American Journal of Epidemiology

Vol. 163, No. 12
DOI: 10.1093/aje/kwj176
Advance Access publication May 17, 2006

Original Contribution

Urban Neighborhood Context, Educational Attainment, and Cognitive Function among Older Adults

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Received for publication June 2, 2005; accepted for publication December 5, 2005.

Existing research has not addressed the potential impact of neighborhood context—educational attainment of neighbors in particular—on individual-level cognition among older adults. Using hierarchical linear modeling, the authors analyzed data from the 1993 Study of Assets and Health Dynamics Among the Oldest Old (AHEAD), a large, nationally representative sample of US adults born before 1924. Data from participants residing in urban neighborhoods ($n = 3{,}442$) were linked with 1990 US Census tract data. Findings indicate that 1) average cognitive function varies significantly across US Census tracts; 2) older adults living in low-education areas fare less well cognitively than those living in high-education areas, net of individual characteristics, including their own education; 3) this association is sustained when controlling for contextual-level median household income; and 4) the effect of individual-level educational attainment differs across neighborhoods of varying educational profiles. Promoting educational attainment among the general population living in disadvantaged neighborhoods may prove cognitively beneficial to its aging residents because it may lead to meliorations in stressful life conditions and coping deficiencies.

aged; cognition; education; residence characteristics; socioeconomic factors

Abbreviation: AHEAD, Study of Assets and Health Dynamics Among the Oldest Old.

Editor's note: *An invited commentary on this article appears on page 1079, and the authors' response is on page 1083.*

To our knowledge, existing research does not address the potential cognitive impact of broad social contexts (e.g., neighborhoods) in which educational attainment among constituents differs. Some evidence suggests that, in terms of cognition, geographic context may matter. Epidemiologic Catchment Area Study investigators identified regional variation in the prevalence of cognitive impairment (1), finding that Mini-Mental State Examination scores differed significantly across five study sites. Speculation about these differences focused on site differences in sociocultural factors such as ethnic composition, urbanization, and quality of educational facilities. Another study found that neighborhood type was associated with Mini-Mental State Examination scores among older Mexican Americans, with barrio residents (i.e., low income, almost exclusively Mexican-American neighborhoods) having a greater risk of cognitive impairment than those living in other neighborhoods, a differential attributed to lower educational levels in the barrios (2).

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Growing bodies of research indicate that neighborhood context is consequential to multiple health outcomes across a variety of populations (3–8). Neighborhoods are proxies for many health risk and protective factors associated with the concentration of socioeconomic disadvantage (6). However, whether neighborhoods disproportionately affect the health of older adults has received little empirical attention, even though older persons may become increasingly vulnerable to neighborhood conditions as their exposure to the environment lengthens and their spatial realms diminish with time (9). Older adults are exposed to the same neighborhood risk factors as other residents, but they may be especially vulnerable as a result of age-related limitations in functional abilities that threaten their independence.

Thus, there is some evidence that neighborhoods affect cognition, and widespread evidence suggests that neighborhood socioeconomic context matters to health in general. However, the nature of any link between neighborhood educational attainment and individual cognition is unknown. Educational attainment of neighborhood residents is a key indicator of socioeconomic context that may have broad social consequences, including socioeconomic disadvantage. In essence, educational attainment sets the stage for a broad spectrum of other socioeconomic factors that can influence health. For example, persons who have not graduated from high school are much more likely than persons with a high school degree to experience economically disadvantaged life-course trajectories (10). Accordingly, large numbers of persons without high school degrees in neighborhoods creates an environment of concentrated economic disadvantage.

At the individual level, previous geriatric studies have established a clear link between an individual's educational attainment and his or her cognition, finding that high educational levels are cognitively protective (11–19). Hypothesized mechanisms include resultant higher synaptic density, mental stimulation, its impact on health and behavior, or test-taking ability (20). Education is often used as an indicator of social class, but educational attainment has consistently been shown to have a separate protective effect on cognition, controlling for other major social and socioeconomic variables (14, 21). Whether the cognitively protective effect of individual-level education varies across neighborhoods characterized by differing levels of educational attainment of residents is not known, however.

