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The Role of Early-Life Educational Quality and Literacy in Explaining Racial Disparities in Cognition in Late Life

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Objectives. Racial disparities in late-life cognition persist even after accounting for educational attainment. We examined whether early-life educational quality and literacy in later life help explain these disparities.

Method. We used longitudinal data from the Washington Heights-Inwood Columbia Aging Project (WHICAP). Educational quality (percent white students; urban/rural school; combined grades in classroom) was operationalized using canonical correlation analysis. Late-life literacy (reading comprehension and ability, writing) was operationalized using confirmatory factor analysis. We examined whether these factors attenuated race-related differences in late-life cognition.

Results. The sample consisted of 1,679 U.S.-born, non-Hispanic, community-living adults aged 65–102 (71% black, 29% white; 70% women). Accounting for educational quality and literacy reduced disparities by 29% for general cognitive functioning, 26% for memory, and 32% for executive functioning but did not predict differences in rate of cognitive change.

Discussion. Early-life educational quality and literacy in late life explain a substantial portion of race-related disparities in late-life cognitive function.

Key Words: Cognition—Life events and contexts—Minority and diverse populations.

RACIAL disparities in late-life cognitive test performance are well documented (Alley, Suthers, & Crimmins, 2007; Fillenbaum et al., 2001; Masel & Peek, 2009; Masel, Raji, & Peek, 2010; Rodgers, Ofstedal, & Herzog, 2003; Schwartz et al., 2004; Zsembik & Peek, 2001). Studies have shown that nondemented black older adults demonstrate lower cognitive test performance compared with white peers. These disparities are sometimes attenuated by demographic factors such as educational attainment and socioeconomic status (Barnes et al., 2011; Schwartz et al., 2004) or other predictors of cognitive function such as physical activity (Masel et al., 2010), occupational attainment (Manly et al., 1998), occupational prestige (Albert, 1995; Del Ser, Hachinsky, Merskey, & Munoz, 1999; Fratiglioni, 1996; Friedland, 1993; Katzman, 1993), and health-related variables (Manly et al., 1998; Mungas et al., 2009). Some studies suggest that race-related differences in late-life cognitive performance are sometimes (Fillenbaum et al., 2001), but not typically, eliminated by accounting for such variables.

Literacy in late life, though highly correlated with years of education (Verhaeghen, 2003), has proven to be a stronger predictor of late-life cognitive functioning than years of education, especially for blacks (Dotson, Kitner-Triolo, Evans, & Zonderman, 2009). Adjusting for literacy has also been shown to greatly attenuate the estimated effect of race and to eliminate most racial differences on neuropsychological test performance in multiethnic elderly samples matched on years of education (Manly et al., 1999; Manly, Jacobs, Touradji, Small, & Stern, 2002; Touradji, Manly, Jacobs, & Stern, 2001).

Literacy has been proposed to be a better predictor of late-life cognitive differences than years of education,

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especially for minorities, because it better approximates the cognitive benefits conferred by the early-life educational experience. Educational experiences can be characterized with respect to duration, for example, using years of schooling completed or degrees attained, or with respect to quality of schooling. The degree of cognitive benefit from education may better correspond with indices of educational quality than measures of educational attainment (Dotson et al., 2009). As Manly, Touradji, Tang, and Stern (2003) demonstrated, educational quality as approximated by literacy in later life is a stronger predictor of late-life cognitive performance than years of education.

Evidence also suggests that educational quality, measured by state education policies, independently predicts late-life differences in cognition (Glymour, 2004). Historically, educational quality has varied widely across states and over time in the United States (Berkman & Glymour, 2006), with pronounced differences especially between northern and southern parts of the country. A majority of adults now aged 50 and older grew up during the influence of Jim Crow laws. Many blacks received their education in the South, where social conditions differed greatly from the North (Barnes, 1983). For example, most Southerners attended segregated schools, and schools for black students offered significantly lower quality education than schools for whites (Glymour & Manly, 2008). Because many of today's black elders attended school under Jim Crow laws in segregated schools, race-based differences in educational quality may account for a substantial portion of the racial differences observed in late-life cognition.

It is difficult to collect direct data on the quality of education received many decades ago, but recent research has taken advantage of historical state and local laws and records. For example, Lleras-Muney (2002) found that state-level compulsory school attendance laws predicted mortality in addition to average years of education completed for people born in a state. Related to the present study, Glymour (2004) found that individuals born in states that had high levels of mandatory schooling performed better on cognitive testing decades after finishing school, after controlling for demographic characteristics. This finding suggests that historical indices of early-life educational experiences, albeit imprecise on an individual level, may partly explain cognitive performance in later life. Considering the significant social and educational disparities that existed during early childhood for today's older adults, state laws dictating educational policy, as well as other indices of educational quality (e.g., classroom size, student:teacher ratio), may independently explain a substantial portion of race-based differences in late-life cognition.

The WHICAP (Washington Heights-Inwood Columbia Aging Project) study, used in the present study, is a community-based study of cognitive aging in a multiethnic population of communities in New York City. WHICAP measured several individual- and state-level characteristics of early-life educational quality and collected individual-level measures of cognition and literacy during late life. The present study examined the utility of both early-life educational quality and literacy in explaining race-related differences in late-life cognitive performance within the WHICAP sample.

