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Indicators of Childhood Quality of Education in Relation to Cognitive Function in Older Adulthood

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Background. The association between years of education and cognitive function in older adults has been studied extensively, but the role of quality of education is unknown. We examined indicators of childhood educational quality as predictors of cognitive performance and decline in later life.

Methods. Participants included 433 older adults (52% African American) who reported living in Alabama during childhood and completed in-home assessments of cognitive function at baseline and 4 years later. Reports of residence during school years were matched to county-level data from the 1935 Alabama Department of Education report for school funding (per student), student–teacher ratio, and school year length. A composite measure of global cognitive function was utilized in analyses. Multilevel mixed effects models accounted for clustering of educational data within counties in examining the association between cognitive function and the educational quality indices.

Results. Higher student–teacher ratio was associated with worse cognitive function and greater school year length was associated with better cognitive function. These associations remained statistically significant in models adjusted for education level, age, race, gender, income, reading ability, vascular risk factors, and health behaviors. The observed associations were stronger in those with lower levels of education (≤12 years), but none of the education quality measures were related to 4-year change in cognitive function.

Conclusions. Educational factors other than years of schooling may influence cognitive performance in later life. Understanding the role of education in cognitive aging has substantial implications for prevention efforts as well as accurate identification of older adults with cognitive impairment.

Key Words: Cognitive aging—Education—Health disparities.

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LOWER level of educational attainment is one of the most consistently identified risk factors for cognitive impairment and dementia in older adulthood (1–3). Studies reporting a relationship between education and cognitive function have examined samples from a number of different countries; however, reviews of the literature have suggested that the association between years of education and cognitive impairment is stronger for those with lower overall levels of education and in locations where education is less dependent on position in society (4).

Education is also an important factor in determining level of impairment on screening tests for dementia (5,6) as well as in-depth neuropsychological measures (7,8). An individual's performance on cognitive testing is typically judged according to the deviation from average performance of others with similar age and level of education. Given the importance of education in cognitive aging research, a crucial issue that has been raised is the need for understanding how quality of education may affect cognitive function in older adulthood (9–11). Despite the large variability in childhood education in the United States and the history of grossly disproportionate educational opportunities for African Americans who attended segregated schools, relatively few studies have attempted to account for quality of education in cognitive aging studies.

The main approach that has been used to account for potential differences in quality of education is using reading ability as a proxy measure of educational experience. Research findings indicate that differences between African Americans and whites in cognitive performance during later life are substantially reduced or eliminated after accounting for reading ability (9,12). In a study that examined state-level laws for mandatory years of education, increases in years of compulsory schooling were associated with better performance on memory tests in older adulthood (13). This study did not include any African Americans but provides

Table 1. Baseline Characteristics of Participants

Characteristic	All Participants (*n* = 493)	Education in Other State (*n* = 60)	Education in Alabama (*n* = 433)	*p* Value
Age	73.6 (5.5)	73.7 (5.9)	73.6 (5.4)	.95
African American, %	47.9	21.7	51.5	<.01
Female gender, %	54.0	51.7	54.2	.70
Rural, %	46.9	38.3	48.0	.16
Annual income < $16,000, %	54.4	33.3	57.3	<.01
Education level				<.01
0–6 years, %	17.0	6.7	18.5	
7–11 years, %	24.5	6.7	27.0	
12 years, %	26.4	28.3	26.1	
13 or more years, %	32.1	58.3	28.4	
WRAT-3 reading score	39.2 (10.4)	46.0 (9.4)	38.3 (10.2)	<.01
MMSE score	26.6 (3.6)	28.2 (2.3)	26.3 (3.7)	<.01
CLOX1 score	11.0 (2.8)	11.5 (2.3)	10.9 (2.8)	.06
Cognitive composite score	0.56 (1.40)	1.02 (0.95)	0.49 (1.43)	<.01
GDS score	1.8 (2.0)	1.9 (1.9)	1.8 (2.0)	.92
Vascular risk factors				
Hypertension, %	67.8	56.7	69.3	.05
Diabetes, %	20.7	20.0	20.8	.89
Myocardial infarction, %	6.9	5.0	7.2	.54
Congestive heart failure, %	5.7	0.0	6.5	.04
Stroke, %	6.5	5.0	6.7	.62
Health behaviors				
Physical activity (kcal/wk)	1,483 (2,048)	1,829 (2,377)	1,435 (1,997)	.16
Smoking pack years	16.3 (29.9)	26.7 (45.5)	14.9 (26.7)	<.01