In this paper, we use a nationally representative sample of older urban adults to test the hypothesis that educational attainment at the contextual level (neighborhood, or US Census tract) is associated with cognition, net of individual-level risk factors and contextual-level economic status. We then examine whether the cognitive impact of a person's own educational attainment differs across educational contexts. Understanding risk factors that affect cognition in late life is germane to both health scientists and policy makers because the population of older adults is increasing worldwide, and cognitive function declines with age. Establishing whether cognitive function is associated with neighborhood education in late life expands the arsenal of targetable risk factors for cognitive impairment and fills a notable research gap concerning the interaction of problematic environments and personal characteristics.

MATERIALS AND METHODS

Survey data were derived from the Study of Assets and Health Dynamics Among the Oldest Old (AHEAD), a US national probability sample of noninstitutionalized persons born in 1923 or earlier (i.e., those aged 70 years or older in 1993) (22). Subjects were selected by using a multistage area probability design and a dual-frame sample of Medicare recipients. Within sampled households, one age-eligible person was sampled; when that person had a spouse, he or she was also included in the sample irrespective of age. The overall response rate of 80 percent yielded an interviewed sample of 8,222 persons from 6,047 households.

For these analyses, the following were dropped from the sample: 775 age-ineligible spouses to limit the analysis to those aged 70 years or older; 791 proxy interviews, which are inappropriate for measuring the dependent variable; and 532 persons for whom data were missing or invalid, principally US Census tract identifier or the dependent variable, cognitive status. The problem of missing cognitive data is discussed in more depth in the Results section. To eliminate the household level of clustering, we randomly sampled one person per household, which eliminated 1,009 persons. Consistent with most neighborhood theories that assume an urban setting (23, 24), we limited the sample to persons living in US Census tracts that are at least 75 percent urban. Census tracts in urban areas encompass a smaller physical area than those in rural settings. Additionally, the concept of neighborhood carries a different substantive meaning in many rural areas, where residences may be very sparsely distributed. The final analytic sample size was 3,442 persons. Weights (provided in the AHEAD data) were used to adjust for variation in the probabilities of selection, including the oversampling of African Americans, Hispanics, and residents of Florida. Weights were further adjusted for our analytic selection of one person per household. Consequently, the analytic sample was nationally representative of persons aged 70 years or older living in the community in urban areas in 1993.

AHEAD utilized a multidimensional measure of cognition based on the Telephone Interview for Cognitive Status (25). Most AHEAD studies have used a total score rather than establishing a cutoff point to designate cognitive impairment. We followed suit, given that our goal was not to estimate the prevalence of cognitive impairment but rather to explore multiple levels of influence on overall cognitive performance. The reliability and validity of the AHEAD cognitive measure has been established previously (26–28). First, memory was assessed with immediate and delayed word recall tasks. The interviewer read a list of 10 nouns and asked the respondent to recall as many as possible. After 5 minutes of asking other cognitive questions, the respondent was again asked to recall the nouns. Scores represent the number of words correctly recalled. Second, working memory was assessed by using the Serial 7's subtraction test. Respondents were asked to subtract 7 from 100 and to continue subtracting 7 from each subsequent number for a total of five trials. Scores represent the number of correct subtractions. Third, mental status was measured by tasks assessing knowledge, language, and orientation: 1) counting backward for 10 continuous numbers beginning with 20, as quickly as possible; 2) reporting the correct date; 3) naming objects; and 4) naming the president and vice-president. Scores represent the number of correct responses. Cognitive function is the sum of component scores (i.e., all correct responses), ranging from 0 to 35.

Individual-level risk factors encompassed several domains. Educational attainment was assessed as the highest grade of school or year of college completed. Other socioeconomic-related measures included household wealth and household income, both logged. Standard sociodemographic information included gender, age, marital status (married, widowed, separated/divorced, never married), and ethnicity (non-Hispanic White, African American, Hispanic, other). In the health domain, activities of daily living represent a count (0–6) of the respondent's self-reported difficulties with personal-care tasks. Depressive symptoms were measured with a count of eight items from the Center for Epidemiologic Studies Depression Scale (29), scored yes (1) or no (0) for being experienced during "much of the time in the past week" ($\alpha = 0.78$). Eight physician-identified major health conditions included heart problems, stroke, psychiatric problems, high blood pressure, diabetes, cancer, lung disease, and arthritis.

