School Quality in Adolescence and Cognitive Functioning 50 Years Later

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Abstract

To advance understanding of how social inequalities from childhood might contribute to cognitive aging, we examined the extent to which the quality of one's school in adolescence is associated with one's 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 teacher quality, with indicators such as the proportion of teachers who had at least five years of teaching experience. Multi-level models indicated that secondary school quality was associated with small advantages in language/executive function at age 65, even after accounting for socioeconomic status (SES) in both childhood and adulthood. Statistical interaction indicated that these advantages were specific to older adults who had lower academic achievement in high school. Findings suggest that school quality is a developmental context of adolescence that has modest implications for intra-cohort differences in aspects of later life cognition.

School Quality in Adolescence and Cognitive Functioning 50 Years Later

An extensive research literature indicates that greater educational attainment is associated with better cognitive health in later life (Herd 2010). Studies have estimated that people who complete fewer than eight years of education have twice the odds of developing dementia compared to their counterparts with more than eight years of education (Beydoun et al. 2014). 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; Glymour et al. 2008; 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 (Matthews et al. 2013; Zissimopoulos et al. 2018).

Very few studies, however, have investigated whether the quality of one's education is related to later life cognitive health, above and beyond number of years of attendance. We seek to address this gap by examining whether variations in school quality in adolescence (i.e., secondary school) are associated with intra-cohort differences in later life cognition. Using data from 3,012 participants in the Wisconsin Longitudinal Study (WLS), we examine whether secondary school quality—as recorded in public state 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, accounts for associations between secondary school quality and later life cognition. Orienting to individual differences, we test whether associations between secondary school quality and later life cognition differ by participants' own academic achievement in adolescence.

School Quality as a Type 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 (Ben-Shlomo and Kuh 2002). Within life course research on cognitive aging specifically, most studies have focused on parental SES in childhood, positing that greater socioeconomic privilege enhances cognitive development in childhood, which can have long-term implications for cognitive aging (Richards and Hatch 2011). For example, scholars have theorized that parents with higher levels of education are more likely to interact with their children using a wide range of vocabulary and complex sentence structures, which can promote their children’s cognitive development and yield benefits well into adulthood (Duncan and Magnuson 2012). Consistent with this theorizing, studies across diverse national contexts have found that older adults who had greater SES as children have lower risk for cognitive impairment and higher levels of cognitive performance than their counterparts (see author citation for a review).

Few studies have considered other potential extra-familial sources of socio-structural differences among children, such as school quality. School quality refers to structural and organizational components of educational systems and is oftentimes measured in terms of the allocation of resources within schools, such as teacher pay, teachers’ level of educational attainment, and class size per teacher (Garcy and Berliner 2018). A growing body of research on child development has found that differences in school quality are associated with cognitive outcomes in childhood and into young adulthood, even when accounting for other risk factors such as low pre-academic literacy and numeracy skills, poverty, minority ethnic background, and gender (Burchinal et al. 2000; Campbell et al. 2002; Garcy and Berliner 2018).

Secondary school quality might be especially important for lifelong cognitive development given a growing body of research suggesting that adolescence is a developmental period marked by high levels of brain plasticity (Fuhrmann, Knoll, and Blakemore 2015). Brain plasticity refers to the ability of neuronal systems to adapt their organization and processes in response to stimuli both external and internal to the individual (Kolb and Whishaw 1998). Exposure to a more cognitively stimulating environment vis-à-vis high quality schools in adolescence, therefore, could promote neurophysiological development. These effects in adolescence could persist well into adulthood through sustained optimization of neuronal networks, as well as increasing the likelihood of individuals seeking out further cognitively stimulating environments throughout the life course. Consistent with this theorizing, a large body of research indicates that greater engagement in cognitively challenging activities at any period of the life course can enhance people's cognitive reserve (Rebok, Carlson, and Langbaum 2007), which is the neurophysiological ability to tolerate age-related changes and pathology without manifesting significant sociobehavioral symptoms of disease, such as memory loss (Stern 2009).