Note: Mean (*SD*) or percent are provided for each characteristic; WRAT-3 = Wide Range Achievement Test-3; MMSE = Mini-Mental Status Examination; CLOX1 = spontaneous clock drawing task; GDS = 15-item Geriatric Depression Scale; WRAT-3 was collected at four-year follow-up; *p* value is for comparison of participants schooled in Alabama versus other states.

intriguing preliminary evidence that early-life educational factors not captured by level of education and not due to individual differences such as intelligence may influence cognitive performance decades later.

In the current study, we examined county-level markers of childhood quality of education as predictors of cognitive function in a sample of older African Americans and whites from Alabama. Residence during school years was matched to objective measures of school funding, ratio of enrolled students to teachers, and days of school per year from 1935 Department of Education records. We hypothesized that indicators of higher quality of early-life education would be associated with better cognitive performance and reduced cognitive decline, independent from level of education and other potential confounds. We also examined whether race or level of educational attainment moderated these associations.

Methods

Participants

This was an ancillary study to the University of Alabama at Birmingham Study of Aging, a longitudinal observational study of community-dwelling Medicare beneficiaries in five counties of central Alabama (14,15). All participants were aged 65 or older at baseline, and individuals living in nursing homes or unable to schedule their own appointments were excluded. Individuals with physician-verified dementia at baseline were also excluded from current analyses. The sample consisted of all participants who (a) reported living in Alabama during childhood and (b) completed in-home assessments of cognitive function at baseline and 4-year follow-up.

Data on location of schooling was gathered at 6.5-year follow-up. There were 529 participants with data on cognitive measures and reading ability alive at 6.5-year follow-up; 493 of these participants (93%) provided information on location of schooling. Only those who reported attending school in Alabama were included in analyses (*n* = 433). Characteristics of the sample are presented in Table 1. Participants schooled in Alabama did not differ from those who went to school in other states in terms of age or gender, but the sample schooled in Alabama included a larger proportion of African Americans and individuals with income below $16,000 per year, lower levels of education, and lower reading scores.

Measures

A composite global cognitive function measure was created by summing *z*-scores for performance on a 30-point mini-mental state examination (16) and a spontaneous clock drawing task (CLOX; 17). Scores on the mini-mental state examination range from 0 to 30 and include items related to orientation, registration and recall, attention, and visuospatial construction. The mini-mental state examination has been criticized for failing to capture problems with executive function (18,19), and newer cognitive screening measures such as the Montreal Cognitive Assessment (MoCA; 20) and the St. Louis University Mental Status Examination (SLUMS; 21) each include a spontaneous clock drawing to measure frontal/executive dysfunction as part of the score. The CLOX task involved instructing participants to draw a clock set to 1:45 without further prompts or cues. This measure was scored on a 15-point scale (17), with higher scores on this task reflecting better cognitive performance. Both cognitive measures were administered at baseline and at 4-year follow-up for the study, and *z*-scores for each time point were based on the overall sample mean and standard deviation from baseline.

To determine the predictors of interest, indicators of childhood quality of education were gathered from the annual report of the Alabama Department of Education for the scholastic year ending in 1935 (22) and matched to participant reported location of early education. Each participant was asked, “Think back to when you were in school, 1st grade to 12th grade, in what county and state was most of your schooling completed?” Birth year for study participants ranged from 1908 to 1936, with a median of 1927. The Department of Education report from 1935 was chosen because 94% of participants were school age (between ages 6 and 18) during the 1930s. Information on school funding (per student), student–teacher ratio, and length of school year was gathered for each of the 67 counties in Alabama. In the state report, data were provided separately for African American and white schools within rural and city school systems. The majority of students in Alabama in 1935 attended rural—now known as county—school systems; a similar proportion of African American and white children were enrolled in county schools (76%). For the three cities in Alabama with the largest enrollment of students (Birmingham, Mobile, and Montgomery), data were averaged across rural and city schools for the respective counties. County of schooling reported by participants was then matched to data from the state report. According to data provided in this report, over 98% of both African American and white students attended public schools in Alabama.