Neighborhood-level constructs were operationalized with 1990 US Census tract data (STF3A data), which were linked with geocodes to the individual-level data. US Census tracts are designed to be relatively homogeneous units with respect to population characteristics, economic status, and living conditions at the time they are established. Ideally, they contain between 1,000 and 8,000 people, with an optimum size of 4,000, although there is wide variation because of population shifts between the decennial US Census data collections. Geographic size varies, depending on population density. US Census tracts are particularly suitable representations of neighborhoods in urban areas because of the dense concentration of persons. In this paper, we treat "neighborhood" and "Census tract" as equivalent terms. The 3,442 participants in our analytic sample resided in 1,217 US Census tracts, with the number of participants per tract ranging from 1 to 31. These tracts consist of 5,344 residents on average (median, 4,678), ranging from 342 to 71,872. Neighborhood education was assessed as the proportion of residents aged 25 years or older without a high school degree. Our analysis of education also controlled for the competing effect of median household income (logged) at the US Census tract level. Among the potential neighborhood-level economic controls, median household income was chosen because it had the lowest zero-order correlation with proportion of residents without a high school degree ($r = -0.699$), reducing potential multicollinearity.

For all analyses, normalized grand sample weights were applied so that findings could be generalized to the urban population of older US adults. Descriptive statistics were calculated with the SVY procedure in the Stata software package, which takes into account the complex sample design in estimating standard errors (30). Hierarchical linear models were estimated with HLM software, version 6.01 (31). Contextual-level variables were grand mean centered to facilitate interpretation. Tests of statistical significance for random-effects models were one sided (31).

The gross variance in cognition associated with neighborhood context was first estimated with a null, or unconditional, model that contained only a random intercept. Second, the impact of individual-level sociodemographic and health risk factors was tested. Third, the main effect of neighborhood-level educational attainment on the average level of cognition was assessed. Fourth, median household income at the neighborhood level was controlled. Fifth, the cross-level interaction between individual-level educational attainment and neighborhood-level educational attainment was assessed. Deviance statistics assessed model fit, and sequential differences between models were considered with the likelihood ratio test.

RESULTS

Individual-level characteristics (weighted) of the sample are shown in table 1. Females outnumbered males, the average respondent was in his or her late seventies, most were non-Hispanic White, nearly half were widowed, average education approximated high school graduation, and both income and wealth were variable. In terms of health, levels of assistance with activities of daily living requirements and number of depressive symptoms were relatively low, and most participants had not experienced serious health problems, although nearly half reported high blood pressure and a substantial minority had arthritis or heart problems. Participants responded correctly to nearly 60 percent of the cognitive items, on average.

At the neighborhood level, wide variation in US Census tract characteristics was evident. The average US Census tract consisted of one quarter of residents aged 25 years or older without a high school degree, but some areas had a high density of such persons (maximum, 86.32 percent) whereas others virtually lacked such persons (minimum, 0.94 percent). On average, median household income was slightly higher than the $30,056 reported in the 1990 US Census for the population as a whole (32).

Table 2 presents the hierarchical linear models of cognition (level 1 is the individual, level 2 is the US Census tract). As shown at the bottom of the table, models 2, 3, 4, and 6 represent significant improvements in fit over previous models (i.e., the deviance statistic significantly decreases), but model 5 does not. In addition, statistically significant random variation (τ) in cognition across US Census tracts was sustained with each sequential model.

As shown in model 1 (the null model), there was significant variation in cognition across the US Census tracts ($\tau = 6.22$, $p < 0.001$). The intraclass correlation (ρ; between-group variation/[between + within-group] variation) was sizable (0.20) and indicated that 20 percent of the variation in cognition in this sample could be attributed to living in different US Census tracts. Model 2 added individual-level sociodemographic variables, which accounted for 22 percent of the level 1 within-group variance. Consistent with

TABLE 1. Characteristics of a sample of US urban adults aged ≥70 years in 1993 (*n* = 3,442)