We hypothesized that both educational quality and literacy account for a significant amount of the variance in general and domain-specific late-life cognitive performance, and both factors significantly attenuate the apparent racial disparities in level and pace of change in late-life cognitive functioning. We hypothesized that literacy is a stronger predictor of late-life cognitive functioning than educational quality for two reasons. First, literacy was measured more proximally to cognitive outcomes. Second, many indicators of early-life educational quality were obtained based on state records at the time participants were in school, and such area-level measures typically show weaker associations than those obtained at the individual level.

Method

Study

We used data from the Washington Heights-Inwood Columbia Aging Project (WHICAP), an ongoing study of community-living Medicare-eligible older adults recruited from northern Manhattan (Tang et al., 2001). Participants, identified based on residence in U.S. census tracts within the study catchment area, were invited to participate in a survey in 1992 and were followed up approximately every 2–3 years. Recruitment opened again in 1999 and has continued for all participants. At each interview, participants completed an extensive set of questions about their health, cognitive function, and in the baseline interview, they answered questions about early-life education. Institutional Review Boards at Columbia Presbyterian Medical Center, Columbia University Health Sciences, and the New York State Psychiatric Institute approved this study.

Participants

The full WHICAP sample included 4,193 participants. We excluded participants who did not undergo neuropsychological testing during at least one study visit ($n = 34$); who did not self-identify as being black or white ($n = 91$); were immigrants ($n = 2,389$); or were Hispanic ($n = 1,703$). We excluded participants who were immigrants because of the lack of common indicators for early-life educational quality between Spanish-speaking immigrants and U.S.-born participants. The remaining group of Hispanic older adults who did not self-identify as black or white comprised too small a sample from which to make inferences. The final analytic sample included $N = 1,679$ participants.

Variables

Early-life educational quality.—We used six indicators to form a composite measure of early-life educational quality. We considered three self-reported indicators of early-life educational quality: the percentage of white students in the primary school that participants attended (a marker of segregated schools), urban versus rural location of the primary school, and whether the primary school had a single room for all grades. We also considered three indicators of early-life educational quality drawn from state-level administrative records: length of the school term, average number of school days attended, and student:teacher ratio. See Glymour and Manly (2008) for full details on study variables used. In this study, we categorized the number of school days attended into more than 140 versus 140 days or less. We also categorized the student:teacher ratio into less than 29 students per teacher and 29 students or more per teacher.

Literacy in later life.—We considered four indicators of late-life literary ability: the reading score from the Wide Range Achievement Test (WRAT), version 3 (Wilkinson, 1993); score from a reading comprehension task; score from a writing task; and self-reported proficiency in English. The reading and writing tasks were relatively simple: For reading, participants read two sentences aloud, or if not able, listened to sentences read by the examiner, and filled in a blank in each with the appropriate word. Scores ranged from 0 to 4 points with an average of 3.7 (SD = 0.6). For writing, they wrote down a dictated sentence, or, if unable, copied a written sentence. Scoring assessed spelling, inclusion of all words, and ability to write from dictation, copy, or neither. Scores ranged from 0 to 3 points with an average of 2.4 (SD = 0.6) in this sample. Self-reported English proficiency was captured as a rating of 1–4 (not at all, not well, well, or very well); 96% of whites and 87% of blacks reported speaking English very well.

Cognitive function.—We constructed composite scores for general cognitive function, memory, and executive function from factor analyses of the neuropsychological battery administered in WHICAP. The WHICAP battery consisted of 11 tests, representing 19 variables. Each composite was scaled to have a mean of 50 and SD of 10 in a nationally representative sample of older adults (Langa et al., 2005). We used total recall, delayed recall, and delayed recognition from the Buschke Selective Reminding Test (Buschke & Fuld, 1974) to construct the memory composite. The executive functioning composite was created using the Color Trail-Making Test (A and B; D'Elia et al., 1999), WAIS-R (Wechsler Adult Intelligence Scale–Revised) Similarities (Wechsler, 1981), Identities/Oddities subtest of the Mattis Dementia Rating Scale (Mattis, 1976), two cancellation tasks (Sano, Rosen, & Mayeux, 1984) and semantic fluency for animals (Wechsler, 1981). All of the above variables, together with phonemic fluency (Wechsler, 1981), the 15-item Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983), a repetition task (high-frequency phrases of the Boston Diagnostic Aphasia Examination [BDAE]; Goodglass & Kaplan, 1983), and a comprehension task (first six items of the Complex Ideational Material subset of the BDAE; Goodglass & Kaplan, 1983), contributed to the composite for general cognition. We scaled each composite to nationally representative norms for older adults using available tests in common between WHICAP and the Aging, Demographics, and Memory Study (ADAMS), a sub-study of the Health and Retirement Study (HRS) (Gross, Benitez, Shih, et al., forthcoming).

Covariates.—We adjusted for years of education to examine whether further adjusting for quality of early-life experiences and later life literacy affects cognitive functioning over and above years of education. We further adjusted models for age, sex, and for baseline performance, a count of vascular risk factors (Schneider, Gross, Bangen, et al., forthcoming), and retest effects (Gross, Jones, Fong, Tommet, & Inouye, forthcoming). Cardiovascular risk factors (CVRFs) were assigned a value of 1 if present and 0 if absent, and a sum score of these factors was used to adjust for vascular risk. Diabetes, hypertension, history of atrial fibrillation/arrhythmia, myocardial infarction, congestive heart failure, angina, smoking, obesity, and stroke were considered CVRFs. Most participants in this sample had at least one CVRF; blacks were more likely to have three or more CVRFs.