Covariates included demographic factors, reading ability, depressive symptoms, vascular risk factors, and health behaviors. Age, race (African American/white), gender, education level, and current residence were self-reported at baseline. Two of the five counties from which participants were recruited were classified as urban and three were rural.

Education was collected by asking participants to report the highest grade completed, which was recorded as: sixth or less, seventh through eleventh, high school, some college, completed technical or junior college, college graduate, some graduate/professional school, or graduate/professional degree. Post-high school categories were subsequently collapsed into one level of classification. Participants reported total family income in categories (ranging from <$5,000 to ≥$50,000/year), which was subsequently coded as a dichotomous variable corresponding to the median income category for the sample (<$16,000 versus ≥$16,000/year). For people who did not report income (17% of baseline sample), responses indicating perceived income difficulty were used to impute income categories based on data from participants who answered both questions.

The reading subtest of the Wide Range Achievement Test-3 (23) was used to assess reading ability. For this test, participants are asked to name letters and/or pronounce an increasingly difficult list of words. Scores can range from 0 to 57. Depressive symptoms were assessed using the 15-item Geriatric Depression Scale (24). This instrument involves asking participants for yes/no responses to potential depressive symptoms experienced in the past week. Higher scores reflect greater depressive symptoms.

Vascular risk factors for cognitive impairment included hypertension, diabetes, myocardial infarction, congestive heart failure, and stroke collected by self-report with physician, hospital discharge, or medication verification at baseline. Conditions were considered verified only if the participant reported taking a medication for the condition, if the primary physician returned a questionnaire indicating the condition, or if a hospital discharge summary in the previous 3 years indicated the disease.

Physical activity and smoking were included as measures of health behaviors. Physical activity was measured using the leisure-time physical activity assessment from the Cardiovascular Health Study (25). Participants reported frequency and duration of participation in 15 different types of activities during the past 2 weeks, scored as kilocalories expended per week. Pack years were calculated from the number of years and number of cigarettes a participant reported smoking.

Data Analysis

We used multilevel mixed effects modeling to examine whether the county-level indicators of educational quality were associated with cognitive performance or change in cognitive function from baseline to 4-year follow-up. Using multilevel modeling allowed us to account for the clustering of educational data within counties. In addition, we were able to maximize statistical power for cross-sectional analyses by using all available observations (ie, participants' baseline and 4-year data). To adjust for the correlated data, we specified that observations were nested within participants who were in turn nested within counties of schooling using SAS procedure MIXED (26). For these analyses, we also standardized the cognitive composite (to have a mean of zero and standard deviation of one) and quality of education measures so that the statistical models would yield standardized estimates. These estimates show the standard deviation unit difference in outcome (cognitive function) associated with one standard deviation increase in the respective quality of education measure.

It was anticipated that student funding, student–teacher ratio, and days of school per year would be highly correlated. Because we were interested in determining which of these variables was most highly associated with cognitive performance, we developed separate models for each indicator of educational quality. In our initial models, the association between each quality of education marker and cognitive function was examined while controlling for time of cognitive testing, age, race, gender, rural residence, and income. In subsequent models, level of education and reading ability were added as covariates. In the final fully adjusted models, we included all previous covariates as well as depressive symptoms, vascular risk factors (entered as a block of yes/no health conditions), and health behaviors.

To investigate whether the association between quality of education and cognitive function differed by race or education level (≤12 vs >12 years), interaction terms for these factors were included in the respective models. To examine the relationship between quality of education variables and 4-year change in cognitive function, the sequence of models used for cross-sectional analyses was repeated with the addition of a time interaction for quality of education variables.

Results

Sample characteristics for the 433 participants with childhood education in Alabama are presented in Table 1. Average age at baseline assessment was 74, 52% of participants were African American, and approximately 46% of the sample had less than a high school level of education. Participants attended school in 40 of the 67 counties in Alabama. Figure 1 shows participant representation across these counties.

