school quality[8,11,17] and other social and structural determinants, the strongest associations were for language ability compared to other cognitive domains. Measures of later-life language ability assume familiarity with stimuli and rely on the assumption that schools introduced, allowed for practice of, and reinforced experience with similar tasks. The extent to which schools in 1960 conferred this familiarity is probably correlated with the indicators of school quality that we used in this study.

Importantly, the population impact of poor school quality is expected to be larger for Black children because of the lower investment in schools that serve Black children. Further, Black students were more likely to attend smaller schools where exposure to teachers with graduate training was rarer, yet associations with later life cognition were of larger magnitude. Our results are aligned with previous research[13,17,34] and show that structural racism and de jure segregation restricted access to high quality schooling for Black children (Table 2). This is a contemporary issue because racial equity in school quality has never been achieved in the United States and school racial segregation has grown more extreme in recent decades.[14] For example, based on 2016 Civil Right Collection data, schools that were attended by non-White students had twice as high number of inexperienced teachers as[35] schools attended by predominantly White students[22] and unequal access to high-quality teachers is among the contributors to the contemporary achievement gap between non-White and White students.[35] Our study highlights how this lack of investment is one systemic tool that contributes to and perpetuates inequalities in cognitive function among older Black adults.

4.1 | Strengths and limitations

Leveraging a sample with national coverage, studying school quality indicators reported by principals using a standard questionnaire across all schools, availability of adolescent cognitive scores at the time of schooling, and inclusion of respondents from marginalized populations (19.6%) are some of the unique features of our study.

Several limitations are worth noting. First, while a standard questionnaire across all schools was used to obtain school quality indicators, the majority of the questions allowed only categorical operationalization of variables, which may reduce power, and options provided for each question may not have been sensitive to key variation in the measured constructs. For example, a large proportion of schools (40.7%) reported that their teachers have $4000-4499 as a starting salary, and this category could not be broken down further. For several key items on the survey, we had to collapse categories due to small sample sizes, which may obscure important variation. Second, our approach does not account for correlation between school quality indicators; thus, additive or even multiplicative effects of school quality may be underestimated. Yet, the correlation among most indicators was modest (0.02 to 0.5). Third, we were only able to formally compare NH Black and White respondents due to insufficient sample sizes for Latinx, Asian, and American Indian participants. Fourth, as eTable 1 shows there were some differences in the characteristics of the PT60 sample, those targeted for PTAS, and PTAS Stage 2 respondents. Because a primary sampling goal for PTAS was overrepresentation of participants from marginalized backgrounds, they are more likely than the PT60 to have lower SES, to have attended desegregated schools, and to have attended schools that primarily serve Black children. We repeated our main analyses using inverse probability weights to adjust for sampling and response bias, which did not change our results. Additionally, selective survival may have occurred, but it would likely bias the main associations toward the null due to survival of the most resilient individuals. Our understanding is also restricted by limitations in data and sample size to examine interactions of racialized group with skin tone, ethnicity, immigration experiences, native language, and other features of identity, including gender and SES. An additional data limitation includes lack of interim data and clinical cognitive status of our respondents. Differences in adolescent abstract reasoning scores between Black and White respondents raise concerns about assessment bias and construct validity of the measures. Especially relevant to the current research question, racially stratified exposure to, for example, higher quality schools earlier in life may teach the skills needed for the high school test[36]. Nevertheless, our main findings remained after adjustment for adolescent cognitive aptitude. Finally, while we account for some confounders, such as parental education and adolescent cognitive aptitude, we cannot rule out that residual confounding, for example, by quality of elementary and middle schools' environment, biases our findings.

4.2 | Unanswered questions and future directions

We were not able to address the role of school quality across the entire educational experience. We examined school quality in high school, but did not have measures of school quality earlier in life. Quality of primary and secondary schools attended by a child are likely to be associated and our findings may partly reflect a cumulative advantage of attending higher quality schools throughout the educational career. Effects of school quality across the educational career may be synergistic. For example, previous research showed that attending high-quality kindergarten programs was associated with better elementary school outcomes only for children that were able to attend high-quality elementary schools[37]. Future studies should examine the role of school quality across multiple time points.

Attending higher quality high school may impact students' life trajectory – such as attending university, the type of job one has, or midlife health and health behaviors. For example, attending higher-quality high schools is predictive of college success[34], earnings, and employment.[33] Research shows these midlife socioeconomic factors are in turn linked to other risk factors for cognitive decline.[38] Our study provides the first step by establishing the link between high quality education and later-life cognition. Future research directions include evaluating the mechanisms linking high-quality education and later-life cognition.