Analysis plan.—The analysis plan followed four main steps. First, we characterized participants in WHICAP using descriptive statistics. Continuous variables were compared by analysis of variance, and categorical variables were compared by χ^2 tests. Second, using canonical correlation analysis (CCA), we characterized educational quality as a formative indicator (i.e., latent construct considered to be the result of observed variables), and using factor analysis, we characterized literacy as a reflective indicator (in which observed variables are considered reflective effects of a latent construct; Howell, Breivik, & Wilcox, 2007; Treiblmaier, Bentler, & Mair, 2011). Third, we modeled cognitive function over age with and without adjustment for the educational quality and literacy constructs.

Formative indicator for educational quality.—We developed a formative indicator for early-life educational quality in two phases. First, we performed a CCA on the indicators using a published R program (González & Déjean, 2012), which combines the indicators into two subcomposites that are independent of one another. It does not matter which variables go into which grouping (Treiblmaier et al., 2011). Second, we derived the formative construct from the two subcomposites using factor analysis (Figure 1A). Because the indicators in this factor analysis are uncorrelated, the

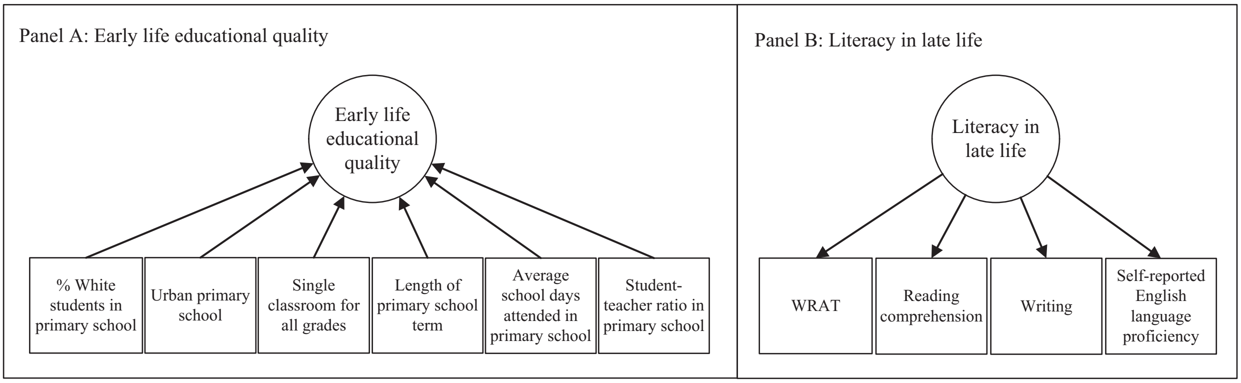

Figure 1. Diagrams for early-life educational quality and late-life literacy. We used six indicators to form a formative indicator representing early-life educational quality using canonical correlation analysis (**A**). We used four indicators to form a reflective indicator representing late-life literacy using confirmatory factor analysis (**B**). WRAT = Wide Range Achievement Test.

factor score from this conceptually becomes a formative construct (Treiblmaier et al., 2011). Approximately 25% of the analytic sample, nearly all of whom were in the first recruitment cohort in 1992, were not asked where they went to primary school as this was not added to the interview form until 1999. We addressed missing data items related to this issue (the three self-reported educational quality indicators) in the formative indicator with a single imputation using chained equations (Barnard & Meng, 1999; Royston, 2004).

Reflective indicator of later life literacy.—We formed a reflective indicator using confirmatory factor analysis. We saved factor scores for use in subsequent growth modeling (Figure 1B).

Growth models for general and domain-specific cognitive function.—We estimated multivariate linear regression models with random effects to characterize baseline level and rate of change in general cognitive function, memory, and executive function (Johnson et al., 2012; Laird & Ware, 1982). All cognitive outcomes were modeled together in one multivariate model. We used age as our timescale of interest and centered age at 75 years, so that model intercepts are interpretable as model-estimated cognitive performance for an average 75-year old participant in the sample.

We estimated two models. In the first model, we adjusted for age, sex, recruitment cohort (1992 or 1999), years of education, count of vascular risk factors, and practice or retest effects resulting from repeat testing. In the second model, we further adjusted for early-life educational quality and late-life literacy using the measures we developed. We adjusted for practice effects by regressing cognitive performance on a variable coded as 0 at each participant's first study visit and the difference in years between the first and second visits for all subsequent visits (see Gross, Benitez, Shih, et al., forthcoming).

Analyses were conducted with M-plus statistical software (version 7; Muthén & Muthén, 1998–2010) using a robust maximum likelihood estimation procedure that assumed outcome observations are missing at random conditional on covariates in the model (Little & Rubin, 1987). Fit of modeled trajectories to the data was assessed by visually inspecting histograms of model-estimated residuals and scatterplots of residuals over time. We also calculated a pseudo-R^2 statistic for each outcome (i.e., general and domain-specific cognitive function). The pseudo-R^2 represents the proportion of variability in observed data explained by the model (Singer & Willet, 2003). It is calculated by squaring the correlation between observed and model-estimated outcome scores.