	% or mean (standard deviation)
Individual-level characteristics (weighted)	
Gender	
Female	62.25
Male	37.75
Age (years)	77.15 (5.69)
Ethnicity	
Non-Hispanic White	84.39
African American	10.16
Hispanic	4.18
Other	1.27
Marital status	
Married	41.66
Widowed	47.25
Separated/divorced	6.59
Never married	4.50
Education (years)	11.54 (3.42)
Household income (US dollars)	28,036.47 (71,407.49)
Household wealth (US dollars)	189,654.90 (423,764.83)
Assistance with activities of daily living (0–6)	0.51 (1.09)
Depressive symptoms (0–8)	1.63 (1.98)
Heart problems	28.94
Stroke	6.69
Psychiatric problems	6.56
High blood pressure	45.57
Diabetes	12.48
Cancer	13.56
Lung disease	9.12
Arthritis	24.82
Cognition (1–35)	20.12 (5.60)
Census-tract-level variables	
Percentage of residents aged ≥25 years without a high school degree	26.01 (16.29)
Median household income (US dollars)	32,010.57 (14,818.57)

previous research (20), low educational attainment, being older, being an ethnic minority, and living in a household with low income were significant risk factors for poor cognitive function. Model 3 added individual-level health variables, which accounted for an additional 2 percent of the level 1 variance in cognition. As shown, high levels of difficulties with activities of daily living, high levels of depressive symptomatology, and having suffered a stroke were negatively associated with cognition, whereas cancer and arthritis were positively associated with cognition. Additionally, female gender was positively and significantly associated with cognition, although it was of borderline significance in the previous model. The coefficients for the remaining individual-level sociodemographic variables were virtually unchanged by controlling for health status.

Model 4 introduced level 2 neighborhood educational attainment. Living in a low-education area was associated with low cognitive function, net of individual-level education and covariates. Neighborhood-level educational level significantly improved the fit of the model, but, in comparison to model 3, it did not affect the amount of intercept variance at level 2 accounted for by the model. The coefficients for the individual-level variables were largely unaltered, with the exception of that for Hispanic ethnicity, which decreased noticeably, meaning that neighborhood education accounted for some of the effect on cognition of being Hispanic. As shown in model 5, inclusion of median household income did not significantly improve the fit of the model, and its coefficient was not significant. The main effect of neighborhood education remained significant, and it actually increased by about 68 percent, indicating that its effect may have been suppressed by not controlling for median household income. Median household income accounted for nearly negligible additional intercept variance at level 2, and the coefficient for Hispanic ethnicity became nonsignificant

The interaction between individual- and neighborhood-level education was examined next. First, we tested whether the slope for individual-level education (from model 5) varied significantly across neighborhoods. This variation was nearly significant ($\tau_{11} = 0.03$, χ^2 (df = 640) = 699.31, $p = 0.06$; based on 643 US Census tracts with sufficient variation). We then modeled the random neighborhood variability in the level 1 education slope as a function of neighborhood-level education (refer to model 6), finding a significant cross-level interaction. The between-group variation increased because the education variable was now conditional.

Figure 1 illustrates the conditional impact of level 1 education on the association between neighborhood education and cognition among these older adults. For neighborhood education, two values—the minimum and maximum—were substituted into the regression equation. For individual-level education, three values (the mean plus and minus one standard deviation) were substituted. Mean values were used for significant continuous variables, and 0 was the value for other variables. As shown in figure 1, as the proportion of neighborhood residents without a high school degree increased, cognition decreased. However, this decrease was not commensurate across the population: The decline was steepest among those with the least education. Cognitive differentials between persons with low educational attainment and high educational attainment were larger in low-education neighborhoods than in high-education neighborhoods.

To further investigate contingencies between individual- and neighborhood-level education, we estimated model 3 from table 2 separately for tertiles of neighborhood education: high (1–16 percent without a high school degree), medium (17–29 percent without a high school degree), and low (30–86 percent without a high school degree). Individual-level educational attainment significantly affected cognition within each neighborhood type, but the coefficient was significantly smaller for those living in high-education areas ($\beta = 0.31$;

TABLE 2. Multilevel regressions of cognitive function (β (standard error)) among US urban adults aged ≥70 years in 1993‡