Data on the county-level indicators of quality of education are presented in Table 2. Large differences were seen between African American and white schools. Average student funding was 4.5 times higher for white compared with African American students, and African American classrooms had 15 more students per teacher and a school year that was 32 days shorter on average. Within the African American and white schools, a wide range of values for each of these indicators was observed.

In terms of educational attainment, African Americans also had significantly lower levels of education compared with whites in our sample ($p < .001$), which is consistent with the observed correlations for educational measures shown in Table 3. Level of education, reading ability, and the three quality of education variables were all moderately to highly correlated with each other.

In our initial mixed effects models, there were significant associations for two of the three quality of education variables (Table 4). Student funding was not significantly associated with cognitive function. However, higher student–teacher ratio predicted lower cognitive performance, and greater number of school days predicted better cognitive

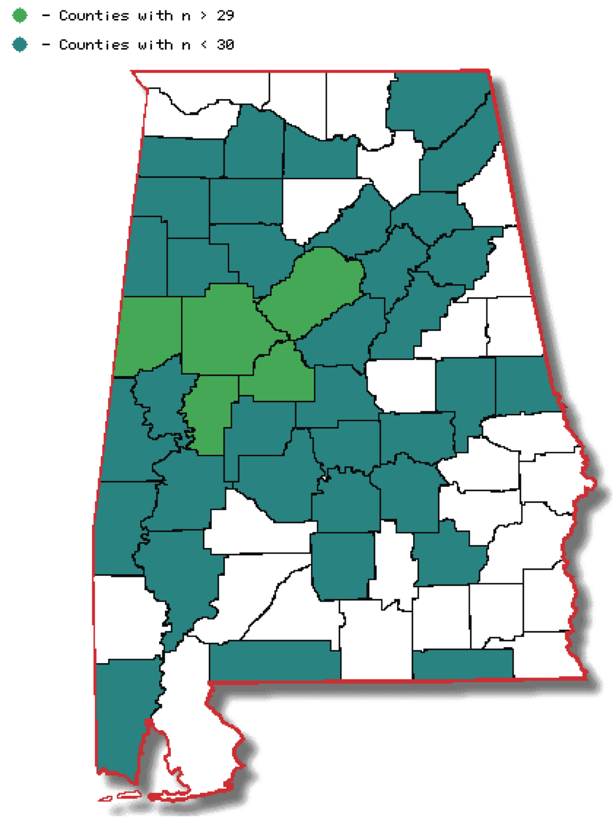

Figure 1. Alabama counties of residence during participants' childhood schooling.

function. When level of education was added to these models, estimates for the significant associations were reduced but remained statistically significant. Additional adjustment for reading ability did not change the observed associations. Findings also remained statistically significant in the final model that controlled for all the previous covariates in addition to depressive symptoms, vascular risk factors, and health behaviors.

We found no evidence of a race interaction with educational quality in predicting cognitive function. Estimates for these interactions are as follows: student funding by race (Est. = 0.254, $SE = 0.236$, $t = 1.08$, $p = .28$); student–teacher ratio by race (Est = –0.062, $SE = 0.145$, $t = -0.42$, $p = .67$); and school days by race (Est = 0.100, $SE = 0.144$, $t = 0.70$,

Table 2. County-Level Indicators of Educational Quality From 1935 Alabama Department of Education Report for African American and White Participants ($n = 433$)

	African American			White		
	M	*SD*	Range	*M*	*SD*	Range
Student funding ($)	7.73	4.91	2.87–17.56	35.46	10.36	15.84–70.46
Student–teacher ratio	46.4	4.9	35.2–57.2	31.2	3.9	16.2–40.5
Days of school	130.9	27.7	68–177	161.9	11.0	140–178

Note: Student funding is amount spent per student for one school year; all racial differences are significant at $p < .0001$ level.