Results

Descriptive Statistics

Descriptive statistics for the sample, including raw components of formative and reflective indicators, are provided in Table 1 for the overall sample and by racial group. Most of the sample was black (n = 1,188, 70.8%), women (n = 1,156, 68.9%), and had 8 or more years of education (n = 1,280, 76.3%). The average age was 77.1 years. Compared to white participants, black participants were older (p = .02), more likely to be women (p < .001), less highly educated (p < .001), more likely to have been recruited in 1999 (p < .001), have a greater cardiovascular risk burden (p = .03), and have lower scores on component scores for early-life educational quality and late-life literacy (all p < .001; Table 1). Neither average follow-up time (p = .16) nor total number of visits (p = .92) differed by race. Black participants had significantly lower reading, writing, and WRAT-3 scores than whites, shorter school terms, fewer average days of school attended, larger student:teacher ratios, and were more likely to attend school in a rural area (Table 1). Classes were clearly segregated, with an average 92% white

Table 1. Descriptive Characteristics of the Sample: Results From WHICAP (N = 1,679)

Variable	Full sample (N = 1,679)	White (n = 491)	Black (n = 1,188)	p Value for group difference
Demographic and health characteristics				
Age, mean (*SD*)	77.1 (6.9)	76.5 (6.9)	77.3 (6.9)	.017
Male sex, *n* (%)	523 (31.1)	187 (38.1)	336 (28.3)	<.001
Years of education, *n* (%)				<.001
7 years or less	397 (23.7)	40 (8.2)	357 (30.1)	
8 or more years	1,280 (76.3)	450 (91.8)	830 (69.9)	
Follow-up time, mean (*SD*)	4.8 (4.3)	5.0 (4.4)	4.7 (4.3)	.16
Number of visits, mean (*SD*)	3.2 (1.9)	3.2 (1.9)	3.2 (1.9)	.92
Recruitment cohort, *n* (%)				<.001
1992 cohort	734 (43.7)	175 (35.6)	559 (47.1)	
1999 cohort	945 (56.3)	316 (64.4)	629 (52.9)	
Count of vascular risk factors, *n* (%)				.03
0	348 (20.7)	122 (24.8)	226 (19.0)	
1	591 (35.2)	177 (36.0)	414 (34.8)	
2	479 (28.5)	128 (26.1)	351 (29.5)	
3	207 (12.3)	53 (10.8)	154 (13.0)	
4	54 (3.2)	11 (2.2)	43 (3.6)	
Early-life educational quality				
Urban primary school, *n* (%)	41.4 (45.5)	346 (88.5)	599 (70.3)	<.001
Combined classrooms in primary school, *n* (%)	945 (76.0)	364 (92.4)	652 (77.1)	<.001
Percent white students in primary school, mean (*SD*)	622 (58.2)	92.9 (17.2)	16.3 (31.7)	<.001
Length of the school term (180+ days), *n* (%)	1,016 (81.9)	327 (94.8)	295 (40.8)	<.001
Average number of school days attended (140+ days), *n* (%)	698 (65.6)	341 (98.8)	357 (49.7)	<.001
Student:teacher ratio (<29 cutoff), *n* (%)	395 (41.1)	206 (67.1)	189 (28.9)	<.001
Late-life literacy				
WRAT-3 reading score, mean (*SD*)	44.1 (8.4)	49.2 (6.1)	41.7 (8.2)	<.001
Reading comprehension, mean (*SD*)	3.7 (0.7)	3.9 (0.4)	3.6 (0.8)	<.001
Writing, *n* (%)	2.4 (0.6)	2.6 (0.5)	2.2 (0.6)	<.001
Self-rated English proficiency, *n* (%)				<.001
Very well	1,052 (90.2)	365 (96.6)	687 (87.3)	
Less than very well	113 (9.8)	13 (3.4)	100 (12.7)	
Cognitive outcomes				
General cognitive performance, mean (*SD*)	49.6 (12.1)	56.0 (11.3)	46.9 (11.4)	<.001
Memory, mean (*SD*)	51.7 (10.5)	56.2 (10.2)	49.8 (10.0)	<.001
Executive functioning, mean (*SD*)	47.9 (11.2)	54.3 (10.2)	45.2 (10.5)	<.001

Note. WHICAP = Washington Heights-Inwood Columbia Aging Project; WRAT = Wide Range Achievement Test.

students in schools attended by white participants, and 16% whites in schools attended by black participants.

Formative Indicator for Educational Quality

We derived the formative indicator for early-life educational quality and examined its distribution by racial group (Figure 2A). Overlap between the two groups was acceptable. White participants clustered near the higher quality end of the scale. Early-life educational quality was moderately correlated with general cognitive performance (r = .4).

Reflective Indicator of Late-Life Literacy

The reflective indicator of late-life literacy was derived using confirmatory factor analysis with categorical variables. Similar to the formative indicator, this measure showed acceptable overlap between black and white groups (Figure 2B). Late-life literacy was moderately correlated with general cognitive performance (r = .52).

Growth Models for General and Domain-Specific Cognitive Function

Cognitive functioning variables were scaled so that a mean of 50 (*SD* of 10) describes normal cognitive performance among older adults in the population-based ADAMS HRS sample (Langa et al., 2005). Models 1 and 2 fit well to the observed data and did not change significantly with the added predictors (pseudo-r^2 for general cognitive performance: .89; pseudo-r^2 for memory: .82; pseudo-r^2 for executive functioning: .84).

