HHS Public Access
Author manuscript
J Health Soc Behav. Author manuscript; available in PMC 2020 February 08.

Published in final edited form as:
J Health Soc Behav. 2019 December ; 60(4): 493–508. doi:10.1177/0022146519887354.

School Context in Adolescence and Cognitive Functioning 50 Years Later

Sara M. Moorman[1], **Emily A. Greenfield**[2], **Sarah Garcia**[3]

[1]Boston College, Chestnut Hill, MA, USA

[2]Rutgers, The State University of New Jersey, New Brunswick, NJ, USA

[3]University of Minnesota, Minneapolis, Minnesota, USA

Abstract

To advance understanding of how social inequalities from childhood might contribute to cognitive aging, we examined the extent to which school context in adolescence was associated with individuals' cognitive performance more than 50 years later. Using data from 3,012 participants in the Wisconsin Longitudinal Study (WLS), we created an aggregate measure of school-level structural advantage, with indicators such as the proportion of teachers who had at least five years of teaching experience and spending per pupil. Multilevel models indicated that secondary school advantage was associated with small benefits in language/executive function at age 65 among older adults who had lower academic achievement in secondary school. Findings suggest that school advantage is a developmental context of adolescence that has modest implications for intracohort differences in aspects of later life cognition.

Keywords

academic achievement; executive function; language; memory; secondary school

---

Educational attainment is strongly associated with better cognitive health in later life (Clouston et al. 2012). Cohort studies using data collected before and after the implementation of compulsory schooling laws have found that additional years of education are associated with better memory and executive function in later life (Banks and Mazzonna 2012; Nguyen et al. 2016). Moreover, scholars have theorized that a downward secular trend in rates of Alzheimer's disease likely reflects increasing levels of education within societies at large (Zissimopoulos et al. 2018).

Very few studies, however, have investigated whether characteristics of the schools that an individual attends are related to later life cognition above and beyond number of years of attendance. We seek to address this gap by examining whether variations in school structural advantage in adolescence (i.e., secondary school) are associated with intracohort differences

---

Corresponding Author: Sara M. Moorman, Department of Sociology, Boston College, 140 Commonwealth Avenue, McGuinn Hall 426, Chestnut Hill, MA 02467, USA., moormans@bc.edu.

SUPPLEMENTAL MATERIAL
Tables OSM-1 and OSM-2 are available in the online version of the article.

in later life cognition. Using data from 3,012 participants in the Wisconsin Longitudinal Study (WLS), we examine whether secondary school advantage—as recorded in public records—is associated with cognitive function at age 65 as well as change in cognitive function between the ages of 65 and 72. We also examine the extent to which parental socioeconomic status (SES) in adolescence as well as participants' own SES in midlife account for associations between secondary school advantage and later life cognition. Orienting to individual differences, we test whether associations differ by participants' academic achievement in adolescence.

BACKGROUND

School Context as a Source of Inequality

A growing body of life course epidemiological research indicates that social inequalities in childhood operate as long-term risk and protective factors for adult health and cognitive aging (Ben-Shlomo and Kuh 2002). Few studies, however, have considered potential extrafamilial sources of socio-structural differences among children, such as those within schools. Because U.S. educational policy and funding is decentralized and largely under the control of state governments and local authorities, schools can vary widely in their characteristics (Lafortune, Rothstein, and Schanzenbach 2018). Many states maintain school finance systems that sustain and create inequities in access to resources for students depending on the school district in which they live (Baker, Farrie, and Sciarra 2018). Even among neighboring school districts, public schools can differ from each other in terms of their spending per pupil and class sizes (Owens, Reardon, and Jencks 2016). Studies have found that structural differences among schools—such as teacher pay, students per teacher, and number of instructional days—are associated with student achievement (Hyman 2017; Lafortune et al. 2018). In particular, advantage at the school level has been shown to improve student achievement among low-income students, suggesting that schools might help to reduce the opportunity gap (Jackson, Johnson, and Persico 2016).

The developmental effects of structural advantage from schools in childhood could influence later life cognition through both direct and indirect processes. Direct processes are those whereby conditions of childhood immediately influence an aspect of neurocognitive functioning with long-term implications and regardless of subsequent exposures to social advantage or disadvantage. Indirect processes refer to when conditions of childhood affect later life health insomuch as they influence exposure to health-related advantages/ disadvantages (Lyu and Burr 2016) at subsequent periods of the life course.

School-level advantages such as smaller class sizes and more experienced teachers could indicate a more cognitively stimulating environment in adolescence, which may promote neurophysiological development in adolescence. These cognitive advantages in adolescence may directly persist into adulthood through sustained optimization of neuronal networks and also may indirectly promote later life cognition by increasing the likelihood that individuals seek cognitively stimulating environments throughout the life course (Rebok, Carlson, and Langbaum 2007). Conversely, attending a school with structural disadvantages such as low expenditures per student could expose individuals to factors that immediately undermine neurophysiological development in adolescence, such as toxins and pollutants in aging school buildings, which could persist into the aging brain regardless of exposure to subsequent life course risk and protective factors (Evans and Kim 2010). Attending a school with structural disadvantages could also have indirect effects by restricting individuals' access to subsequent opportunities, such as postsecondary education and occupational environments (Domina, Penner, and Penner 2017), that would enhance later life cognition.

School Context and Adult Health Outcomes

Although most studies on early-life schooling and later life cognitive outcomes have examined education in terms of years of educational attainment, there is an emerging literature on characteristics of the schools that individuals attend, particularly within research on physical health outcomes in midlife (Walsemann, Gee, and Ro 2013). Secondary school context measures—such as teacher experience and daily average school attendance—have been shown to predict a variety of adult health outcomes independent of individuals' sociodemographic characteristics and health in childhood (Dudovitz et al. 2016). Other school context measures—such as percent of economically disadvantaged students—have also been shown to predict health-induced work limitations (Walsemann, Geronimus, and Gee 2008). Beyond secondary schooling, selective college attendance, which is operationalized using measures such as average college entrance test scores and grade point average, is associated with health behaviors, physical functioning, and perceived health in adulthood (Fletcher and Frisvold 2011, 2012).

Within the field of cognitive aging specifically, most research on school context has used proxy measures for school advantage. One common proxy is level of reading ability in adulthood, which is correlated with but distinct from educational attainment and is associated with better cognition in later life (Crowe et al. 2008; Manly et al. 2002). Racial desegregation is also oftentimes used as a marker of access to more advantaged schools for black older adults (Whitfield and Wiggins 2003). In general, research has found that having attended a racially integrated school is associated with better later life cognition among older black adults (Aiken-Morgan et al. 2015; Whitfield and Wiggins 2003).

Few studies have directly assessed school advantage and later life cognition. One study gathered 102 black older adults' self-reports of school context and found no association between self-reported educational quality and cognitive functioning after accounting for demographic and health covariates (Gamaldo et al. 2018). Three others have had access to regional administrative data. The largest used data from 1,679 Medicare-eligible older adults living in New York City. Controlling for participants' own educational attainment and later life literacy, the study found that attending a more advantaged school, as measured by state-level indicators such as mandatory number of school days, was associated with better general cognitive performance and executive function, though not with memory, among black participants (but not for white participants; Sisco et al. 2015). A second study analyzed data from 433 older adults who could be matched to data from a 1935 report from the Alabama Department of Education. Smaller class sizes and more days in the school year were associated with higher baseline levels of cognitive function, though not change over four years, especially for participants who had no college experience (Crowe et al. 2013). Finally, a third study examined cognitive performance among a predominantly black sample of 130 community-dwelling adults in Philadelphia. Several aspects of secondary school context—such as ratio of academic to nonacademic courses and academic course load—were associated with cognitive performance at the bivariate level (Mantri et al. 2019).