Educational Quality 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 school quality, particularly within research on physical health outcomes in midlife (Dudovitz et al. 2016; Fletcher and Frisvold 2011, 2012; Gamaldo et al. 2018; Garcy and Berliner 2018; Ross and Mirowsky 1999; Walsemann, Gee, and Ro 2013; Walsemann, Geronimus, and Gee 2008; Zajacova and Everett 2014). Within the field of cognitive aging specifically, research has focused on racial disparities in early-life education, with racial desegregation oftentimes used as a marker of access to higher-quality education for children of color (Whitfield and Wiggins

2003). In general, research has found that attending a racially-integrated school is associated with better later life cognition among older African American adults (Aiken-Morgan et al. 2015; Allaire and Whitfield 2004; Frisvold and Golberstein 2011; Whitfield and Wiggins 2003).

Only one study on later life cognition, to our knowledge, has considered aspects of early-life educational quality in addition to racial segregation (Sisco et al. 2015). This study used data from Medicare-eligible older adults in New York City, who identified as Black or White. The measures of educational quality included self-reported retrospective reports (e.g., the recalled racial composition of the primary school) and state-level indicators (e.g., mandatory number of school days). Controlling for participants' own educational attainment and later life literacy, the study found that higher early-life educational quality was associated with better general cognitive performance and executive function, but not memory, among Black participants. No such associations were found between early-life educational quality and later life cognitive functioning among White participants.

Focus of the Current Study

Our study aims to extend the nascent literature on school quality in adolescence as a risk/protective factor for later life cognitive functioning. We use data from the WLS, which uniquely offers high-quality measures of secondary schools and later life cognition that allow us to expand on prior literature. First, measures of school quality were based on information that schools provided to the state of Wisconsin when participants were in adolescence. This administrative measurement avoids potential limitations in the reliability and validity of participants' retrospective reports of secondary school quality—an aspect of childhood that respondents are unlikely to know or remember (Jivraj et al. n.d.). Second, the WLS offers assessments of cognition at two points in later life—age 65 and 72—which allows for examining both intra-cohort variation in baseline levels of cognition, as well as rates of change over time. This feature is important given that many prior studies have found evidence for robust linkages between childhood inequalities and baseline levels of cognition, with less consistent evidence for linkages with rates of decline (Cermakova, Formanek, and Winkler n.d.; Everson-Rose et al. 2003; Glymour, Tzourio, and Dufouil 2012). Third, the WLS assessments of later life cognition also allow for measuring two domains—memory and language/executive function—which is useful for examining the extent to which the potential long-term implications of secondary school quality are specific to particular aspects of cognition.

In addition to addressing the overall lack of empirical evidence on school quality within the field of cognitive aging, we also seek to advance broader understanding of how social factors throughout the life course influence later life cognitive health, with a particular focus on SES. We first consider individuals' SES in adolescence because a large body of research has documented that higher SES families have greater access, on average, to higher-quality schools (Currie and Thomas 2001). Thus, high quality schooling may be simply a benefit of high SES, rather than an independent source of advantage. Given a large body of evidence for childhood SES as a risk/protective factor for later life cognition (see author citation for a review), it is important to examine whether linkages with secondary school quality remain even after accounting for individuals' parental SES in adolescence.

We further examine the extent to which participants' own SES in midlife accounts for associations between school quality and later life cognition. Some studies have found that participants' SES in adulthood accounts for much of the association between other sources of childhood advantage/disadvantage and later life cognition (Lyu and Burr 2016; Xu et al. 2017; Zhang et al. 2017). We extend this inquiry by testing the extent to which midlife SES mediates associations for secondary school quality as well, theorizing that attending a better quality 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 (Hoekstra 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 2016), we examine whether associations between secondary school quality 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 (Spinath 2012). Different theoretical perspectives provide competing predictions as to whether higher or lower performing students might benefit the most from attending better quality 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 better quality 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 the quality of their secondary school. 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 high-quality secondary school, being especially poised to take advantage of resources within such settings.

Guided by this prior scholarship, our study examined the following hypothesis (H) and research questions (RQ):

H. Attending a better quality 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.

RQ1. To what extent do associations between secondary school quality and later life cognitive functioning remain after accounting for SES in adolescence?

RQ2. To what extent does midlife SES account for associations between attending a better quality secondary school and later life cognition?

RQ3. Do associations between secondary school quality and later life cognition differ by individuals' level of academic achievement in adolescence?

Methods

Data

The Wisconsin Longitudinal Study (WLS) includes a random sample of a cohort of men and women from Wisconsin who were primarily born in 1939, graduated from Wisconsin high 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 include 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 comprise the initial WLS sample are all non-Hispanic White high school graduates. In 1960, 97% of Wisconsin residents were White (Wisconsin Legislative Reference Bureau 2017). WLS participants of non-White racial/ethnic backgrounds were too few in number to include race/ethnicity as a variable in the dataset, both for statistical and ethical reasons (Herd, Carr, and Roan 2014). This racial/ethnic homogeneity of the sample precludes broader population inferences.