The first model did not adjust for early-life educational quality or late-life literacy. The difference in general cognitive performance at age 75 between black and white participants represented a 0.54 *SD* difference (95% confidence interval [CI]: 0.39, 0.69 *SD*). Model-estimated general cognitive performance at age 75 was significantly lower in black participants (mean score: 49.8 points, 95% CI: 49.2, 50.5 points) compared with white participants (mean score: 55.3, 95% CI: 53.9, 56.6 points) when we adjusted for covariates (Table 2). The model-estimated annual pace of decline in general cognitive performance was significant and negative for both race groups but did not differ significantly (difference: −0.08 points, 95% CI: −0.2, 0.01 points), although there was a small significant difference between groups for decline in executive functioning

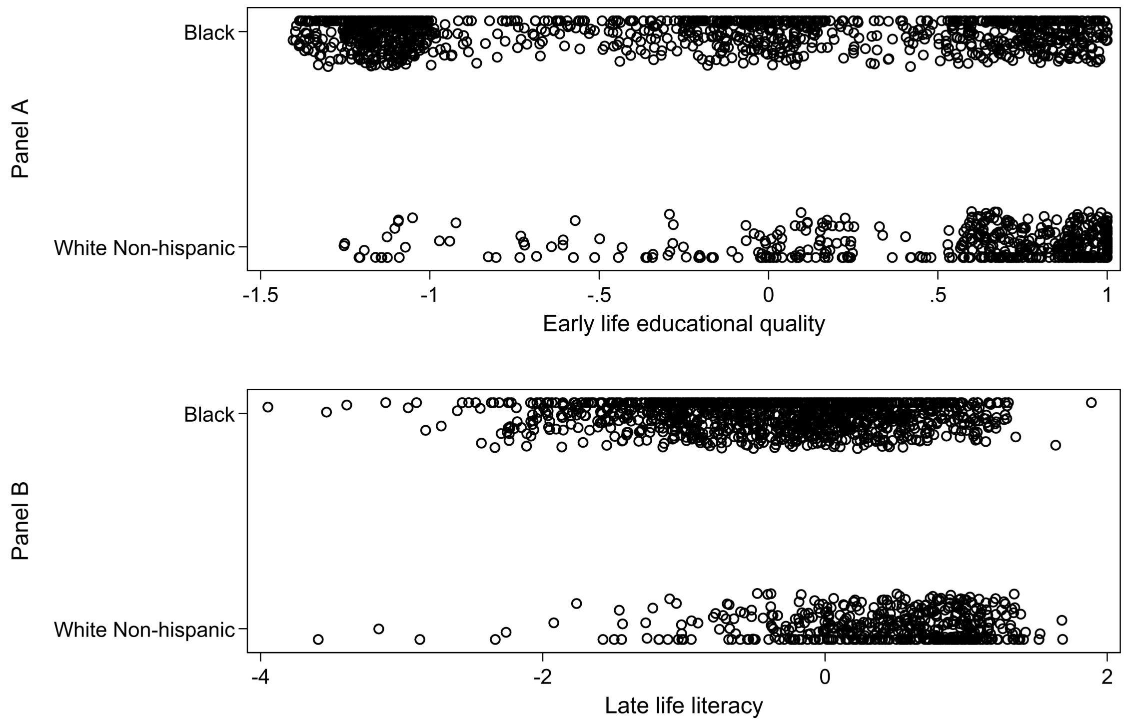

Figure 2. Empirical distribution of scores for early-life educational quality and late-life literacy by racial group: results from Washington Heights-Inwood Columbia Aging Project (WHICAP; N = 1,676). There is a dot for each participant in the sample. Plots demonstrate acceptable overlap for both scales between the groups.

Table 2. Estimates for Covariates in Models 1 and 2 on General Cognitive Performance, Memory, and Executive Function: Results From WHICAP (N = 1,679)

	General cognitive performance	Memory	Executive functioning
Parameter	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)
White participants (n = 491)			
Regressions on level of performance			
Sex (male)	−3.59* (−5.19, −2.06)	−4.05* (−5.61, −2.49)	−2.11* (−3.47, −0.75)
Education	1.02* (0.8, 1.25)	0.60* (0.34, 0.85)	1.02* (0.85, 1.2)
Cohort (1999)	0.62 (−1.63, 2.86)	−0.94 (−3.48, 1.61)	2.18 (0.004, 4.36)
Vascular risk	−1.13* (−1.86, −0.4)	−0.82* (−1.59, −0.05)	−0.88* (−1.55, −0.2)
Regressions on linear change			
Sex (male)	0.08 (−0.04, 0.2)	0.06 (−0.08, 0.2)	0.013 (0.00, 0.25)
Education	0.002 (−0.01, 0.02)	−0.002 (−0.02, 0.02)	0.014 (−0.008, 0.04)
Cohort (1999)	0.26* (0.18, 0.34)	0.36* (0.27, 0.45)	0.01 (−0.14, 0.15)
Black participants (n = 1,188)			
Regressions on level of performance			
Sex (male)	−1.72* (−2.95, −0.49)	−2.79* (−3.99, −1.6)	0.14 (−0.92, 1.20)
Education	1.29* (1.17, 1.42)	0.86* (0.75, 0.97)	1.23* (1.11, 1.34)
Cohort (1999)	−0.70 (−1.95, 0.54)	−1.53* (−2.68, −0.38)	2.24* (0.98, 3.50)
Vascular risk	−1.37* (−1.75, −1.00)	−0.94* (−1.32, −0.57)	−1.41* (−1.77, −1.05)
Regressions on linear change			
Sex (male)	0.08 (−0.01, 0.17)	0.05 (−0.05, 0.14)	0.05 (−0.05, 0.15)
Education	−0.01 (−0.02, 0.001)	−0.01 (−0.02, 0.02)	−0.01* (−0.02, −0.001)
Cohort (1999)	0.20* (0.14, 0.26)	0.12* (0.04, 0.2)	0.05 (−0.02, 0.12)

Note. CI = confidence interval; WHICAP = Washington Heights-Inwood Columbia Aging Project.