Focus of the Current Study

Our study aims to extend the literature on school advantage in adolescence as a risk/protective factor for later life cognitive functioning. We use data from the WLS, which provides a larger population sample than prior studies. It includes measures of secondary school context gathered from administrative sources, with a predominant focus on measurement in adolescence. Adolescence is an important developmental period in which to examine school context given that it is one of several sensitive periods for brain development, whereby individuals' neurophysiological functioning is especially amenable to influences from social environments (Fuhrmann, Knoll, and Blakemore 2015).

Our study also examines how SES in adolescence and adulthood might attenuate linkages between secondary school advantage and later life cognition. We first consider parental SES in adolescence because a large body of research has documented that higher SES families have greater access, on average, to more advantaged schools (Hanselman and Fiel 2017). Thus, more advantaged schools may be simply a benefit of high SES rather than an independent source of advantage. Given a large body of evidence for parental SES as a risk/protective factor for later life cognition, it is important to examine whether linkages with secondary school advantage remain even after accounting for individuals' parental SES in adolescence (Greenfield and Moorman 2019).

We further examine the extent to which participants' own SES in midlife accounts for associations between school advantage and later life cognition. Some studies have found that participants' SES in adulthood accounts for much of the association between parental SES and later life cognition (Lyu and Burr 2016; Richards et al. 2019). We extend this inquiry by testing the extent to which midlife SES mediates associations for secondary school advantage as well, theorizing that attending a more advantaged secondary school can situate individuals on life course trajectories that make them more likely to obtain higher levels of education, income, and occupational status as adults (Ferraro and Shippee 2009), which are associated with better cognition in later life (Lyu and Burr 2016).

Finally, addressing calls for greater attention to co-occurring sources of advantage and disadvantage across the life course (Ferraro and Morton 2018), we examine whether associations between secondary school advantage and later life cognition depend on participants' academic achievement in adolescence. Academic achievement refers to individuals' performance outcomes in relationship to learning goals and is typically reflected in indicators such as grades, test scores, and rank in class (Spinath 2012). Different theoretical perspectives provide competing predictions as to whether higher or lower performing students might benefit the most from attending more advantaged schools in adolescence. First, a risk and resilience perspective (Fergus and Zimmerman 2005) would suggest that students with lower levels of academic achievement might have the most to gain from attending a more advantaged secondary school and that individuals with high levels of academic achievement might be likely to maintain high levels of cognitive performance in later life regardless of secondary school context. On the contrary, a Matthew effect perspective (Dannefer 1987) would suggest that students with high levels of academic achievement might benefit the most from a more advantaged secondary school, being especially poised to take advantage of resources within such settings.

Our study examined the following hypothesis and research questions:

Hypothesis: Attending a more advantaged secondary school will be associated with higher levels of cognitive functioning at age 65 and less decline in cognitive functioning between ages 65 and 72.

Research Question 1: To what extent do associations between secondary school advantage and later life cognitive functioning remain after accounting for SES in adolescence?

Research Question 2: To what extent does midlife SES account for associations between attending a more advantaged secondary school and later life cognition?

Research Question 3: Do associations between secondary school advantage and later life cognition differ by individuals' level of academic achievement in adolescence?

DATA AND METHODS

Data

The WLS included a random sample of a cohort of men and women from Wisconsin who were primarily bom in 1939, graduated from Wisconsin secondary schools in 1957, and were approximately 72 years old when last interviewed in 2011. Data were collected via telephone, mail, and in-person surveys in 1957, 1964, 1975, 1992, 2004, and 2011. The WLS surveys included questions aimed to measure social background, youthful aspirations, schooling, military service, family formation, labor market experiences, social participation, and health.

The 10,317 people who comprised the initial WLS sample were all non-Hispanic white secondary school graduates. In 1960, 97% of Wisconsin residents were white (Wisconsin Legislative Reference Bureau 2017). WLS participants of nonwhite racial-ethnic backgrounds were too few in number to include race/ethnicity as a variable in the data set both for statistical and ethical reasons (Herd, Carr, and Roan 2014). This racial-ethnic homogeneity of the sample precluded broader population inferences.

Our analytic sample excluded participants without valid scores on several key variables. First, of the original sample of 10,317 participants, 1,790 did not have a match to school-level data, in most cases (n = 1,357) because the participant attended a private secondary school. Second, 2,334 of the remaining participants left the study before age 65 because of death (n = 1,078), loss to follow-up, or refusal. Third, 1,948 participants were excluded because they did not provide saliva for genetic assay at age 72 (see "covariates" in the following). Finally, we excluded 1,233 participants who remained in the study but did not have sufficient measures of cognitive function at age 65, two-thirds of whom were not randomly selected for any neurocognitive testing as part of the study protocol. The remaining third was missing because they completed half or fewer of the cognitive tests. Therefore, our analytic sample included 3,012 participants who attended one of 277 public secondary schools and provided valid cognitive data at age 65 and valid genetic data at age 72. We conducted sensitivity analyses to assess the potential effect of selection bias on our findings, as reported in the results.

Adult Cognitive Function

Weschler Adult Intelligence Scale similarities.—At ages 65 and 72, all participants responded to six items from the Weschler Adult Intelligence Scale Revised (WAIS-R; Wechsler 1981). Participants were asked to name similarities between items such as an orange and a banana, and answers were scored using standard guidelines based on their level of abstraction (Wechsler 1997a; 1997b). Each item was scored on a scale from 0 to 2, and scores were summed such that the total score ranged from 0 (lowest) to 12 (highest).

Letter fluency.—Eighty percent of participants were randomly selected to complete the letter fluency task at age 65, and 100% of participants completed it at age 72. Participants named all the words they could beginning with the letter "L" or "F" in one minute, where the letter was randomly assigned. The score represents the number of qualifying words named. Participants who completed the task at age 65 repeated the task using the same letter at age 72.

Category fluency.—Fifty percent of participants were randomly selected to complete the category fluency task at age 65, and these participants repeated the task at age 72. Participants named all the words they could belonging to the categories "animals" or "foods" in one minute, where the total score represented the total number of qualifying words named. The assignment of animals versus foods was random at age 65, and the same category was repeated at age 72.

Immediate and delayed word recall.—At ages 65 and 72, 80% of participants were read a list of 10 words and asked to repeat as many as they could (Brandt, Spencer, and Folstein 1988). Participants were later asked—without warning—to repeat the 10 words again. The score for both measures was the number of words correctly recalled.

Digit ordering.—At ages 65 and 72, 80% of participants were selected to complete a test that involved reordering series of single digits from smallest to largest (beginning with a series of three digit numbers and up to eight digits, depending on performance), following a modified protocol of the WAIS-III digit backward subtest (Wechsler 1997a; 1997b). The final score ranged from 0 to 12.

Confirmatory factor analyses yielded a two-factor solution (results available on request). *Memory* included the scores from the immediate recall, delayed recall, and digit ordering tasks. *Language/executive function* included the scores from the WAIS-R similarities, letter fluency, and category fluency tasks. Because the six tests were scored on different metrics, we calculated the percent of maximum possible scores for each test (Cohen et al. 1999). We then averaged test scores within each domain. The correlation between memory and language was .23 in 2004 and .38 in 2011 (both: $p < .001$).

Secondary School Advantage

In 2006, WLS researchers used the Wisconsin State Historical Society to access the annual reports that school districts filed with the Wisconsin Department of Public Instruction for the years 1954 to 1957, when participants were in secondary school (Halpern-Manners, Warren, and Brand 2009). Records for private schools, which 1,357 (13.2%) WLS participants attended, were unavailable. The majority of these private schools (88.4%) were Catholic schools. Over 90% of WLS participants attended a school district with only one secondary school; indicators of secondary school advantage within districts that had more than one secondary school were averaged across their secondary schools. Reports were available for 280 public schools, of which 277 were represented in our analytic sample. Records were linked to each student using school identifiers from the original 1957 survey. There were 433 WLS participants who could not be matched to a school or attended a school for which the Wisconsin Department of Public Instruction was missing reports for the focal years.