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Individual-level sociodemographic variables						
Years of education		0.52 (0.03)***	0.50 (0.03)***	0.48 (0.03)***	0.48 (0.03)***	0.48 (0.03)***
Female (vs. male)		0.34 (0.19)	0.39 (0.19)*	0.38 (0.19)*	0.38 (0.19)*	0.38 (0.19)*
Age		−0.28 (0.02)***	−0.26 (0.02)***	−0.26 (0.02)***	−0.26 (0.02)***	−0.26 (0.17)***
Widowed§		0.08 (0.21)	0.10 (0.20)	0.09 (0.20)	0.08 (0.20)	0.08 (0.20)
Separated/divorced§		0.10 (0.35)	0.17 (0.35)	0.18 (0.35)	0.15 (0.35)	0.19 (0.35)
Never married§		0.14 (0.42)	0.08 (0.41)	0.09 (0.41)	0.07 (0.41)	0.09 (0.41)
African American¶		−3.10 (0.28)***	−3.09 (0.27)***	−2.85 (0.30)***	−2.89 (0.30)***	−2.72 (0.30)***
Hispanic¶		−1.30 (0.37)**	−1.15 (0.36)**	−0.80 (0.40)*	−0.75 (0.40)	−0.69 (0.41)
Other ethnicity¶		−1.98 (0.66)**	−2.11 (0.65)**	−2.04 (0.65)**	−2.03 (0.65)**	−1.90 (0.66)**
Household wealth (log)		0.26 (0.16)	0.15 (0.16)	0.10 (0.16)	0.13 (0.17)	0.16 (0.17)
Household income (log)		0.58 (0.12)***	0.53 (0.12)***	0.51 (0.12)***	0.50 (0.12)***	0.51 (0.12)***
Individual-level health variables						
Assistance with activities of daily living			−0.53 (0.10)***	−0.52 (0.10)***	−0.52 (0.10)***	−0.53 (0.10)***
Depressive symptoms			−0.18 (0.05)***	−0.18 (0.05)***	−0.18 (0.05)***	−0.18 (0.05)***
Heart problems (vs. no)			0.12 (0.18)	0.13 (0.18)	0.13 (0.18)	0.14 (0.18)
Stroke (vs. no)			−1.32 (0.34)***	−1.33 (0.34)***	−1.32 (0.34)***	−1.32 (0.34)***
Psychiatric problems (vs. no)			−0.31 (0.35)	−0.31 (0.35)	−0.32 (0.35)	−0.31 (0.35)
High blood pressure (vs. no)			0.20 (0.17)	0.21 (0.17)	0.21 (0.17)	0.20 (0.17)
Diabetes (vs. no)			−0.22 (0.24)	−0.22 (0.24)	−0.22 (0.24)	−0.20 (0.25)
Cancer (vs. no)			0.57 (0.24)*	0.57 (0.24)*	0.56 (0.24)*	0.61 (0.24)*
Lung disease (vs. no)			0.15 (0.29)	0.15 (0.29)	0.15 (0.29)	0.17 (0.28)
Arthritis (vs. no)			0.47 (0.20)*	0.47 (0.20)*	0.47 (0.20)*	0.48 (0.20)*
Intercept	20.16 (0.12)***	33.66 (1.51)***	33.01 (1.48)***	33.40 (1.48)***	33.37 (1.48)***	33.37 (1.48)***
Census-tract-level variables						
% with no high school degree				−1.76 (0.81)*	−2.57 (1.05)*	−6.29 (1.80)**
Median household income (log)					−0.36 (0.31)	−0.40 (0.31)
Cross-level interaction						
% with no high school degree × years of education						0.33 (0.15)*
Random variance component						
Between group						
Intercept (τ)	6.22***	1.20***	1.00***	1.01***	0.97***	6.98*
Years of education						0.03†
Within group (σ^2)	24.31	18.91	18.36	18.31	18.34	18.03
Model comparison (vs. previous model)						
Chi-square		1,266.12***	126.51***	6.40*	1.48	10.78*
Degrees of freedom		11.0	10.0	1.0	1.0	3.0

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
† $p = 0.07$.
‡ For more information about the models, refer to the Results section of the text.
§ Reference group: married.
¶ Reference group: non-Hispanic White.

standard error, 0.06; $p < 0.001$) compared with medium- ($\beta = 0.60$; standard error, 0.06; $p < 0.001$) or low- ($\beta = 0.57$; standard error, 0.05; $p < 0.001$) education areas, supporting the finding that individual-level education is less cognitively influential in high-education areas than in low-education areas.

In a final set of analyses, we considered the possible influence of missing cognitive data on the observed findings.