*$p < 0.05$.

(difference: 0.14 points, 95% CI: −0.14, −0.04) that became nonsignificant after adjusting for educational quality and late-life literacy. In terms of covariate effects, participants who were women had more years of education, and those with fewer vascular risk factors demonstrated higher cognitive performance (Table 2). Earlier recruitment cohort was associated with attenuated rates of cognitive decline. Inferences were largely similar for memory and executive functioning (Table 2).

We conducted a sensitivity analyses using nonverbal cognitive tasks (Color Trails, Dementia Rating Scale - Identities & Oddities subtest) as the outcome variable, to test whether literacy held as a predictor of cognitive function when verbal ability was not a component of the outcome variable. In this analysis, literacy remained a significant predictor of late-life cognitive performance. Model-estimated general cognitive performance at age 75 was significantly poorer in black participants (Color Trails mean score: 174.63 points, 95% CI: 167.36, 181.91 points; Identities/Oddities mean score: 14.5 points, 95% CI: 14.39, 14.61 points) compared with white participants (Color Trails mean score: 149.28 points, 95% CI: 130.37, 168.19 points; Identities/Oddities mean score: 14.8 points, 95% CI: 14.62, 14.99 points) demonstrating that literacy remained a significant predictor of late-life cognitive performance even when the criterion variables did not include measures of verbal ability.

When we adjusted for early-life educational quality using the formative construct and late-life literacy using the reflective construct, differences in average cognitive functioning at age 75 were dramatically attenuated by 29% for general cognitive functioning, 26% for memory, and 32% for executive functioning (Table 3). As shown in Table 3, late-life literacy attenuated differences the most. Early-life educational quality was a significant predictor of cognitive level among black, but not white, participants for general cognitive functioning (estimate: 0.9, 95% CI: 0.3, 1.5) and executive functioning (estimate: 1.7, 95% CI: 1.1, 2.2). Importantly, neither predictor completely eliminated racial disparities in cognitive level, so a portion of that difference remains unexplained.

Discussion

The purpose of this study was to investigate the extent to which early-life educational quality and late-life literacy explain race-related differences in late-life cognitive level and change, beyond the variance accounted for by years of education, age, sex, cardiovascular factors, and practice effects. We found that accounting for these predictors reduced, but did not eliminate, estimated racial disparities in level of cognitive functioning. In our sample, race-related differences existed only for baseline cognitive level; there were no significant differences between whites and blacks in the degree of cognitive change over time.

The findings of the present study add to previous reports by Manly and colleagues (2003) that accounting for late-life literacy attenuates racial differences in cognitive performance and further demonstrate that this finding holds for the U.S.-born subset of the WHICAP sample. This also extends findings of Glymour (2004) by considering indices of educational quality at both the state and the individual level, and demonstrating that these measures predict late-life cognitive performance as well as explain racial differences in late-life cognition.

Estimated effects of literacy in later life were generally larger than those for educational quality. Literacy was likely a stronger predictor of late-life cognitive level because for educational quality, three of the six indices were obtained at the state level. There is usually tremendous variability within a state, so state average values would be expected to correspond only weakly with actual educational quality experienced by the individual (Oakes & Kaufman, 2006). Further, it may be because they were measured concurrently that literacy and cognitive performance are more strongly related, and educational quality was a weaker predictor partly because it reflects experience from decades earlier in the life course. Another reason for the comparative strength of literacy as a predictor of late-life cognition may be that, because it was measured in late life, it captures benefits of both early-life educational quality and any other enriching experiences encountered during the life course. People continue to develop cognitively after school is finished, through work and leisure activities, and these experiences also contribute to literacy and cognitive functioning in later life (Hertzog, Kramer, Wilson, & Lindenberger, 2009).

Blacks reported lower educational quality and demonstrated lower literacy than whites in this study. These measures serve as proxies for processes early in the life course that affect cognitive outcomes later in life. These processes may affect cognition by way of increased risk for exposure to factors harmful to cognition, deprivation of access to factors enhancing cognition, or may affect cognition indirectly by influencing another related variable (e.g., physical health). Any or all of these effects may take place across the life course, within the framework of cumulative inequality (Ferraro & Shippee, 2009). That is, early-life disadvantage may place one at risk for exposure to future disadvantage, resulting over time in cumulative inequality. In the context of this study, poorer early-life educational equality may limit one's occupational choices, which may result in greater risk for poverty and chronic stress (a factor harmful to cognition), while also limiting opportunities for occupation-related cognitive enrichment (a factor enhancing cognition). One may then also be at greater risk for stress-related health conditions (e.g., cardiovascular disease, a risk factor for cognitive decline) and may have reduced access to adequate health care for managing the condition. Explicating the process by which early-life education affects late-life cognition is beyond the scope of this study, but these examples offer a few of the processes these findings may represent.