WLS coders recorded school advantage on eight indicators for each school in each year: (1) duration of the school year, (2) average daily attendance, (3) student-teacher ratio, (4) annual per pupil expenditures, (5) average teacher salary, and the proportion of teachers at each school who had: (6) worked in the district for more than five years, (7) five or more years of overall teaching experience, and (8) five or more years of education past the 12th grade. Data on residential moves in adolescence were not available from the WLS. Consistent with prior studies, we standardized and averaged school advantage scores from 1954 to 1957 ($\alpha = .74$) for one secondary school per student (Olson and Ackerman 2000).

Other Focal Measures

Rank in class.—We used rank in graduating class as the indicator of individuals' academic achievement in high school. In 1957, secondary schools reported this information to the WLS in percentiles, where the first percentile was the lowest and the 99th percentile was the highest. We standardized this measure.

Parental SES.—On the original survey in 1957, participants reported their mother's educational attainment and their father's educational attainment in years. The WLS collected tax filings for participants' parents from 1957 to 1960, which included reports of fathers' occupations and family income. Fathers' occupations were coded on the 1950 Duncan Socioeconomic Index (SEI). The SEI is a weighted average of occupational education and occupational income (Hauser and Warren 1997). Scores ranged from 1 to 100, where low scores indicated low occupational education and income (e.g., farm laborer scores 6), and high scores indicated high occupational education and income (e.g., surgeon scores 92). We averaged both SEI and income across the four-year period. We standardized all four measures and averaged them ($\alpha = .72$). We took the natural log of the measure and standardized it.

Midlife SES.—We used three measures collected when participants were age 54 to create an index of SES in midlife. Consistent with prior studies, we selected this timepoint because it preceded the measurement of cognition and presumably the onset of potentially significant age-related cognitive decline (Warren 2015). First, we created a continuous measure of *years of education* based on detailed information about educational degrees and years spent as a student, which was collected at each wave of data collection. All participants graduated from secondary school such that the lowest educational attainment was 12 years. The highest level of educational attainment was 21 years, corresponding to multiple graduate degrees. Second, we used a measure of occupational education to indicate *occupational prestige*. WLS researchers coded participants' reports of their occupation based on the percentage of 1970 U.S. census participants in each occupation (e.g., insurance underwriters) who completed at least one year of college (Hauser and Warren 1997). The measure was normally distributed and ranged from 20 (2.0% of employees had a year or more of college) to 960 (96.0% of employees had a year or more of college). Third, the WLS included detailed information about *household income* from all sources. Because this measure was skewed, we divided it into quartiles to create an ordinal measure. Then we standardized educational attainment, occupational prestige, and household income at age 53, averaged them (α = .67), and standardized the final measure.

Covariates—We adjusted models for several covariates, including gender (male/female), number of siblings reported in 1975, and whether participants reported living with both parents up until 1957. (The reasons for a participant living with one or no parents were not recorded.) To assess geographic setting in adolescence, we also included a measure of whether participants attended secondary school in a community with fewer than 10,000 residents (rural) versus more than 10,000 residents (not rural).

Finally, we included a polygenic score for general cognitive ability. A polygenic score is an estimate of genetic propensity, in this case for high cognitive ability (Maher 2015). It is the sum total of genes identified as related to cognitive ability that each participant carries, weighted for the strength of the association between the gene and the trait. Gene identification in the WLS followed the genome-wide association study (GWAS) of Lee and colleagues (2018). The polygenic score was calculated using the multitrait analysis of GWAS (MTAG) method. Scores were normally distributed in the population and expressed in standard deviations. Additional details on score creation are available on the WLS website (Okbay, Benjamin, and Visscher 2018). To account for population stratification by ancestry, we included five principal components in the analyses.

Analytic Strategy

Statistical approach.—We used multilevel models to estimate level and change in cognition simultaneously. The approach allowed us to retain both the 2,759 participants who were active throughout the study as well as the 253 participants who completed surveys at age 65 and provided genetic data at age 72 but did not have cognitive data at age 72. Schools (n = 277) formed level three, participants (n= 3,012) formed level two, and observations at ages 65 and 72, where available, formed level one (n = 5,771). We modeled time as a linear function and allowed for random intercepts (i.e., between-person and between-school variation in baseline cognitive scores).

For each of the outcomes, we estimated a series of four models. To account for the fact that memory and language/executive function were not independent outcomes but rather two related domains of overall cognition, all models controlled for the other domain of cognition. All models also controlled for five principal components to account for population stratification by ancestry. Furthermore, each predictor was interacted with time to determine both the relationship between the predictor and cognition at baseline and between the predictor and change in cognition over the seven-year study period. Model 1 included secondary school advantage and all covariates to test our hypothesis. Model 2 added measures of SES in adolescence to test whether selection into more advantaged secondary schools explained associations in Model 1, as per our first research question. Model 3 further included the measure of SES in adulthood to examine midlife SES as a potential mediator between secondary school advantage and later life cognition, in line with our second research question. To test our third research question, Model 4 tested the interaction of secondary school advantage with the individuals rank in his or her graduating class.

Missing data.—Within the analytic sample of 3,012 participants, there were missing data only on the measures of family structure, number of siblings, and rank in graduating class. Rank in class was the measure with the most missing data(150 observations, or 5% of cases). Our analysis detected no systematic differences among participants with and without missing data; therefore, following all variable creation and transformation (von Hippel 2009), we conducted multiple imputation by chained equations using the multiple imputation routine included in Stata 15. We then estimated our models and combined the estimates across the five data sets using Rubin's (1987) rules. Results estimated using listwise deletion were substantively similar and not shown here. Further analysis of another kind of missingness, attrition, was addressed in the following (see "Sensitivity Analyses").

RESULTS

Descriptive Statistics

Table 1 presents descriptive statistics for the sample with respect to each of the indicators of secondary school advantage across the 277 secondary schools that participants in our analytic sample attended, and Table 2 describes the characteristics of the 3,012 individual participants. Cognitive test scores at age 65 and 72 were normally distributed. Average scores on each test declined modestly but significantly (in the statistical sense) over the seven-year study period.

We estimated the intraclass correlations for each domain of cognition (not shown) to examine the amount of variance in the outcomes accounted for by intraindividual change between ages 65 and 72, stable differences among participants, and stable differences among the schools they attended. For memory, 7.83% ($p < .001$) of the variance in memory scores was due to factors at the school level. In other words, the correlation between the memory scores of two older adults who had been students at the same school would be correlated at $\rho = .0783$. For language/executive function, 9.91% ($p < .001$) of the variance was at the school level. Therefore, despite the distance of several decades, differences among secondary schools accounted for a significant variation in cognitive functioning among adults aged 65 and 72.

Findings from Multilevel Models

Table 3 presents abridged results of the multilevel regression models (unabridged results are available in Table OSM-1 in the online version of the article). Model 1 showed no significant associations between secondary school advantage and either baseline memory at age 65 or change in memory between age 65 and 72. For language/executive function, Model 1 indicated that secondary school advantage was associated with performance at the baseline age of 65 but not with change over seven years. An increase of one standard deviation of secondary school advantage was associated with an improvement in baseline language/ executive function of .67 percentage points ($p < .01$). This association held net of the statistically significant relationships between later life cognition and both rank in class and polygenic score for cognitive ability. However, 5.44% of the unexplained variance remained at the school level, compared to 7.83% in the empty model, indicating that our measure of secondary school advantage identified only some of the school-level influences on later life language/executive function.