Prior research among NH Black older adults living in Chicago indicates that those who attended desegregated schools in the southern region of United States had lower cognitive scores than those who attended segregated southern schools and schools in the North.[13] We were unable to examine school quality and segregation of schools within Black participants because of our small sample sizes. Additionally, the role and importance of individual school quality predictors may be influenced by contextual factors, such as rurality or area level SES[19], yet we were unable to examine these interactions due to data limitations.

While we were able to examine multiple school quality indicators that are relevant for high school students today[22,23], there may be other relevant school quality metrics we were not able to operationalize. Thus, future studies should explore the role of additional aspects of school quality, such as class size.

4.3 | Conclusions & implications

This study suggests that school quality contributes to level of cognitive function in older age. Since Black people were disproportionately exposed to low quality schooling due to educational segregation and structural racism – and such inequalities persist today – increased investment in schools, especially those that serve Black children, could be a powerful strategy to improve cognitive health among older adults in the United States.

AUTHOR CONTRIBUTIONS

Drs Seblova, Eng, and Manly had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Manly, Glymour, Prescott, and Lapham.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Seblova, Manly, Glymour.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Seblova, Eng, Dworkin, Glymour, and Jones

Obtained funding: Manly and Prescott.

Administrative, technical, or material support: Peters.

Supervision: Manly.

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CONFLICT OF INTEREST STATEMENT

The authors listed certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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REFERENCES

1. Opdebeeck C, Martyr A, Clare L. Cognitive reserve and cognitive function in healthy older people: a meta-analysis. *Aging Neuropsychol Cogn*. 2016. doi: 10.1080/13825585.2015.1041450
2. Xu W, Tan L, Wang HF, Tan MS, Tan L, Li JQ, et al. Education and Risk of Dementia: dose-Response Meta-Analysis of Prospective Cohort Studies. *Mol Neurobiol*. 2016;53:3113-3123. doi: 10.1007/s12035-015-9211-5
3. Caamaño-Isorna F, Corral M, Montes-Martínez A, Takkouche B. Education and dementia: a meta-analytic study. *Neuroepidemiology*. 2006;26:226-232. doi: 10.1159/000093378
4. Glymour MM, Manly JJ. Compulsory Schooling Laws as quasi-experiments for the health effects of education: reconsidering mechanisms to understand inconsistent results. *Soc Sci Med*. 2018;214:67-69. doi: 10.1016/j.socscimed.2018.08.008
5. Seblova D, Fischer M, Fors S, Johnell K, Karlsson M, Nilsson T, et al. Is there a direct causal effect of education on dementia? A Swedish natural experiment on 1.3 million individuals. *Am J Epidemiol*. 2019;190(5):817-826.
6. Nguyen TT, Tchetgen EJT, Kawachi I, Gilman SE, Walter S, Liu SY, et al. Instrumental variable approaches to identifying the causal effect of educational attainment on dementia risk. *Ann Epidemiol*. 2016;26:71-76. doi: 10.1016/j.annepidem.2015.10.006. e3.
7. Act ESS. Every student succeeds act (ESSA). *Pub L*. 2015:114-195.
8. Sisco S, Gross AL, Shih RA, Sachs BC, Glymour MM, Bangen KJ, et al. The role of early-life educational quality and literacy in explaining racial disparities in cognition in late life. *J Gerontol B Psychol Sci Soc Sci*. 2015;70:557-567.
9. Hyman J. Does money matter in the long run? Effects of school spending on educational attainment. *Am Econ J Econ Policy*. 2017;9:256-280.
10. Whitfield KE, Wiggins SA. The impact of desegregation on cognition among older African Americans. *Journal of Black Psychology*. 2003;29:275-291.
11. Aiken-Morgan AT, Gamaldo AA, Sims RC, Allaire JC, Whitfield KE. Education desegregation and cognitive change in African American older adults. *J Gerontol B Psychol Sci Soc Sci*. 2015;70:348-356.
12. Mantri S, Nwadiogbu C, Fitts W, Dahodwala N. Quality of education impacts late-life cognition. *Int J Geriatr Psychiatry*. 2019;34:855-862. doi: 10.1002/gps.5075
13. Lamar M, Lerner AJ, James BD, Yu L, Glover CM, Wilson RS, et al. Relationship of early-life residence and educational experience to level and change in cognitive functioning: results of the Minority Aging Research Study. *J Gerontol Ser B*. 2020;75:e81-92.
14. Rosiek J. School segregation: a realist's view. *Phi Delta Kappan*. 2019;100:8-13.
15. Jackson CK, Johnson RC, Persico C. The effects of school spending on educational and economic outcomes: evidence from school finance reforms. *Q J Econ*. 2016;131:157-218.
16. Crowe M, Clay OJ, Martin RC, Howard VJ, Wadley VG, Sawyer P, et al. Indicators of childhood quality of education in relation to cognitive function in older adulthood. *J Gerontol - Biol Sci Med Sci*. 2013;68:198-204.
17. Moorman SM, Greenfield EA, Garcia S. School Context in Adolescence and Cognitive Functioning 50 Years Later. *J Health Soc Behav*. 2019;60:493-508. doi: 10.1177/0022146519887354
18. Brenowitz WD, Manly JJ, Murchland AR, Nguyen TT, Liu SY, Glymour MM, et al. State school policies as predictors of physical and mental health: a natural experiment in the REGARDS cohort. *Am J Epidemiol*. 2020;189:384-393.