Our analytic sample excludes 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 high 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, we excluded 1,915 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. Finally, 1,266 participants were excluded because they did not provide saliva for genetic assay at age 72 (see "covariates" below). 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 below.

Adult Cognitive Function

At age 65, participants completed a battery of six cognitive tests that was repeated when they were age 72. These tests are described below.

WAIS similarities. All participants responded to the same 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 1997b). Each item was scored on a scale from 0-2, 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 were selected to repeat 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 represents 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 common words and asked immediately to repeat as many as they could remember (Brandt, Spencer, and Folstein 1988). Participants were later asked—without warning—to repeat as many of the 10 words as they could remember. The score for both measures is 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 1997b). The final score ranged from 0 to 12.

We conducted confirmatory factor analyses with scores on the six tests, which yielded a two-factor solution (results available upon request). First, the domain of memory included the scores from the immediate recall, delayed recall, and digit ordering tasks. Second, the domain of 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 0.23 in 2004 and 0.38 in 2011 (both: $p < .001$).

Secondary School Quality

In 2006, WLS researchers went to 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 high school (Halpern-Manners, Warren, and Brand 2009). Records for private schools, which 1,357 (13.2%) WLS participants attended, were inaccessible. The vast majority of these private schools (88.4%) were Catholic schools. Over 90% of WLS participants attended a school district with only one high school; indicators of secondary school quality within districts that had more than one high 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 who attended a school for which the Wisconsin Department of Public Instruction was missing reports for the focal years.

WLS coders recorded teacher quality on four indicators for each school in each year: (a) average teacher salary, and the proportion of teachers at each school who: (b) had worked in the district for more than 5 years; (c) had 5 or more years of overall teaching experience; and (d) who had 5 or more years of education past the 12th grade. Because data on residential moves in adolescence are not available from the WLS, we standardized and averaged school quality scores from 1954 to 1957 ($\alpha = 0.89$) for one secondary school per student, which is consistent with prior studies (Olson and Ackerman 2000).

Other Focal Measures

Academic achievement in secondary school. In 1957, secondary schools reported to the WLS each participant's rank in their class. This information was in percentiles, where the first percentile was the lowest, and the 99th percentile was the highest. We standardized this measure.

Parental SES in adolescence. 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 objective 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 income (Hauser and Warren 1997). Scores range from 1 to 100, where low scores indicate low occupational education and occupational income (e.g., farm laborer scores 6), and high scores indicate 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 ($\alpha = 0.72$). This measure skewed low, and so we took its natural log, and finally standardized it.

Midlife SES. We used three measures collected in 1993 when participants were approximately age 53 to create an index of SES in midlife. Consistent with prior studies using data from the WLS to examine adult SES as a mediator of earlier-life conditions, we selected this time point because it preceded the measurement of cognition and presumably the onset of potentially clinically significant age-related cognitive decline (Warren 2015). First, we created a continuous measure of *years of completed 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 high 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 ($\alpha = 0.67$), 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, which 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. A polygenic score is an estimate of genetic propensity, in this case for high cognitive ability (Maher 2015). Gene identification followed the genome-wide association study (GWAS) of Lee and colleagues (Lee et al. 2018). The polygenic score was calculated using the multi-trait analysis of GWAS (MTAG) method.

Scores are normally distributed in the population and are 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 include five principal components in the analyses.

Analytic Strategy

Statistical approach. Multilevel models—which are equivalent to latent change score models (Rabe-Hesketh and Skrondal 2012)—allowed us 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. School quality formed level 3. We modeled time as a linear function and allowed for random intercepts (i.e., between-person 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, so as to determine both the relationship between the predictor and cognition at baseline and between the predictor and change in cognition over the 7-year study period. Model 1 included secondary school quality and all covariates, to test our hypothesis. Model 2 also added measures of SES in adolescence, to test whether selection into high quality 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 quality 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 quality with the student's own academic achievement.

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 academic achievement in secondary school. Academic achievement 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, we conducted multiple imputation by chained equations, which assumes that data are missing at random. We estimated our models and combined the estimates across the five datasets using Rubin's (1987) rules. Results estimated using listwise deletion were substantively similar and are not shown here. Further analysis of another kind of missingness, attrition, is addressed below (see "Sensitivity Analyses").