Model 2 indicated that parental SES in adolescence was associated with both memory and language/executive function at age 65. Parental SES accounted for part of the relationship between secondary school advantage and language/executive function, suggesting a selection effect whereby the children of higher SES families experienced more advantaged schools. Secondary school advantage had a marginal association with baseline language/ executing functioning net of parental SES ($B = .51$, $p = .053$).

Model 3 showed that the participant's own SES in midlife significantly influenced both outcomes at baseline as well as change in memory over time. Moreover, midlife SES accounted for another additional portion of the association between secondary school advantage and language/executive function ($B = .46$, $p = .064$), indicating an accumulation of advantages over time: On average, students who went to more advantaged secondary schools obtained higher SES in midlife.

Model 4 demonstrated a caveat to the association between school context and language/ executive function, examining whether associations between secondary school advantage and later life cognition differed for students with relatively low versus high levels of academic achievement in adolescence. We found a statistically significant interaction between secondary school advantage and rank in graduating class (controlling for both adolescent and midlife SES) at age 65 ($B = -.48$, $p < .01$). This effect is displayed graphically in Figure 1, demonstrating that more advantaged schools were associated with better language/executive function for students with lower rank. Simple slopes tests indicated that secondary school advantage had no association with the language/executive function at age 65 of students whose secondary school performance was average or above.

Sensitivity Analyses

We estimated additional models to test the robustness of our results. (Where noted, results are available in the online version of the article. Other results are available on request.) First, we tested for gender interactions. There were no significant interactions between gender and school advantage or among gender, school advantage, and rank in class. Second, we analyzed primary school context data for the subsample of participants for whom this information is available (50% of participants who were still active in the study at age 65). As in the results presented previously, primary school advantage was associated with better language/executive function at age 65 only among participants who would go on to have below average class ranking in secondary school. Third, we tested whether the effects of school context were nonlinear, whereby small improvements might have large associations with later life cognition in disadvantaged schools whereas similarly small improvements in school advantage might have little long-term effects in already advantaged schools. The bivariate distribution of school advantage was normal, and results from supplementary regressions indicated that effects were linear for language/executive function. For memory, there was evidence that decline between ages 65 and 72 was more rapid among participants who attended schools in the bottom 10% of secondary school advantage. This association did not differ by respondents' rank in their graduating class, nor did we find this association with a dichotomous indicator of schools in the lowest 25% of advantage.

Missing data—especially on account of study attrition—could have introduced bias to the sample if the participants removed from the analyses would have had poorer cognition than participants in the analytic sample. For example, although people who left the study before age 65 experienced a similar range of school contexts as participants who remained, they were ranked lower in their classes and had lower parental SES in adolescence (see Table OSM-2 in the online version of the article). Therefore, we conducted additional analyses to simulate results if people who left the study before age 65 or did not have valid cognitive scores might have had poorer cognition than those in the analytic sample. We followed the strategy as presented by Rubin (1987). First, we used multiple imputation on all missing reports of cognition for participants who attended a school available in the data (N = 8,527). Then we subtracted a standard deviation from the imputations of memory and language/executive function to test the possibility that multiple imputation would overestimate these scores. We reestimated the models using this complete data set. Results were similar to those presented here. School advantage was unrelated to memory in all four models. Greater school advantage was associated with language/executive function at age 65 (Model 1: $B = .71$, $p < .01$). Parental SES in adolescence as well as participants' own SES in midlife accounted for some of this association, but students whose performance was below average continued to benefit from more advantaged schools (Model 4: $B = -.42$, $p < .01$). Finally, given the large number of participants who were excluded from our analytic sample because of missing data on polygenetic scores (see "Data" section), we reestimated models without the inclusion of this variable, which added over 1,000 participants to our sample. Results were consistent with those reported here, and notably, participants who did and did not contribute genetic data did not differ significantly on either adult cognition or secondary school advantage. Overall, this stability of findings across various treatments of the analytic sample increases the likelihood that they are not an artifact of selection bias.

DISCUSSION

Research has yielded consistent evidence that social positions early in the life course have implications for cognition decades later. Much of this research, however, has focused on educational attainment (Beydoun et al. 2014; Clouston et al. 2012) as well as parental SES in childhood (Richards and Hatch 2011). Building from an emerging literature on early-life school context and adult health, our study examined whether school advantage in adolescence is associated with individuals' cognition more than 50 years later. Results from multilevel models using data from 3,012 older adults who attended Wisconsin public secondary schools in the 1950s indicated that greater secondary school advantage was associated with better language/executive function at age 65, specifically for individuals with low levels of academic achievement in adolescence. These associations remained after accounting for both parental SES in adolescence (as a potential selection factor into more advantaged secondary schools) as well as participants' own SES in midlife (as a potential mediator of associations between secondary school advantage and later life cognition). We discuss the implications of these findings for future research on how developmental contexts in childhood potentially contribute to later life cognitive functioning.

Adolescent Academic Achievement

Similar to the results of the study by Sisco and colleagues (2015), we found subgroup differences in associations between school advantage and language/executive functioning, with results indicating associations specifically for participants with lower levels of academic achievement in secondary school. These findings are also consistent with other research finding that children with relatively poor academic skills benefit most from high-quality instruction in terms of test score gains and rates of college attendance (Jennings et al. 2015). These results can be interpreted according to a risk-and-resilience framework (Fergus and Zimmerman 2005), suggesting that more advantaged secondary school serves as a protective factor against the potential long-term disadvantages of lower levels of academic achievement in adolescence.

Notably, our study measures achievement as rank in class, which is relative to one's peers within the school rather than an absolute ranking among all Wisconsin secondary school students in 1957. An absolute measure would be confounded with school context; that is, part of the definition of a more advantaged school is one in which students exhibit higher levels of achievement, on average, relative to students in more disadvantaged schools. Rank in class avoids this problem while still yielding important information about student performance. For example, lower-performing students might achieve higher levels of learning in more advantaged schools compared to their counterparts in less advantaged schools, strengthening their long-term cognitive reserve and allowing them to maintain better cognition in later life despite age-related threats (Bezerra et al. 2012).

Further, rank in class contains unique qualitative information about peer comparisons, sometimes known as "frog pond" or "big fish little pond" effects. Net of standardized test scores, highly ranked students are more likely to attend college than their lower-ranked peers, in part because of social expectations about their abilities (Elsner and Isphording 2016). This association is beginning to be codified into social policy, with recent initiatives in some states granting students automatic admission to the state university system based on secondary school rank (Black et al. 2015). The theory is that compared to tests scores, rank in class may better identify cognitively well-prepared students who are from communities of color or low socioeconomic status. Nevertheless, evidence from Texas suggests that students who were at the top of their class in disadvantaged secondary schools do not perform as well in college as students who came from the state's more advantaged secondary schools (Black et al. 2015). Future studies are necessary to explore the longer-term cognitive implications of absolute and relative measures of academic achievement.

Secondary School Context and SES across the Life Course

Although school advantage was strongly associated with parental SES, school context had independent associations with later life cognition for lower-ranked students. Much has been written recently about the strengthening association between socioeconomic advantage and educational opportunity due to persistent residential segregation by SES (Hanselman and Fiel 2017; Owens et al. 2016). The present study indicates that even in Wisconsin in 1957, wealthier families had access to more advantaged school contexts. However, this study also suggests that for some students, such as low performers, schools are related to adult cognition in ways other than simple replication of the socioeconomic resources that are available through parents.