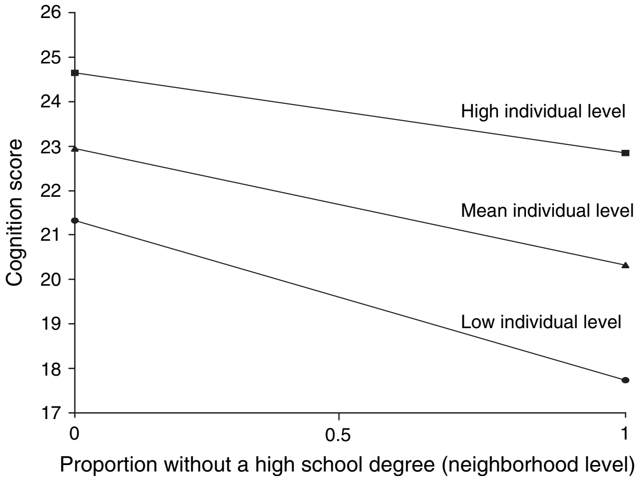

FIGURE 1. Effects of individual-level education on the association between cognition and neighborhood-level education (cross-level interaction) among US urban adults aged ≥70 years in 1993.

First, we performed a logistic regression by using all study variables to predict missing on cognition (i.e., 1 = missing cognition, 0 = not missing cognition). Those with the following characteristics had significantly ($p < 0.05$) higher odds of lacking cognitive data: being married (as opposed to being separated/divorced), having low levels of wealth, requiring high levels of assistance with activities of daily living, scoring high on depressive symptoms, and not having high blood pressure, diabetes, or arthritis. Second, we conducted a logistic hierarchical linear model to determine whether there was neighborhood variation in the odds of missing cognitive data. The variation of the log-odds of missing cognitive data was estimated to be 0.49 (standard deviation, 0.70, $\chi^2 = 991.81$, $p > 0.50$), indicating nonsignificant variability across US Census tracts.

DISCUSSION

Our findings provide compelling evidence that cognitive functioning in late life does not manifest in isolation from social context, and this study is the first of its kind known to identify particular aspects of neighborhoods that are associated with cognition among older adults. First, we found that cognition varied significantly across urban US Census tracts. Second, cognition was associated with educational profiles of the neighborhood, in that older adults living in concentrated low-education areas were worse off cognitively, on average, than those living in areas where most residents had attained at least a high school education. Importantly, the main effect of contextual-level education occurred net of personal characteristics of the individual, most notably his or her own educational attainment level, meaning that the contextual effect was not merely the manifestation of compositional differences across neighborhoods. Third, the cognitive impact of neighborhood education was sustained when controlling for median household income at the contextual level, demonstrating that education is uniquely important. Fourth, the cognitive impact of one's own educational attainment was contingent on neighborhood education, with low educational attainment being somewhat more consequential in low-education areas than in high-education areas. Thus, cognition in late life is a product of the personal characteristics of the individual in interaction with his or her environment.

High school graduation was the modal level of educational attainment for this sample of older persons, but, for the most part, these older persons live surrounded by younger cohorts. For these subsequent cohorts, educational attainment has risen considerably generation by generation. Thus, it could reasonably be expected that older persons might be surrounded, on average, by younger neighbors with higher levels of educational attainment. Since education is associated with cognition, this general environmental advantage may offset individual deficits in education. However, low educational attainment of one's neighbors, as evidenced by low rates of high school graduation, is not normative for the general population but evidence of the type of limited achievement that often goes with socioeconomic disadvantage. In this situation, older persons whose cognition is compromised by their own limited education may find little compensation in their surroundings.

Applying a taxonomy developed by Catalano and Pickett (33), we suggest that the specific etiologic connection between neighborhood education and cognition in late life may be generated in three ways. First, persons living in low-education areas may be disproportionately exposed to chronic, stressful life conditions that create multiple hazards such as reduced employment opportunities, marginal occupations, and truncated incomes, which lead to a concomitant dearth of safe physical resources (e.g., well-lit walkways, bicycle paths, parks, gyms) and social resources (e.g., well-kept shopping areas, social clubs, neighborhood organizations), thereby hindering engagement in both physical and social activities, which have been linked to better cognitive functioning (11, 34, 35). Second, there is an unequal distribution of cognitively stimulating coping resources in low-education neighborhoods (e.g., medical screening facilities, health clinics, bookstores, libraries), which have been linked to better cognitive function (36–39), and are scarce or absent because of the lack of an educated consumer demand or monetary tax base for such resources. Third, low-education neighborhoods may be characterized by a high tolerance for illness, which stems from untreated chronic conditions (e.g., diabetes), elevated exposure to hazards, and limited coping strategies, generating widespread cognitive deficits, which are viewed as normative or socially acceptable, especially for older persons who may already have other forms of impairment such as those that limit their mobility (40, 41).