Results

Descriptive Statistics

Table 1 presents descriptive statistics for the sample with respect to each of the four indicators of secondary school quality across the 277 secondary schools that participants in our analytic sample attended. The mean average teacher salary was $3,900 per school year. The mean percentage of teachers with five years or more of teaching experience was 51.37%, and the mean percentage of teachers with five or more years in the district was 32.58%. The mean percentage of teachers with five or more years of post-secondary education was approximately a quarter (23.89%).

[Table 1 about here]

Table 2 describes the characteristics of individual participants. Over half (55.64%) attended a secondary school in a rural area, and the average participant lived with two parents who had completed some high school but not obtained a diploma, and three other siblings. The average household's income in the late 1950s was US $5,400. (The median household income nationwide in 1960 was US $5,620 (Bureau of Labor Statistics 2006)).

[Table 2 about here]

Table 3 presents scores on the six cognitive tests at age 65 and 72. Scores were normally distributed. Average scores on each test declined modestly but significantly (in the statistical sense) over the 7-year study period.

[Table 3 about here]

Findings from Multilevel Models

Table 4 presents results of the multilevel regression models. Model 1 indicated that secondary school quality was associated with language/executive function at the baseline age of 65, but not with change over seven years. An increase of one standard deviation of secondary school quality was associated with an improvement in baseline language/executive function of 0.76% ($p < .01$). This association held net of the significant relationships between later life cognition and both academic achievement and polygenic score for cognitive ability. No associations were found between secondary school quality and baseline memory at age 65 or change in memory between age 65 and 72.

Model 2 indicated that parental SES in adolescence was associated with both language/executive function and memory at age 65. Parental SES accounted for part of the relationship between secondary school quality and language/executive function, suggesting a selection effect whereby the children of higher SES families experienced better quality schools. However, secondary school quality continued to have a significant association with baseline language/executing functioning net of parental SES ($B = 0.57$, $p < .05$).

[Table 4 about here]

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 quality and language/executive function ($B = 0.50$, $p < .05$), indicating an accumulation of advantages over time: On average, students who went to higher quality schools obtained higher SES in midlife. However, midlife SES did not fully account for associations between secondary school quality and language/executive function at age 65.

Model 4 showed a caveat to this association, examining whether associations between secondary school quality 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 quality and academic achievement (controlling for both adolescent and midlife SES) for language/executive function at age 65 ($B = -0.50$, $p < .01$). This effect is displayed graphically in Figure 1, demonstrating that higher secondary school quality was associated with better language/executive function for students with lower academic achievement. Simple slopes tests indicated that secondary school quality had no association with the language/executive function at age 65 of students whose secondary school performance was average or above.

[Figure 1 about here]

Sensitivity Analyses

Missing data—especially on account of study attrition—could have introduced bias to the sample if the participants removed from the analyses had cognitive scores that were systematically different than participants in the analytic sample. To address this possibility, we conducted additional analyses to simulate results if people who left the study before age 65, or who 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 re-estimated the models using this complete dataset. Results (available upon request) were similar to those presented here. School quality was unrelated to memory in all four models. School quality was associated with language/executive function at age 65 (Model 1: B = 0.71, 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 high quality schools (Model 4: B = -0.42, 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" above), we re-estimated models without the inclusion of this variable, which added over 1,000 participants to our sample. Results were consistent with those reported here. Overall, this stability of findings across various treatments of the analytic sample increases the confidence 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 cognitive health decades later. Much of this research, however, has focused on educational attainment (Beydoun et al. 2014; Herd 2010), as well as parental SES in childhood (Duncan and Magnuson 2012; Richards and Hatch 2011). Building from research indicating that school quality influences children's cognitive development, our study examined whether school quality in adolescence is associated with individuals' cognition more than 50 years later. Results from multilevel models using data from 3,012 participants in the WLS indicated that secondary school quality was associated with 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 higher quality secondary schools), as well as participants' own SES in midlife (as a potential mediator of associations between secondary school quality and later life cognition). We discuss the implications of these findings for future research and theory on how developmental contexts in childhood potentially contribute to later life cognitive health.