Regarding life course pathways, we examined midlife SES as a potential mediator of associations between secondary school advantage and later life cognition—theorizing that participants who attended more advantaged secondary schools would be more likely to pursue postsecondary education, obtain higher-status employment, and accrue more income, which could thereby promote their better cognitive functioning in later life. We found that midlife SES accounted for all of the statistically significant association between secondary school advantage and language/executive function at age 65 for students whose class rank was average or better. Overall, these results indicate support for cascading advantages accrued across different periods of the life course, whereby advantages from childhood (e.g., attending more advantaged secondary schools) enhance the likelihood of exposure to additional advantages in adulthood (Ferraro and Shippee 2009). SES, as a fundamental cause of health, allows for individuals to access good health via various mechanisms over time (Phelan, Link, and Tehranifar 2010). Accordingly, future research is necessary to unpack the likely complex mechanisms by which individual-level SES links school advantage to adult cognitive health. Better understanding these pathways is especially important for informing policies and practices to optimize cognitive health among individuals who attended more disadvantaged schools in adolescence.

Limitations

Despite this study's methodological strengths— including its administrative-based measures of secondary school advantage and measurement of two domains of cognitive functioning at two points in later life—it also has features that limit our conclusions. One such aspect is that the WLS sample comprises only non-Hispanic white participants who graduated from public secondary schools in Wisconsin in 1957, which limits the ability to generalize results from this study to other populations. Three are worth special mention. First, the study excludes people who did not graduate from secondary school, which likely truncates the observed range of cognitive function in adulthood. The levels of educational attainment that are most associated with rates of dementia are likely lower than the secondary school level, especially in regions of the United States with greater school disadvantage than Wisconsin in the late 1950s (Beydoun et al. 2014). Second, the study's lack of inclusion of older adults of color is especially problematic given dramatic racial-ethnic disparities in Alzheimer's disease and other aspects of cognitive aging (Carvalho et al. 2015), which likely parallel inequalities in secondary school advantage (Mayeda et al. 2016). Third, measures of school quality were not available for WLS participants who attended private schools, who were more likely to come from higher income families and were much less likely to have lived in a rural area in adolescence (results not shown). Issues of spatial inequality in school resources are important to consider both empirically and theoretically given that residential segregation by race-ethnicity and income profoundly shape school contexts (Owens et al. 2016).

Another limitation of our study is its exclusive focuses on school advantage and secondary school. Unmeasured aspects of school context, such as peer effects, might explain the associations between school characteristics and later life cognition. With regard to timing, a growing body of research suggests that the educational experiences in earlier years of childhood may have the largest effects on brain development (Brown and Jernigan 2012; Kremen et al. 2019). Because of the limited availability of measures of school context, especially at younger ages, we were unable to conduct analyses that account for broader contexts of educational environment across childhood and into adolescence. This constitutes an important direction for future research, which will become more feasible as participants in other longitudinal birth cohort studies age throughout adulthood.

Our study also was limited to the assessments of cognition that were included in the WLS when participants were ages 65 and 72, which are not clinical evaluations of dementia. Greater intracohort variation in cognition—especially in terms of rate of decline—would be more likely with an older sample studied across a longer period of time. Moreover, while the data allowed for examining memory and language/executive function as two related yet distinct domains of cognition, the WLS did not include measures of other potentially important domains of cognition (e.g., spatial orientation, visual perception) or neurophysiological functioning at the suborganism levels.

Finally, we note that although the strength of the association between secondary school advantage and language/executive function at age 65 was statistically robust, it was modest in size. Research on other childhood risk and protective factors for later life cognition similarly suggests small effect sizes (Gow et al. 2008). Moreover, prior research with the WLS has indicated that the effects of secondary school advantage for even more proximal outcomes—such as employment outcomes in earlier periods of adulthood—are relatively modest (Olson and Ackerman 2000). Although such effects may be small from a clinical perspective, they still are arguably important to consider from a population health perspective, especially in regards to preventing or forestalling the onset of age-related cognitive impairment (Barnes and Yaffe 2011).

Despite these limitations, findings of this study suggest the continued importance of investigating schools as an important developmental context for not only child development but also for later life cognition and potentially other aspects of adult health and well-being. Continuing to understand the long-term public health implications of individuals' experiences within schools is becoming increasingly feasible as participants from more racially/ethnically diverse and recent U.S. cohort studies mature into adulthood (e.g., Walsemann, Ailshire, and Gee 2016). This area of inquiry is also of growing societal relevance in light of evidence that school-aged children today face even greater inequalities in access to financial, human, and social capital than prior cohorts (Hanselman and Fiel 2017). Further empirical and theoretical advancements at the intersections of life course epidemiology, educational sociology, public health, and cognitive aging have the potential to help integrate critical directions for policy and practice, particularly in the context of increasing longevity and growing inequality within social institutions, such as schools.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

FUNDING

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was funded by grant R01AG057491 from the National Institute on Aging to the first two authors. We received additional support from the 2017 Genomics for Social Scientists workshop at the University of Michigan, funded by R25AG053227 from the National Institute on Aging.

AUTHOR BIOGRAPHIES

Sara M. Moorman is associate professor of Sociology at Boston College. She studies early life predictors of later life cognitive function, as well as family decision-making at the end of life.

Emily A. Greenfield is associate professor of Social Work at Rutgers, the state university of New Jersey. She studies early life predictors of later life cognitive function, as well as age-friendly community development.

Sarah Garcia is a doctoral student in Sociology at the University of Minnesota. She studies how socioeconomic inequality contributes to disablement in midlife.

REFERENCES

Aiken-Morgan Adrienne T., Gamaldo Alyssa A., Sims Regina C., Allaire Jason C., and Whitfield Keith E.. 2015 "Education Desegregation and Cognitive Change in African American Older Adults." The Journals of Gerontology: Series B 70(3):348–56.

Baker Bruce D., Farrie Danielle, and Sciarra David. 2018 Is School Funding Fair? A National Report Card. Newark, NJ: Education Law Center.

Banks James, and Mazzonna Fabrizio. 2012 "The Effect of Education on Old Age Cognitive Abilities: Evidence from a Regression Discontinuity Design." The Economic Journal 122(560):418–48. [PubMed: 22611283]

Barnes Deborah E., and Yaffe Kristine. 2011 "The Projected Effect of Risk Factor Reduction on Alzheimer's Disease Prevalence." The Lancet. Neurology 10(9):819–28. [PubMed: 21775213]

Ben-Shlomo Yoav, and Kuh Diana. 2002 "A Life Course Approach to Chronic Disease Epidemiology: Conceptual Models, Empirical Challenges and Interdisciplinary Perspectives." International Journal of Epidemiology 31(2):285–93. [PubMed: 11980781]

Beydoun May A., Beydoun Hind A., Gamaldo Alyssa A., Teel Alison, Zonderman Alan B., and Wang Youfa. 2014 "Epidemiologic Studies of Modifiable Factors Associated with Cognition and Dementia: Systematic Review and Meta-analysis." BMC Public Health 14(1). doi: 10.1186/1471-2458-14-643

Bezerra Ana Beatriz Costa, Freire Coutinho Evandro Silva, Barca Maria Lage, Engedal Knut, Engelhardt Eliasz, and Laks Jerson. 2012 "School Attainment in Childhood Is an Independent Risk Factor of Dementia in Late Life: Results from a Brazilian Sample." International Psychogeriatrics 24(1):55–61. [PubMed: 21813041]

Black Sandra E., Lincove Jane, Cullinane Jennifer, and Veron Rachel. 2015 "Can You Leave High School behind?" Economics of Education Review 46:52–63.

Brandt Jason., Miriam Spencer, and Folstein Marshal F.. 1988 "Telephone Interview for Cognitive Status." Neuropsychiatry, Neuropsychology, Behavioral Neurology 1(2):111–17.

Brown Timothy T., and Jernigan Terry L.. 2012 "Brain Development during the Preschool Years." Neuropsychology Review 22(4):313–33. [PubMed: 23007644]

Carvalho Janessa O., Tommet Doug, Crane Paul K., Thomas Michael L., Claxton Amy, Habeck Christian, Manly Jennifer J., and Romero Heather R.. 2015 "Deconstructing Racial Differences: The Effects of Quality of Education and Cerebrovascular Risk Factors." The Journals of Gerontology: Series B 70(4):545–56.