19. Liu SY, Glymour MM, Zahodne LB, Weiss C, Manly JJ. Role of place in explaining racial heterogeneity in cognitive outcomes among older adults. *J Int Neuropsychol Soc*. 2015;21:677-687.
20. Ross CE, Mirowsky J. Sex differences in the effect of education on depression: resource multiplication or resource substitution? *Soc Sci Med*. 2006;63:1400-1413.
21. Prescott CA, Achorn DL, Kaiser A, Mitchell L, McArdle JJ, Lapham SJ. The Project Talent twin and sibling study. *Twin Res Hum Genet*. 2013;16:437-448.
22. Cardichon J, Darling-Hammond L, Yang M, Scott C, Shields PM, Burns D. Inequitable Opportunity to Learn: student Access to Certified and Experienced Teachers. *Learning Policy Institute*. 2020.
23. Baker BD. How Money Matters for Schools. *School Finance Series Learning Policy Institute*. 2017.
24. Newman M, Garrett Z, Elbourne D, Bradley S, Noden P, Taylor J, et al. Does secondary school size make a difference?: a systematic review. *Educ Res Rev*. 2006;1:41-60.
25. Morris JC, Heyman A, Mohs RC, Hughes JP, van Belle G, Fillenbaum G, et al. The consortium to establish a registry for alzheimer's disease (CERAD). Part I. Clinical and neuropsychological assessment of alzheimer's disease. *Neurology*. 1989;39:1159-1165. doi: 10.1212/wnl.39.9.1159
26. Goodglass H, Kaplan D. The assessment of aphasia and related disorders. *Philadelphia: Lea and Febiger*. 2nd ed.. 1983.
27. Hamad R, Nguyen TT, Glymour MM, Vable A, Manly JJ, Rehkopf DH. Quality and quantity: the association of state-level educational policies with later life cardiovascular disease. *Prev Med*. 2019;126:105750. doi: 10.1016/j.ypmed.2019.06.008
28. Liu SY, Glymou MM, Zahodne LB, Weiss C, Manly JJ. The role of place in explaining racial heterogeneity in cognitive outcomes among older adults. *J Int Neuropsychol Soc*. 2015.
29. Richiardi L, Bellocco R, Zugna D. Mediation analysis in epidemiology: methods, interpretation and bias. *Int J Epidemiol*. 2013;42:1511-1519.
30. Huang AR, Strombotne KL, Horner EM, Lapham SJ. Adolescent cognitive aptitudes and later-in-life Alzheimer disease and related disorders. *JAMA Netw Open*. 2018;1:e181726-e181726.
31. Wayne AJ, Youngs P. Teacher characteristics and student achievement gains: a review. *Rev Educ Res*. 2003;73:89-122.
32. Goldhaber DD, Brewer DJ, Evaluating the effect of teacher degree level on educational performance. 1996.
33. Jackson CK, Johnson RC, Persico C. The effects of school spending on educational and economic outcomes: evidence from school finance reforms. *NBER*. 2015.
34. Rothstein J, Schanzenbach DW. Does money still matter? Attainment and earnings effects of post-1990 school finance reforms. *J Labor Econ*. 2022;40:S141-78.
35. Clotfelter CT, Ladd H, Vigdor JL. How and why do teacher credentials matter for student achievement. *National Bureau of Economic Research Cambridge, Mass*. 2007.
36. Glymour MM, Manly JJ. Lifecourse social conditions and racial and ethnic patterns of cognitive aging. *Neuropsychol Rev*. 2008;18:223-254.
37. Carr RC, Peisner-Feinberg ES, Kaplan R, Mokrova IL. Effects of North Carolina's pre-kindergarten program at the end of kindergarten: contributions of school-wide quality. *J Appldev Physio*. 2021;76:101317.
38. Chapko D, McCormack R, Black C, Staff R, Murray A. Life-course determinants of cognitive reserve (CR) in cognitive aging and dementia–a systematic literature review. *Aging Ment Health*. 2018;22:921-932.

SUPPORTING INFORMATION

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

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