Table 3. Correlations Between Educational Measures

	1	2	3	4	5
1. Education level	—	0.730*	0.439*	−0.401*	0.459*
2. Wide Range Achievement Test-3 reading score		—	0.519*	−0.484*	0.477*
3. Student funding			—	−0.854*	0.779*
4. Student–teacher ratio				—	−0.691*
5. Days of school					—

Notes: Education was included as a four-level ordinal variable (0–6, 7–11, 12, and 13+ y).

**p* < .001.

p = .49). In contrast, there were significant interactions between education level (≤12 vs >12 years) and measures of education quality. Estimates for these interactions are as follows: student funding by education level (Est. = −0.266, *SE* = 0.077, *t* = −3.45, *p* < .001); student–teacher ratio by education level (Est = 0.498, *SE* = 0.144, *t* = 3.46, *p* < .001); and school days by education level (Est = −0.446, *SE* = 0.142, *t* = −3.14, *p* = .002). Analyses stratified by education level are presented in Table 5. The association between quality of education measures and cognitive function was observed only for participants with ≤12 years of education.

In terms of change in cognitive performance, time was significantly associated with cognitive performance, with a change of −0.18 *SD* in cognitive function (*SE* = 0.036, *t* = −4.88, *p* < .001) over the 4-year interval. There was no race by time interaction (*Est* = −0.350, *SE* = 0.073, *t* = −0.48, *p* = .630), suggesting that there were not different rates of cognitive decline for African Americans versus whites in our sample. None of the quality of education by time interactions approached statistical significance (*p* values >.60). Thus, the quality of education measures were not predictive of change in cognitive function during the 4-year time interval.

Discussion

In this sample of older adults from Alabama, indicators of childhood quality of education predicted performance on cognitive testing. Individuals who went to schools in counties with higher student–teacher ratios showed lower cognitive performance and those from counties with a longer school year had better cognitive performance in older adulthood. Funding per student did not emerge as a significant predictor of cognitive function. All analyses controlled for age, race, gender, rural residence, and income. Fully adjusted models included education level, reading ability, depressive symptoms, vascular risk factors, and health behaviors.

We also found a significant interaction between level of education and quality of education in relation to cognitive performance. The association between quality of education measures and cognitive function was observed only for participants with ≤12 years of education, suggesting that education beyond high school could mitigate the relationship between lower quality of education and poorer performance on cognitive testing. There was no interaction between race and quality of education in predicting cognitive performance, suggesting only that the size of associations did not differ by race. Because of the observed racial disparities in education level and quality, older African Americans would be disproportionately affected by any association of these factors with cognitive performance. Lack of interaction effects with race should not be interpreted as meaning that accuracy of cognitive impairment or dementia classification is equivalent for racial groups, which we could not examine in this study.

Although these educational indicators did not predict cognitive decline over the 4 years of follow-up, the association with overall cognitive performance has implications for assessment of cognitive impairment and risk of dementia. Factors related to either baseline cognitive performance or to decline are important for dementia risk because these both influence the point at which neuropathological and functional changes would reach the threshold at which dementia is apparent. In terms of assessment, these educational factors may also reflect biased measurement because norms based on years of education fail to account for differences in quality of education (27). Further research is needed to clarify the influence that educational quality may have on cognitive test performance and accuracy of detection of cognitive impairment in older adults.

Table 4. Standardized Estimates for Associations Between Indicators of Quality of Education and Cognitive Function From Mixed Effects Models

	Adjusted for Time and Demographics Other Than Education Level*				Adjusted for All Previous Covariates and Education Level				Adjusted for All Previous Covariates and Reading Ability				Fully Adjusted Models†			
	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value
Student funding	0.143	0.090	1.58	.114	0.061	0.080	0.76	.445	0.053	0.074	0.72	.472	0.063	0.075	0.84	.402
Student–teacher ratio	−0.214	0.077	−2.78	.006	−0.138	0.070	−1.98	.048	−0.140	0.065	−2.16	.031	−0.142	0.065	−2.18	.030
Days of school	0.193	0.051	3.79	<.001	0.108	0.052	2.09	.037	0.123	0.049	2.53	.012	0.104	0.050	2.09	.037

Notes: Est. = standardized estimate.

*Model includes time of cognitive testing, age, race, gender, rural residence, and income.