Clouston Sean A. P., Kuh Diana, Herd Pamela, Elliott Jane, Richards Marcus, and Hofer Scott M.. 2012 "Benefits of Educational Attainment on Adult Fluid Cognition: International Evidence from Three Birth Cohorts." International Journal of Epidemiology 41(6):1729–36. [PubMed: 23108707]

Cohen Patricia, Cohen Jacob, Aiken Leona S., and West Stephen G.. 1999 "The Problem of Units and the Circumstance for POMP." Multivariate Behavioral Research 34(3):315–46.

Crowe Michael, Clay Olivio J., Martin Roy C., Howard Virginia J., Wadley Virginia G., Sawyer Patricia, and Allman Richard M.. 2013 "Indicators of Childhood Quality of Education in Relation to Cognitive Function in Older Adulthood." The Journals of Gerontology: Series A 68(2):198–204.

Crowe Michael, Clay Olivio J., Sawyer Patricia, Crowther Martha R., and Allman Richard M.. 2008 "Education and Reading Ability in Relation to Differences in Cognitive Screening between African American and Caucasian Older Adults." International Journal of Geriatric Psychiatry 23(2):222–23. [PubMed: 17907267]

Dannefer Dale. 1987 "Aging as Intracohort Differentiation: Accentuation, the Matthew Effect, and the Life Course." Sociological Forum 2(2):211–36.

Domina Thurston, Penner Andrew, and Penner Emily. 2017 "Categorical Inequality: Schools as Sorting Machines." Annual Review of Sociology 43(1):311–30.

Dudovitz Rebecca N., Nelson Bergen B., Coker Tumaini R., Biely Christopher, Li Ning, Wu Lynne C., and Chung Paul J.. 2016 "Long-Term Health Implications of School Quality." Social Science & Medicine 158:1–7. [PubMed: 27100212]

Elsner Benjamin, and Isphording Ingo E.. 2016 "A Big Fish in a Small Pond: Ability Rank and Human Capital Investment." Journal of Labor Economics 35(3):787–828.

Evans Gary W., and Kim Pilyoung. 2010 "Multiple Risk Exposure as a Potential Explanatory Mechanism for the Socioeconomic Status-Health Gradient." Annals of the New York Academy of Sciences 1186(1):174–89. [PubMed: 20201873]

Fergus Stevenson, and Zimmerman Marc A.. 2005 "Adolescent Resilience: A Framework for Understanding Healthy Development in the Face of Risk." Annual Review of Public Health 26(1): 399–419.

Ferraro Kenneth F., and Morton Patricia M.. 2018 "What Do We Mean by Accumulation? Advancing Conceptual Precision for a Core Idea in Gerontology." The Journals of Gerontology: Series B 73(2):269–78.

Ferraro Kenneth F., and Shippee Tetyana Pylypiv. 2009 "Aging and Cumulative Inequality: How Does Inequality Get under the Skin?" The Gerontologist 49(3):333–43. [PubMed: 19377044]

Fletcher Jason M., and Frisvold David E.. 2011 "College Selectivity and Young Adult Health Behaviors." Economics of Education Review 30(5):826–37.

Fletcher Jason M., and Frisvold David E.. 2012 "The Long Run Health Returns to College Quality." Review of Economics of the Household 12(2):295–325.

Fuhrmann Delia, Knoll Lisa J., and Blakemore Sarah-Jayne. 2015 "Adolescence as a Sensitive Period of Brain Development." Trends in Cognitive Sciences 19(10):558–66. [PubMed: 26419496]

Gamaldo Alyssa A., Sardina Angie L., Corona Richard T., Willingham Kurtis, Migoyo Rafael V., and Andel Ross A.. 2018 "The Association between Educational Parameters and a Cognitive Screening Measure in Older Blacks." International Psychogeriatrics 30(3):311–22. [PubMed: 28689501]

Gow Alan J., Johnson Wendy, Pattie Alison, Whiteman Martha C., Starr John, and Deary Ian J.. 2008 "Mental Ability in Childhood and Cognitive Aging." Gerontology 54(3):177–86. [PubMed: 18287787]

Greenfield Emily A., and Moorman Sara M.. 2019 "Childhood Socioeconomic Status and Later Life Cognition: Evidence from the Wisconsin Longitudinal Study." Journal of Aging and Health 31(9): 1589–615. [PubMed: 29969933]

Halpern-Manners Andrew, Warren John Robert, and Brand Jennie E.. 2009 "Dynamic Measures of Primary and Secondary School Characteristics: Implications for School Effects Research." Social Science Research 38(2):397–411.

Hanselman Paul, and Fiel Jeremy E.. 2017 "School Opportunity Hoarding? Racial Segregation and Access to High Growth Schools." Social Forces 95(3):1077–104.

Hauser Robert M., and Warren John Robert. 1997 "Socioeconomic Indexes for Occupations: A Review, Update, and Critique." Sociological Methodology 27(1):177–298.

Herd Pamela, Carr Deborah, and Roan Carol. 2014 "Cohort Profile: Wisconsin Longitudinal Study (WLS)." International Journal of Epidemiology 43(1):34–41. [PubMed: 24585852]

Hyman Joshua. 2017 "Does Money Matter in the Long Run? Effects of School Spending on Educational Attainment." American Economic Journal: Economic Policy 9(4):256–80.

Jackson C. Kirabo, Johnson Rucker C., and Persico Claudia. 2016 "The Effects of School Spending on Educational and Economic Outcomes: Evidence from School Finance Reforms." The Quarterly Journal of Economics 131(1):157–218.

Jennings Jennifer L., Deming David, Jencks Christopher, Lopuch Maya, and Schueler Beth E.. 2015 "Do Differences in School Quality Matter More Than We Thought? New Evidence on Educational Opportunity in the Twenty-First Century." Sociology of Education 88(1):56–82.

Kremen William S., Beck Asad, Elman Jeremy A., Gustavson Daniel E., Reynolds Chandra A., Tu Xin M., Sanderson-Cimino Mark E., Panizzon Matthew S., Vuoksimaa Eero, Toomey Rosemary, et al. 2019 "Influence of Young Adult Cognitive Ability and Additional Education on Later-Life Cognition." Proceedings of the National Academy of Sciences of the United States of America 116(6):2021–26. [PubMed: 30670647]

Lafortune Julien, Rothstein Jesse, and Schanzenbach Diane Whitmore. 2018 "School Finance Reform and the Distribution of Student Achievement." American Economic Journal: Applied Economics 10(2):1–26.

Lee James J., Okbay Aysu, Kong Edward, Maghzian Omeed, Zacher Meghan, Nguyen-Viet Tuan Anh, Bowers Peter, Sidorenko Julia, Linnér Richard Karlsson, Fontana Mark Alan, et al. 2018 "Gene Discovery and Polygenic Prediction from a Genome-Wide Association Study of Educational Attainment in 1.1 Million Individuals." Nature Genetics 50(8): 1112–21. [PubMed: 30038396]

Lyu Jiyoung, and Burr Jeffrey A.. 2016 "Socioeconomic Status across the Life Course and Cognitive Function among Older Adults: An Examination of the Latency, Pathways, and Accumulation Hypotheses." Journal of Aging and Health 28(l):40–67. [PubMed: 26006338]

Maher Brion S. 2015 "Polygenic Scores in Epidemiology: Risk Prediction, Etiology, and Clinical Utility." Current Epidemiology Reports 2(4):239–44. [PubMed: 26664818]

Manly Jennifer J., Jacobs Diane M., Touradji Pegah, Small Scott A., and Stern Yaakov. 2002 "Reading Level Attenuates Differences in Neuropsychological Test Performance between African American and White Elders." Journal of the International Neuropsychological Society 8(3):341–48. [PubMed: 11939693]

Mantri Sneha, Nwadiogbu Chinwe, Fitts Whitney, and Dahodwala Nabila. 2019 "Quality of Education Impacts Late-Life Cognition." International Journal of Geriatric Psychiatry 34(6):855–62. [PubMed: 30714212]

Mayeda Elizabeth Rose, Glymour M. Maria, Quesenberry Charles P., and Whitmer Rachel A.. 2016 "Inequalities in Dementia Incidence between Six Racial and Ethnic Groups over 14 Years." Alzheimer's & Dementia: The Journal of the Alzheimer's Association 12(3):216–24.