First, it is important to note that evidence of associations between secondary school quality and later life cognition emerged specifically in terms of baseline levels of language/executive function at age 65 and not with the rate of decline between age 65 and 72. This finding is consistent with a larger body of research on the long-term cognitive implications of other types of social advantage/disadvantage in childhood such as parental SES. Studies generally have found robust associations between parental SES and baseline levels of cognition in later life, with less evidence for associations with decline (Duncan and Magnuson 2012; Richards and Hatch 2011). Taken as a whole, these findings suggest that social advantages and disadvantages from childhood might be more likely to influence intra-cohort variation in levels of cognitive function at a given age in adulthood, whereas perhaps proximal factors in adulthood (e.g., disease pathology) potentially exert more powerful influence on rates of change in adulthood (Boyle et al. 2017). Additional studies with assessments of cognition throughout the life course are necessary to empirically test these differentiated processes, especially in light of evidence that age-related changes in cognition and neurophysiology can occur decades before late life (Singh-Manoux et al. 2012).

Second, findings indicated that linkages between secondary school quality and later life cognition were specific to language/executive function; we did not find evidence of associations between school quality and memory. This finding is congruent with prior research that has found differential patterns of associations between other social factors—such as perceived discrimination (Barnes et al. 2012), childhood SES (Beck et al. 2018), and early life adversity (Richards and Wadsworth 2004)—and specific aspects of later life cognition. It also is consistent with the one prior study that specifically addressed school quality and later life cognition, which found associations in the anticipated direction among African Americans for executive function, but not memory (Sisco et al. 2015).

Also similar to the results of the study by Sisco and colleagues (2015), we found subgroup differences in associations between school quality and language/executive functioning, with results indicating associations specifically for participants with lower levels of academic achievement in high school. These findings are also consistent with other research that shows that children with relatively poor academic skills benefit most from high-quality instruction in terms of test score gains (Aaronson, Barrow, and Sander 2007; Stipek and Chiatovich 2017). These results can be interpreted according to a risk-and-resilience framework (Fergus and Zimmerman 2005), suggesting that higher quality secondary school serves as a protective factor against the potential long-term disadvantages of lower levels of academic achievement in adolescence. For example, lower-performing students might achieve higher levels of learning in high quality schools compared to their counterparts in lower quality schools, strengthening their long-term cognitive reserve and allowing them to maintain better cognition in later life in spite of age-related threats (Bezerra et al. 2012). High quality teachers have been characterized as educators who focus on helping students to discover meaning in material in order to understand as opposed to rote memorization in order to reproduce material (Trigwell and Prosser 1991). High quality teachers have also been shown to have high expectations for students—particularly those at risk for poor outcomes—which might have benefits that extend well beyond high school (Goe 2007).

Regarding life course pathways, we examined midlife SES as a potential mediator of associations between secondary school quality and later life cognition—theorizing that participants who attended higher quality secondary schools would be more likely to pursue post-secondary education, obtain higher-status employment, and accrue more income, which can thereby promote their better cognitive health in later life. We found that midlife SES accounted for some—but not all—of the association between secondary school quality and language/executive function at age 65. This partial mediation indicates some support for cascading advantages accrued across different periods of the life course, whereby advantages from childhood (such as attending higher quality secondary schools) enhance the likelihood of exposure to additional advantages in adulthood (Ferraro and Shippee 2009). However, the fact that midlife SES did not fully account for the association suggests that alternative life course processes also play a role. For example, consistent with a latency pathway, attending schools with more experienced teachers might have immediate effects on neurophysiological development in adolescence, which could directly extend into later life regardless of individuals' SES in adulthood.

Despite this study's methodological strengths—including its administrative-based measures of secondary school quality and its measurement of two domains of cognitive functioning at two points in later life—it also has features that limit its external and internal validity. Regarding external validity, the WLS sample comprises only White participants who graduated from public high schools in Wisconsin in 1957, which limits the ability to generalize results from this study to other populations (e.g., by race/ethnicity, birth cohort, geographic region, lower levels of education, private school attendance). This study's lack of inclusion of non-White older adults is especially problematic given dramatic racial/ethnic disparities in Alzheimer's disease, with Black, and American Indian/Alaska Native older adults at especially high risk (Mayeda et al. 2016).

Regarding internal validity, despite our study's inclusion of control variables for factors that might account for participants' differential selection into higher or lower quality secondary schools—such as a polygenic scores for general cognitive ability, family size, neighborhood context, and parental SES—there are other life course factors preceding secondary school quality that could account for the associations reported in this study. Examples include social aspects of participants' home environments in childhood (e.g., cognitive stimulation, familial disruption), physical aspects of home and school environments (e.g., lead exposure), other aspects of the neighborhood context (e.g., social cohesion, neighborhood SES), as well as childhood health and ability (e.g., perinatal complications).