†Model includes all demographic covariates and reading ability plus depressive symptoms, vascular risk factors (hypertension, diabetes, myocardial infarction, congestive heart failure, and stroke) and health behaviors (physical activity and pack years of smoking).

Table 5. Standardized Estimates for Associations Between Indicators of Quality of Education and Cognitive Function Stratified by Level of Education

	Education ≤ 12 y								Education > 12 y							
	Adjusted for Time and Demographics*				Fully Adjusted Models†				Adjusted for Time and Demographics*				Fully Adjusted Models†			
	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value	Est.	*SE*	*t*	*p* Value
Student funding	0.189	0.120	1.58	.115	0.123	0.101	1.22	.224	−0.055	0.066	−0.83	.408	−0.044	0.064	−0.68	.497
Student–teacher ratio	−0.234	0.085	−2.74	.007	−0.187	0.074	−2.54	.012	0.015	0.103	0.14	.886	0.030	0.101	0.30	.767
Days of school	0.208	0.063	3.32	.001	0.134	0.057	2.34	.020	−0.030	0.054	−0.56	.574	−0.030	0.052	−0.58	.562

Notes: Est. = standardized estimate.

* Model includes time of cognitive testing, age, race, gender, rural residence, and income.

† Model includes demographic covariates, reading ability, depressive symptoms, vascular risk factors (hypertension, diabetes, myocardial infarction, congestive heart failure, and stroke) and health behaviors (physical activity and pack years of smoking).

It is particularly notable that the significant associations for markers of quality of education were not fully explained by overall level of education or reading ability. The quality of education variables were significantly correlated with reading ability, supporting prior use of this construct as a proxy indicator of educational quality (9,12,28). But, our overall findings support the idea that neither reading ability nor years of education fully captures disparities in educational quality.

Vascular health is related to educational attainment (29) and is also thought to influence cognitive aging and risk of dementia (2,30,31). Thus, it is feasible that the association between quality of education and cognitive function would be mediated by vascular risk factors. In the current study, the observed associations remained statistically significant after adjustment for vascular health conditions, physical activity, and smoking, which suggests alternate mechanisms may also play a role. However, our study was limited to vascular conditions and physical activity in older adulthood, whereas other studies have highlighted the importance of these factors at midlife in predicting cognitive function and dementia in later life (32–35).

To our knowledge, no prior study has examined county-level indicators of educational quality in relation to cognitive aging or any other age-related outcomes. This is despite the well-documented variability in quality of schooling in the United States. There are advantages and limitations to having participants only from Alabama. In terms of generalizability, it is not known the extent to which observed associations would be similar for older adults from other states, other regions of the United States, or other countries. On the other hand, restricting our sample to those educated in Alabama had little effect in terms of reducing total sample size because the large majority of our older adult participants lived in Alabama during childhood.

We did not obtain reports of childhood schooling location until 6.5-year follow-up for the study. Thus, the sample was limited to those who survived and continued study participation until this time point. This may have hindered finding an association between quality of education variables and change in cognitive function. Participants remaining in the sample had better baseline cognitive function and less evidence of cognitive decline at 4-year follow-up (15), thereby restricting range of change in cognitive function. In terms of the quality of education variables, we were limited to data from the 1935 Alabama Department of Education report. Changes in these measures over time as well as factors such as access to grade-level textbooks, mixed grade levels, education outside of school setting at home or church, missing school due to work or family demands, or having a teacher that motivated, encouraged, and pushed for academic success could all be important aspects of education that are not captured by years of education or by the variables included in the present study.

Our study demonstrates that there is substantial within-state variability for historical indicators of educational quality and that these differences are associated with cognitive performance in older adulthood. Findings support the idea that educational factors other than overall level of schooling may influence cognitive function in later life. This study was unable to address the question of whether the relationship between higher quality of education and better cognitive function reflected cognitive reserve versus biased measurement. Dementia diagnoses were not performed, so we could not examine whether adjustment for quality of education may improve specificity of screening for dementia. Clinicians and researchers should be aware that factors not captured by years of education or reading ability are associated with performance on cognitive tests in older adults.

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