Nguyen Thu T., Tchetgen Tchetgen Eric J., Kawachi Ichiro, Gilman Stephen E., Walter Stefan, Liu Sze Y., Manly Jennifer J., and Glymour M. Maria. 2016 "Instrumental Variable Approaches to Identifying the Causal Effect of Educational Attainment on Dementia Risk." Annals of Epidemiology 26(1):71–76. [PubMed: 26633592]

Okbay Aysu, Benjamin Daniel J., and Visscher Peter M.. 2018 "Documentation." https://www.ssc.wisc.edu/wlsresearch/documentation/GWAS/Lee_et_al_(2018)_PGS_WLS.pdf.

Olson Craig A., and Ackerman Deena. 2000 "High School Inputs and Labor Market Outcomes for Male Workers in Their Mid-Thirties: New Data and New Estimates from Wisconsin" Institute for Research on Poverty Discussion Papers 1205-00, University of Wisconsin Institute for Research on Poverty, Madison, WI.

Owens Ann, Reardon Sean F., and Jencks Christopher. 2016 "Income Segregation between Schools and School Districts." American Educational Research Journal 53(4):1159–97.

Phelan Jo C., Link Bruce G., and Tehranifar Parisa. 2010 "Social Conditions as Fundamental Causes of Health Inequalities: Theory, Evidence, and Policy Implications." Journal of Health and Social Behavior 51 (Suppl):S28–40. [PubMed: 20943581]

Rebok George W., Carlson Michelle C., and Langbaum Jessica B. S.. 2007 "Training and Maintaining Memory Abilities in Healthy Older Adults: Traditional and Novel Approaches." The Journals of Gerontology: Series B 62(Special Issue 1):53–61.

Richards M, James Sarah-Naomi, Sizer Alison, Sharma Nikhil, Rawle Mark, Davis Daniel H. J., and Kuh Diana. 2019 "Identifying the Lifetime Cognitive and Socioeconomic Antecedents of Cognitive State: Seven Decades of Follow-up in a British Birth Cohort Study." BMJ Open 9(4):e024404. doi:10.1136/bmjopen-2018-024404

Richards Marcus, and Hatch Stephani L.. 2011 "A Life Course Approach to the Development of Mental Skills." The Journals of Gerontology: Series B 66B(Suppl 1):i26–35.

Rubin Donald R. 1987 Multiple Imputation for Nonresponse in Surveys. New York: John Wiley & Sons.

Sisco Shannon, Gross Alden L., Shih Regina A., Sachs Bonnie C., Glymour M. Maria, Bangen Katherine J., Benitez Andreana, Skinner Jeannine, Schneider Brooke C., and Manly Jennifer J.. 2015 "The Role of Early-Life Educational Quality and Literacy in Explaining Racial Disparities in Cognition in Late Life." The Journals of Gerontology: Series B 70(4):557–67.

Spinath Birgit. 2012 "Academic Achievement" Pp. 1–8 in Encyclopedia of Human Behavior, edited by Ramachandran VS. San Diego: Academic Press.

von Hippel Paul T. 2009 "8. How to Impute Interactions, Squares, and Other Transformed Variables." Sociological Methodology 39(1):265–91.

Walsemann Katrina M., Ailshire Jennifer A., and Gee Gilbert C.. 2016 "Student Loans and Racial Disparities in Self-Reported Sleep Duration: Evidence from a Nationally Representative Sample of US Young Adults." Journal of Epidemiology and Community Health 70(1):42–48. [PubMed: 26254292]

Walsemann Katrina M., Gee Gilbert C., and Ro Annie. 2013 "Educational Attainment in the Context of Social Inequality New Directions for Research on Education and Health." American Behavioral Scientist 57(8):1082–104.

Walsemann Katrina M., Geronimus Arline T., and Gee Gilbert C.. 2008 "Accumulating Disadvantage over the Life Course: Evidence from a Longitudinal Study Investigating the Relationship between Educational Advantage in Youth and Health in Middle Age." Research on Aging 30(2):169–99.

Warren John Robert. 2015 "Does Growing Childhood Socioeconomic Inequality Mean Future Inequality in Adult Health?" The Annals of the American Academy of Political and Social Science 663(1):292–330.

Wechsler David. 1981 Wechsler Adult Intelligence Scale-Revised (WAIS-R). New York, NY: Psychological Corporation.

Wechsler David. 1997a WAIS-III: Administration and Scoring Manual: Wechsler Adult Intelligence Scale. New York, NY: Psychological Corporation.

Wechsler David. 1997b WAIS-III, Wechsler Adult Intelligence Scale: Administration and Scoring Manual. New York, NY: Psychological Corporation.

Whitfield Keith E., and Wiggins Sebrina A.. 2003 "The Impact of Desegregation on Cognition among Older African Americans." Journal of Black Psychology 29(3):275–91.

Wisconsin Legislative Reference Bureau. 2017 "2015–2016 Wisconsin Blue Book." http://legis.wisconsin.gov/LRB/publications/wisconsin-blue-book-2015/.

Zissimopoulos Julie M., Tysinger Bryan C., St. Clair Patricia A., and Crimmins Eileen M.. 2018 "The Impact of Changes in Population Health and Mortality on Future Prevalence of Alzheimer's Disease and Other Dementias in the United States." The Journals of Gerontology: Series B 73(Suppl 1):S38–47.