We focused on education as the single most relevant neighborhood socioeconomic characteristic in terms of cognition among these older adults because education is conceptualized as being the catalyst for various other forms of neighborhood disadvantage, as described above. These other neighborhood-level characteristics (e.g., proportion of residents living below the poverty level, proportion of households receiving public assistance, proportion of unemployed adults) are highly correlated with neighborhood education (average $r = 0.757$) and each other (average $r = 0.802$) and, in additional analysis, were found to form a single principal component. We replicated the neighborhood main-effects model by using this principal component instead of neighborhood education, and we found that the principal component approached significance ($\beta = -0.24$; standard error, 0.13; $p = 0.066$). However, we prefer the results with neighborhood education because they suggest two types of influence on older persons' cognition: 1) a general impact of socioeconomic disadvantage (shared in common with the other socioeconomic indicators) and 2) a specific impact of educational disadvantage.

The finding that cognitive deficits associated with being Hispanic became nonsignificant once the neighborhood characteristics were controlled deserves mention. It appears that neighborhood context may be of special cognitive importance for these persons and that contextual-level education and income may account for the observed individual-level association between Hispanic background and cognition. This finding should be interpreted with caution, however, because of the small proportion of Hispanics in the sample (4 percent). Ethnic variation in cognition was not the focus of our analysis, and ethnicity was included primarily as a control variable. Targeted studies are needed to fully investigate how neighborhood socioeconomic characteristics may be uniquely consequential to older Hispanics, especially given previous findings of neighborhood effects among older Mexican Americans (2).

This study has several strengths. First, the data were derived from a large, national probability sample of older adults, enhancing external validity and generalizability of the findings. Second, the measure of cognition was multifaceted, and it tapped into both memory capabilities and the mental status of participants. Third, linkage of the individual-level data with US Census tract data provided a unique opportunity to assess the impact of neighborhood-level education on cognition. Fourth, controlling for a comprehensive list of individual-level risk factors enabled us to largely eliminate their potentially confounding impact on the results.

There are also limitations to acknowledge. First, as discussed in other analyses of the AHEAD data (27), results are somewhat biased toward a cognitively well-functioning population because we excluded institutionalized persons, proxy-assisted interviews, and persons for whom a large portion of cognitive data was missing. Our analysis of the impact of missing cognitive data on our findings supports this possibility, in that those missing cognitive data do differ in several ways from participants in our analytic sample. Importantly, however, missing cognitive data is not a systematic function of neighborhood clustering, and we are confident in the basic nature of the relation between neighborhood education and cognition. Second, selection effects (endogeneity) related to unique characteristics of persons who reside in certain residential areas may have affected the findings, and social selection remains an alternative explanation for our results. Third, the study was cross-sectional; thus, causal pathways cannot be definitively determined.

Overall, however, by showing that cognition varied across urban neighborhoods and that the neighborhood-level education accounted for some of this variation, controlling for neighborhood-level income, individual-level education, and other risk factors, we conclude that social context is indeed consequential to cognitive function among older adults. Furthermore, it is apparent that education-related neighborhood risk factors for poor cognition may be offset by one's own educational attainment, particularly in disadvantaged neighborhoods. This finding suggests that context-specific health assessments may facilitate the early identification and treatment of cognitive health problems, and targeting older persons with limited education in disadvantaged neighborhoods may prove especially beneficial. In addition, promoting educational attainment in the general population in disadvantaged neighborhoods may prove cognitively beneficial to its aging residents because it may lead to meliorations in stressful life conditions and coping deficiencies in the neighborhood.

ACKNOWLEDGMENTS

This research was supported by a grant from the National Institute on Aging (R01 AG022537, Dr. Carol S. Aneshensel, Principal Investigator).

Conflict of interest: none declared.

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