Third, our study was limited to the assessments of cognition that were included in the WLS when participants were ages 65 and 72. While these measures 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) nor clinical measures of cognitive status and neurophysiological functioning at the sub-organism levels. Moreover, cognition was assessed when participants were in their 60s and 70s; greater intra-cohort 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.

Finally, we note that although the strength of the association between secondary school quality 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 quality 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 (Parcel, Dufur, and Cornell Zito 2010), but also for later life cognition and potentially other aspects of adult health and well-being (Dudovitz et al. 2016). 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 (Engel et al. 2016). 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, population aging, and growing inequality within social institutions, such as schools.

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Table 1

Measures of Secondary School Teacher Quality Averaged across 1954-1957, 277 Public School Districts in the Wisconsin Longitudinal Study

	M	*SD*
Average teacher salary (dollars)	3,927.98	447.25
Percentage of teachers with 5+ years of teaching experience	51.37	18.25
Percentage of teachers with 5+ years of tenure in the district	32.58	19.65
Percentage of teachers with 5+ years of education past 12th grade	23.89	17.35

Table 2

Descriptive Statistics for Time-Invariant Measures, 3,012 Participants in the Wisconsin Longitudinal Study

	M	*SD*
Academic Achievement and Cognitive Ability		
High school rank (percentile)	54.62	28.14
Polygenic score for cognitive ability	-0.34	0.22
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
Percentage 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 (percentage)	52.06	--
Rural residence in adolescence (percentage)	55.64	--
Number of siblings	2.98	2.23
Lived with both parents most of the time until 1957 (percentage)	9.17	--

Note. All values reported on their original metrics (i.e., prior to the creation of indices, skew correction, or standardizing).

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

Table 3

Descriptive Statistics for Adult Cognitive Function by Age, 3,012 Participants in the Wisconsin Longitudinal Study, Years 2004 and 2011

	Age 65		Age 72	
	M	*SD*	*M*	*SD*
WAIS similarities (out of 12)	6.76	2.33	6.39	2.32
Letter fluency (# words)	11.57	4.35	11.32	4.17
Category fluency (# 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

Note. All values reported on their original metrics (i.e., prior to the creation of indices or calculation of percent of maximum possible).

*Table 4. Hierarchical Linear Regressions Indicating Associations between Secondary School Quality and Cognition (in Percent of Maximum Possible) at Age 65 Baseline and Change across a Seven-Year Period (*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 quality (effect on baseline)	0.06 (0.35)	0.06 (0.35)	-0.10 (0.35)	-0.10 (0.35)	0.76** (0.27)	0.57* (0.26)	0.50* (0.25)	0.49 (0.25)
School quality (effect on change)	0.53 (0.40)	0.61 (0.40)	0.64 (0.40)	0.64 (0.40)	-0.01 (0.26)	0.01 (0.26)	0.02 (0.26)	0.02 (0.26)
Socioeconomic Status								
Parental (baseline)		0.91** (0.29)	0.50 (0.29)	0.50 (0.29)		1.32*** (0.22)	0.78*** (0.22)	0.78*** (0.22)
Parental (change)		-0.68 (0.34)	-0.40 (0.34)	-0.40 (0.34)		-0.09 (0.22)	-0.11 (0.22)	-0.11 (0.22)
Midlife (baseline)			2.41*** (0.31)	2.41*** (0.31)			2.93*** (0.23)	2.93*** (0.23)
Midlife (change)			-1.63*** (0.37)	-1.63*** (0.37)			0.14 (0.24)	0.14 (0.24)
Interaction Terms								
Secondary school quality x academic achievement (baseline)				-0.11 (0.21)				-0.50** (0.16)