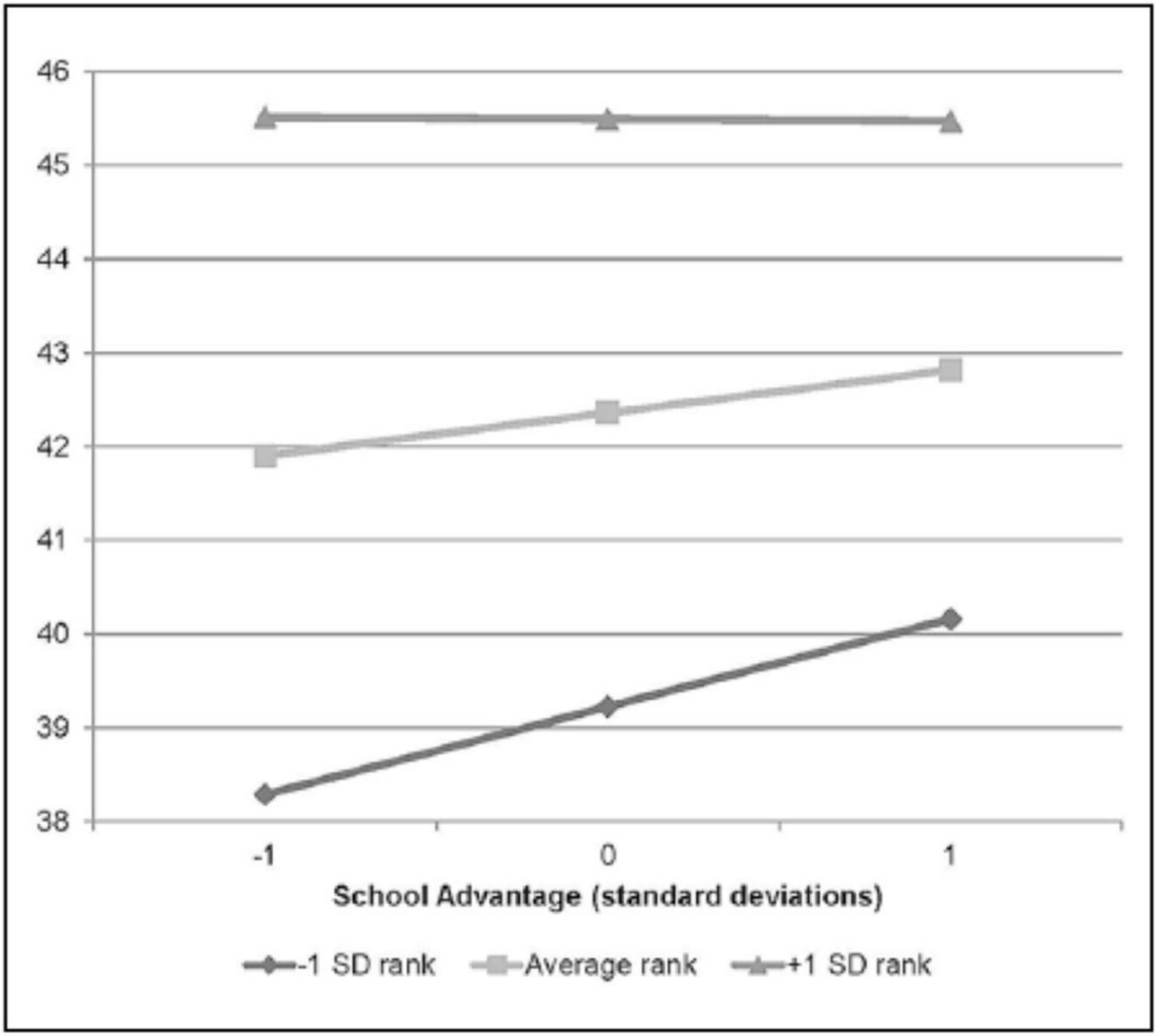

Figure 1.
Language/Executive Function (Percent of Maximum Possible): Interaction of Secondary School Advantage and Rank in Class at Age 65.

Table 1.

Measures of Secondary School Context Averaged across 1954–1957, 277 Public School Districts in the Wisconsin Longitudinal Study.

	Mean	*SD*
Number of days in the school year	175.90	2.04
% average daily attendance	92.10	2.38
Student-teacher ratio	20.56	3.26
Annual expenditures per pupil (dollars)	235.36	32.83
Average annual teacher salary (dollars)	3,927.98	447.25
% of teachers with 5+ years of teaching experience	51.37	18.25
% of teachers with 5+ years of tenure in the district	32.58	19.65
% of teachers with 5+ years of education past 12th grade	23.89	17.35

Note: SD = standard deviation.

Table 2.

Descriptive Statistics, 3,012 Participants in the Wisconsin Longitudinal Study, 1957–2011.

	Age 65		Age 72	
	Mean	***SD***	**Mean**	***SD***
Time-varying measures				
WAIS similarities (out of 12)	6.76	2.33	6.39	2.32
Letter fluency (*n* words)	11.57	4.35	11.32	4.17
Category fluency (*n* words)	21.05	6.11	19.58	5.93
Immediate recall (out of 10)	6.10	1.73	5.47	1.43
Delayed recall (out of 10)	4.01	2.10	3.44	1.76
Digit ordering (out of 12)	7.16	3.03	6.77	2.63
Time-invariant measures				
Academic achievement and cognitive ability				
Rank in graduating class (percentile)	54.62	28.14		
Polygenic score for cognitive ability	−.34	.22		
Socioeconomic status				
Mother's education (years)	10.65	2.96		
Father's education (years)	10.30	3.08		
Father's 1950 Duncan SEI	29.56	22.05		
Family income[a] (dollars)	5,400	300–99,800		
Own education (years)	13.74	2.34		
% of workers in own field with a BA	49.2	22.7		
Own income at age 53[a] (dollars)	56,650	−14,400 – 5,939,814		
Covariates				
Female (%)	52.06	—		
Rural residence in adolescence (%)	55.64	—		
Number of siblings	2.98	2.23		
Did not live with both parents most of the time until 1957 (%)	9.17	—		

Note: All values are reported on their original metrics (i.e., prior to the creation of indices, skew correction, calculation of percent of maximum possible, or standardizing) and prior to multiple imputation. *SD* = standard deviation; SEI = socioeconomic index; WAIS = Weschler Adult Intelligence Scale.

[a]Median and range reported due to skew. A negative value indicates debt.

Table 3.

Hierarchical Linear Regressions Indicating Associations between Secondary School Advantage and Cognition at Age 65 Baseline and Change across a Seven-Year Period, Wisconsin Longitudinal Study, 1957–2011 (N = 3,012).

	Memory				Language/Executive Function			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Secondary school context								
School advantage (effect on baseline)	−.03 (.35)	−.13 (.35)	−.15 (.34)	−.15 (.34)	.67** (.27)	.51 (.26)	.46 (.25)	.46 (.25)
School advantage (effect on change)	.77 (.40)	.84 (.40)	.85* (.40)	.85* (.39)	−.01 (.26)	.01 (.26)	.03 (.26)	.03 (.26)
Secondary school performance								
Class rank (baseline)	2.54*** (.32)	2.41 (.32)	1.59*** (.35)	1.61*** (.40)	4.04*** (.22)	3.81*** (.22)	2.65*** (.24)	3.10*** (.28)
Class rank (change)	−.31 (.37)	−.22 (.37)	.31 (.39)	.35 (.45)	−.13 (.24)	−.11 (.24)	−.18 (.26)	−.44 (.30)
Socioeconomic status								
Parental (baseline)		.92** (.29)	.50 (.29)	.50 (.29)		1.33*** (.22)	.78*** (.22)	.78*** (.22)
Parental (change)		−.69* (.34)	−.41 (.34)	−.41 (.34)		−.09 (.22)	−.12 (.22)	−.12 (.22)
Midlife (baseline)			2.41*** (.31)	2.41*** (.31)			2.93*** (.23)	2.93*** (.23)
Midlife (change)			−1.63*** (.37)	−1.62*** (.37)			.15 (.24)	.15 (.24)
Interaction terms								
Secondary school advantage × Class rank (baseline)				−.02 (.21)				−.48** (.16)
Secondary school advantage × Class rank (change)				−.05 (.25)				.27 (.16)
Random components								
School-level intercept	1.11 (.62)	1.17 (.59)	.98 (.67)	.97 (.67)	.85 (.48)	.51 (.63)	.00 (.00)	.00 (.00)
Person-level intercept	7.80 (.26)	7.79 (.26)	7.76 (.26)	7.76 (.26)	7.71 (.17)	7.66 (.17)	7.27 (.16)	7.26 (.16)

	Memory				Language/Executive Function			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**
Observation-level intercept	11.51 (.16)	11.50 (.16)	11.45 (.16)	11.45 (.16)	7.54 (.10)	7.54 (.10)	7.53 (.10)	7.52 (.10)
Deviance; *df*	46,504; 22	46,494; 24	46,432; 26	46,432; 28	43,007; 22	42,964; 24	42,745; 26	42,736; 28

Note: All models adjust for: time, the other domain of cognition, polygenic score for cognitive ability, five principal components of population stratification by ancestry, gender, adolescent geographic setting, family structure in adolescence, and number of siblings. Unabridged results are available in Table OSM-1 in the online version of the article. All predictors are standardized. Memory and language/executive function are presented as percentage of maximum possible. *SE* = standard error.

* $p < .05$,

** $p < .01$,

*** $p < .001$.