Table 3. Results of Growth Models of General Cognitive Performance, Memory, and Executive Functioning (N = 1,679)

	General cognitive performance		Memory		Executive functioning	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Parameter	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)
White participants (n = 491)						
Means						
Performance at age 75	55.28* (53.94, 56.63)	54.24* (52.40, 56.08)	56.02* (54.49, 57.55)	55.20* (53.11, 57.29)	53.27* (52.01, 54.54)	52.14* (50.48, 53.80)
Retest	0.82 (−0.62, 2.26)	0.84 (−0.39, 2.07)	0.82 (−0.46, 2.09)	0.81 (−0.44, 2.05)	0.60 (−1.02, 2.23)	0.67 (−0.88, 2.21)
Annual linear change	−0.68* (−0.75, −0.61)	−0.64* (−0.75, −0.53)	−0.64* (−0.72, −0.55)	−0.59* (−0.74, −0.45)	−0.58* (−0.67, −0.48)	−0.56* (−0.73, −0.38)
Regressions on performance level						
Late-life literacy	—	4.21* (2.72, 5.70)	—	2.97* (1.40, 4.54)	—	3.02* (1.67, 4.37)
Early-life educational quality	—	−0.53 (−2.33, 1.26)	—	−0.17 (−2.08, 1.75)	—	0.23 (−1.57, 2.03)
Years of education	1.02* (0.80, 1.25)	0.60* (0.32, 0.88)	0.60* (0.34, 0.85)	0.30 (−0.04, 0.63)	1.02* (0.85, 1.19)	0.71* (0.46, 0.95)
Regressions on linear change						
Late-life literacy	—	−0.04 (−0.15, 0.07)	—	−0.06 (−0.22, 0.10)	—	0.08 (−0.08, 0.24)
Early-life educational quality	—	−0.04 (−0.18, 0.11)	—	−0.04 (−0.21, 0.13)	—	−0.08 (−0.28, 0.12)
Years of education	0.00 (−0.01, 0.02)	0.01 (−0.02, 0.03)	0.00 (−0.02, 0.02)	0.00 (−0.02, 0.03)	0.01 (−0.01, 0.04)	0.01 (−0.02, 0.03)
Black participants (n = 1,188)						
Means						
Performance at age 75	49.87* (49.21, 50.52)	50.40* (49.83, 50.96)	51.90* (51.28, 52.51)	52.15* (51.56, 52.74)	47.94* (47.28, 48.60)	48.52* (47.92, 49.11)
Retest	0.65 (−0.04, 1.34)	0.68* (0.12, 1.23)	0.48 (−0.17, 1.13)	0.53 (−0.09, 1.14)	0.67 (−0.10, 1.44)	0.66 (−0.06, 1.39)
Annual linear change	−0.60* (−0.64, −0.57)	−0.60* (−0.63, −0.57)	−0.59* (−0.63, −0.55)	−0.59* (−0.63, −0.55)	−0.44* (−0.47, −0.40)	−0.43* (−0.47, −0.40)
Regressions on performance level						
Late-life literacy	—	5.26* (4.64, 5.87)	—	3.88* (3.23, 4.53)	—	4.16* (3.66, 4.66)
Early-life educational quality	—	0.89* (0.29, 1.49)	—	−0.18 (−0.77, 0.41)	—	1.66* (1.13, 2.19)
Years of education	1.29* (1.17, 1.42)	0.58* (0.46, 0.70)	0.86* (0.75, 0.97)	0.40* (0.28, 0.53)	1.23* (1.11, 1.34)	0.59* (0.47, 0.70)
Regressions on linear change						
Late-life literacy	—	−0.11* (−0.15, −0.07)	—	−0.14* (−0.18, −0.10)	—	−0.03 (−0.07, 0.02)
Early-life educational quality	—	0.05* (0.00, 0.09)	—	0.07* (0.02, 0.12)	—	0.02 (−0.02, 0.06)
Years of education	−0.01 (−0.02, 0.00)	0.00 (−0.01, 0.01)	−0.01 (−0.02, 0.01)	0.00 (−0.01, 0.01)	−0.01* (−0.02, −0.00)	−0.01* (−0.02, −0.00)
Mean group differences[a]						
Performance at age 75	−5.42* (3.92, 6.92)	−3.85* (1.92, 5.77)	−4.13* (2.48, 5.77)	−3.05* (0.87, 5.22)	−5.34* (3.91, 6.76)	−3.62* (1.86, 5.39)
Linear change	0.08 (−0.15, 0.00)	0.04 (−0.16, 0.08)	0.05 (−0.14, 0.04)	0.00 (−0.15, 0.15)	0.14* (−0.24, −0.04)	0.13 (−0.30, 0.05)

Note. CI = confidence interval.
*$p < 0.05$.

As there were no race-based differences in rate of cognitive change, we did not examine whether educational quality and literacy had differential effects in cognitive change between racial groups. This finding is similar to other studies examining cross-sectional and longitudinal effects of race on cognitive performance, which have found that despite race-related differences in baseline cognitive performance, rate of cognitive decline either does not differ between races (Atkinson et al., 2005; Early et al., 2013) or these differences are inconsistent (Alley et al., 2007; Sloan & Wang, 2005). Findings regarding race-related differences in cognitive decline have been varied, with reports of both faster (Blazer, Hays, Fillenbaum, & Gold, 1997) and slower decline among blacks (Barnes et al., 2005).

Results also showed that the pattern of significance of literacy and educational quality in predicting cognition differed by race, in a way suggesting they may be more strongly related to cognitive function for blacks. Specifically, for whites, only literacy predicted only cognitive level, but both literacy and educational quality predicted level and change for blacks. Where literacy and educational quality had significant effects, those effects were universally larger for blacks. This finding may be partly due to the fact that there was greater variability of scores for blacks in literacy and especially in educational quality (see Figure 2). For comparison, educational quality for most white participants was at the high end of the range in this sample (Figure 2). There may have been too little variability in literacy and educational quality among whites for these predictors to have as significant an effect on cognitive level and change as it did for blacks. Among blacks, poorer educational quality was associated with both lower cognitive level and greater negative cognitive change.