Table 4 *cont'd*	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 quality x academic achievement (change)				0.07 (0.25)				0.22 (0.16)
Covariates								
High school rank (baseline)	2.54*** (0.32)	2.41*** (0.32)	1.59*** (0.35)	1.70*** (0.41)	4.04*** (0.22)	3.81*** (0.22)	2.65*** (0.24)	3.14*** (0.28)
High school rank (change)	-0.31 (0.37)	-0.22 (0.37)	0.30 (0.39)	0.24 (0.45)	-0.13 (0.24)	-0.11 (0.24)	-0.18 (0.26)	-0.38 (0.30)
Polygenic score for cognitive ability (baseline)	0.26 (0.27)	0.26 (0.27)	0.15 (0.27)	0.15 (0.27)	1.40*** (0.21)	1.39*** (0.21)	1.20*** (0.20)	1.21*** (0.20)
Polygenic score for cognitive ability (change)	0.74* (0.32)	0.75* (0.32)	0.82* (0.32)	0.82* (0.32)	-0.19 (0.21)	-0.19 (0.21)	-0.17 (0.21)	-0.18 (0.21)
Language (baseline)	0.17*** (0.02)	0.16*** (0.02)	0.12*** (0.02)	0.12*** (0.02)				
Language (change)	0.11*** (0.03)	0.12*** (0.03)	0.16*** (0.03)	0.16*** (0.03)				
Memory (baseline)					0.07*** (0.01)	0.06*** (0.01)	0.05*** (0.01)	0.05*** (0.01)
Memory (change)					0.10*** (0.02)	0.10*** (0.02)	0.10*** (0.02)	0.10*** (0.02)
Gender (baseline)	6.69*** (0.53)	6.77*** (0.53)	8.00*** (0.56)	8.00*** (0.56)	-0.20 (0.42)	-0.06 (0.42)	1.49*** (0.43)	1.47** (0.43)
Gender (change)	-3.17*** (0.64)	-3.23*** (0.64)	-4.06*** (0.67)	-4.06*** (0.67)	-0.70 (0.43)	-0.72 (0.43)	-0.67 (0.45)	-0.66 (0.45)
Adolescent geographic setting (baseline)	-0.92 (0.87)	-0.73 (0.88)	-0.50 (0.86)	-0.50 (0.86)	-0.48 (0.68)	-0.23 (0.65)	-0.01 (0.63)	-0.01 (0.63)

Table 4 *cont'd*	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*)
Adolescent geographic setting (change)	0.50 (1.00)	0.36 (1.00)	0.22 (1.00)	0.22 (1.00)	0.16 (0.66)	0.15 (0.66)	0.22 (0.67)	0.22 (0.66)
Adolescent family structure (baseline)	-1.71 (0.89)	-1.45 (0.89)	-1.54 (0.88)	-1.53 (0.89)	-0.04 (0.69)	0.33 (0.69)	0.20 (0.67)	0.25 (0.67)
Adolescent family structure (change)	1.49 (1.07)	1.30 (1.07)	1.36 (1.07)	1.35 (1.07)	-0.12 (0.70)	-0.15 (0.71)	-0.13 (0.71)	-0.15 (0.71)
Siblings (baseline)	-0.11 (0.12)	-0.03 (0.12)	0.03 (0.12)	0.03 (0.12)	-0.17 (0.09)	-0.05 (0.09)	0.02 (0.09)	0.03 (0.09)
Siblings (change)	0.10 (0.14)	0.03 (0.14)	-0.01 (0.14)	-0.01 (0.14)	-0.02 (0.09)	-0.03 (0.10)	-0.03 (0.10)	-0.03 (0.71)
Age (65/72)	-9.57*** (1.70)	-9.70*** (1.70)	-10.65*** (1.70)	-10.68*** (1.70)	-6.31*** (1.10)	-6.35*** (1.05)	-6.55*** (1.05)	-6.57*** (1.05)
Random Components								
School-level intercept	1.08 (0.66)	1.15 (0.61)	0.95 (0.70)	0.95 (0.71)	0.80 (0.48)	0.14 (9.29)	0.00 (0.00)	0.00 (0.00)
Person-level intercept	7.81 (0.26)	7.79 (0.26)	7.76 (0.26)	7.76 (0.26)	7.71 (0.17)	7.66 (0.17)	7.27 (0.16)	7.26 (0.16)
Observation-level intercept	11.52 (0.16)	11.51 (0.16)	11.45 (0.16)	11.45 (0.16)	7.54 (0.10)	7.54 (0.10)	7.53 (0.10)	7.53 (0.10)
Deviance; *df*	46,506; 22	46,496; 24	46,434; 26	46,434; 28	43,005; 22	42,963; 24	42,745; 26	42,724; 28

Note. All models adjust for five principal components of population stratification by ancestry.

*** p < .001, ** p < .01, * p < .05

Figure 1

Language/ Executive Function: Interaction of Secondary School Quality and Rank in Class, at Baseline