The limitations of the present study should be mentioned. Most importantly, neither of our proposed predictors (school quality and literacy) were randomized, and thus our inferences depend on strong assumptions, including that there are no unmeasured factors that influence the mediators and late-life cognitive outcomes. For example, if early-life (preschool) cognition influences both literacy and late-life cognitive function, this will lead to an overestimation of the role of literacy as a mediator between race and late-life cognitive outcomes, even if early-life cognition is completely unrelated to race. Further, the educational quality factor combined retrospectively gathered individual- and state-level measures, meaning its temporal and geographic specificity was not optimal. Participants could have lived in more than one state during childhood, and retrospective measurement is subject to errors in recall. The items measured for this composite (e.g., urban vs. rural primary schooling, percent white students in primary school, length of school

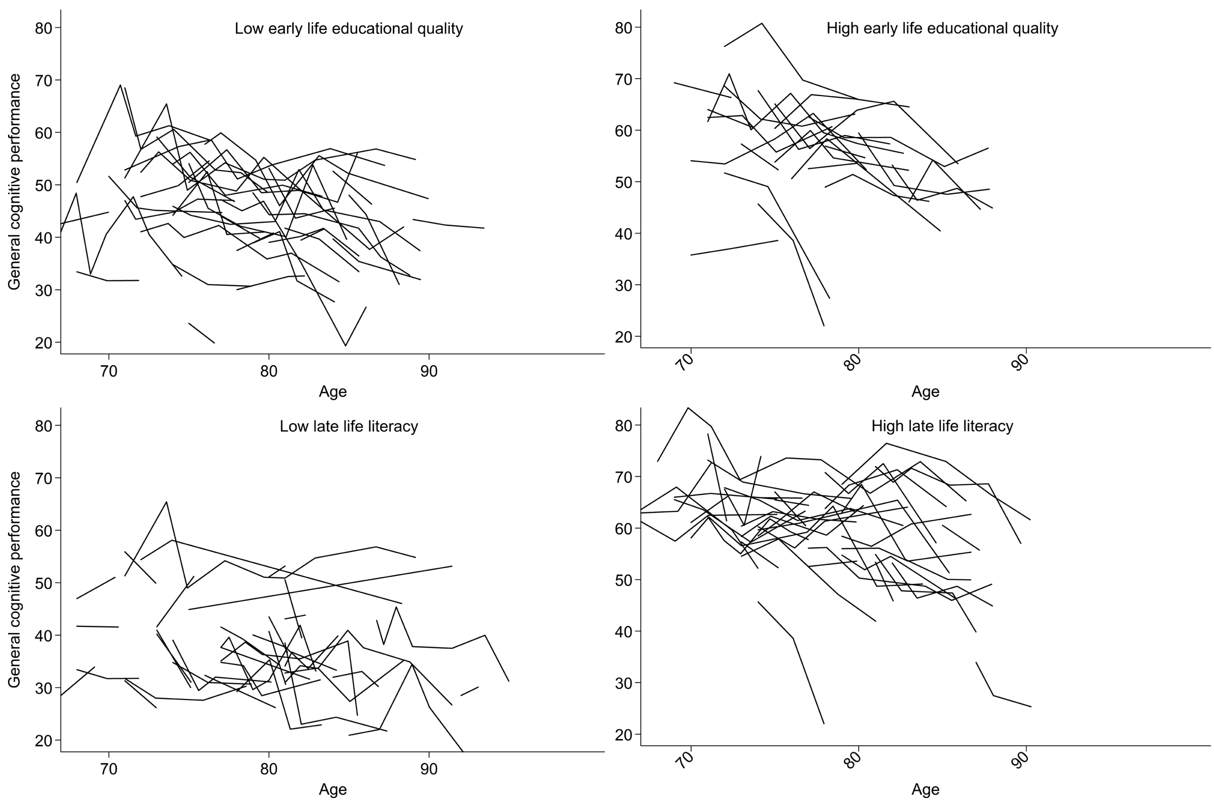

Figure 3. General cognitive trajectories of top and bottom 3% for educational quality and literacy. Shown is a random sample of general cognitive trajectories for participants in the lowest 3% of early-life educational quality (top left), top 3% of early-life educational quality (top right), lowest 3% of late-life literacy (bottom left), and top 3% of late-life literacy (bottom right).

term) were also inferential rather than direct measures of educational quality (e.g., teacher ratings). One question for future study, as the large immigrant and Hispanic portions of the WHICAP sample were not included in the present study, should be to examine whether educational quality also explains race-related differences in late-life cognition between Hispanic Americans and U.S. immigrants. Because this study did not fully explain the racial differences in late-life cognitive function, future research should also consider other potential predictors of these differences, such as chronic minority stress due to individual and institutional racism, or limitations in upward social mobility (e.g., allowing fewer opportunities for occupational prestige) related to racial discrimination (Figure 3).

The present study found that factor measures of literacy and early-life educational quality attenuated racial differences in late-life cognitive performance for U.S.-born blacks and whites in the WHICAP sample. The estimated effect of literacy was stronger relative to the effect of educational quality. The pattern of findings suggested that overall, cognitive performance for blacks was more sensitive to the effects of literacy and educational quality than for whites. These findings contribute to the existing literature on literacy as a predictor of race differences in late life cognition, and extend the literature by offering more precise indices of educational quality, as well as demonstrating it to be a predictor of race-related differences in late life cognition.

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