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RESEARCH ARTICLE

Neighborhood socioeconomic status and segregation linked to cognitive decline

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Abstract

Introduction: Few longitudinal studies have examined the joint impact of neighborhood segregation and neighborhood socioeconomic status (NSES) in cognitive decline over time.

Methods: This study included non-Hispanic White (NHW, $n = 209$) and Black participants ($n = 118$) whose cognition was evaluated as part of an ongoing longitudinal study. Four distinct categories of segregation and NSES were evaluated for their association with cognitive outcomes (episodic memory, semantic memory, executive function, and spatial ability) using race-specific mixed-effects models.

Results: Compared to Black participants living in higher segregation-lower NSES areas, Black participants living in lower segregation-lower NSES areas or higher segregation-higher NSES areas experienced slower decline in episodic memory over time. Compared to NHW participants living in higher segregation-lower NSES areas, NHWs living in lower segregation-higher NSES areas experienced faster decline in spatial ability.

Discussion: Segregation and NSES are differentially associated with cognition depending on participant race. Further research is needed to replicate study results.

KEYWORDS
cognition, disparities, neighborhoods, race/ethnicity, residential segregation

1 | INTRODUCTION

With the proportion of Americans ages 65 and older projected to increase from 16% of the population in 2019 to 22% of the population by 2040,[1] the largest growth being among racial/ethnic minorities, it is imperative that we address racial/ethnic disparities in the prevalence of Alzheimer's disease and related disorders (ADRD).[2,3] Many studies have identified individual risk factors associated with dementia-related cognitive changes such as age, education, genetics, and medical conditions such as cardiovascular disease.[4,5] However, social and structural

RESEARCH IN CONTEXT

1. **Systematic Review**: A literature review was conducted using traditional sources (e.g., PubMed) and keywords such as "segregation," "neighborhood socioeconomic status (NSES)," and "cognition." Although many studies have examined the impact of NSES on cognition, few have focused on residential segregation and NSES together or included longitudinal follow-up data.
2. **Interpretation**: This is the first known study to suggest that distinct combinations of residential segregation and NSES are associated with specific cognitive trajectories for African American/Black and non-Hispanic White (NHW) individuals.
3. **Future Directions**: Future studies should do the following: (1) re-examine associations between neighborhood residential segregation-NSES and longitudinal change in cognition in other racially and ethnically diverse cohorts with larger sample sizes, (2) include other neighborhood variables that might explain the segregation-NSES associations with cognition, and (3) use mixed-methods studies that explore perceptions of neighborhoods by its residents.

determinants of health, including neighborhood environments, play an important role in shaping individual health and health care disparities for minoritized populations.[6,7] These contextual factors are important contributors to cognitive health disparities but have been relatively understudied. Given that these factors may be targeted by public health policies and interventions, it is important that their role be elucidated in research on ADRD disparities. The focus of this study is on two neighborhood social contextual factors—neighborhood residential segregation and neighborhood socioeconomic status (NSES).

Williams and Collins[8] posited that racial segregation, or the spatial separation of groups, is a fundamental cause of health disparities among Black populations. In the pre-1960s United States, segregation, a product of structural racism, was pervasive and enforced by legal, social, and public policies such as Jim Crow laws and the historical act of redlining. Redlining played a role in the segregation of neighborhoods by race and SES through involvement of the national mortgage market.[9,10] Despite the geographical diversity in birthplace for the Black/African American community, individuals are connected through their shared experiences of systemic racism.[11] Older African Americans were born before the repeal of Jim Crow laws and, thus, are directly affected by de jure policies of the Jim Crow era as well as ongoing de facto policies that have continued into the present day.[12]

When individuals are systematically relegated into environments with higher levels of poverty and policing/crime, individuals tend to socially isolate from each other, which limits their interactions.[13] This may result in inhibited opportunities for cognitive enrichment and stimulation. Moreover, concentrated poverty is linked to poorer cognitive functioning due to lack of resources such as quality education, access to health care, job opportunities, healthy grocery stores, and safe recreational and greenspace areas, all of which can impact health and cognition.[14] In a review conducted by Majoka and Schimming, living in economically-deprived neighborhoods with limited access to physical and social resources was associated with greater risk of ADRD.[15] It was concluded that racial prejudice, residential segregation, and poor neighborhood environments contribute to a greater risk of ADRD overall.

In a nationally representative sample, greater Black neighborhood segregation (measured using the isolation index[16]) was not associated with cognitive function or cognitive decline for non-Hispanic White (NHW), non-Hispanic Black, and Hispanic older adults.[17] In another study of diverse older adults from northern California, using the Gi* statistic as a measure of racial/ethnic segregation, Black older adults living in areas with greater clustering of Black and Hispanic residents had lower baseline cognitive scores but no differences in their longitudinal cognitive change.[18] Recently, Caunca and colleagues examined life-course or long-term residential segregation of Black participants in the Coronary Artery Risk Development in Young Adults (CARDIA) study.[6] They found that the longer Black participants were segregated in young adulthood, the worse their processing speed was in midlife. Our own work has shown that although the race–segregation interaction was not significant, African American/Black participants with greater neighborhood segregation had greater processing speed decline in race-stratified analyses.[19]

Given that there are only a handful of longitudinal studies on residential segregation and cognition, it is unclear how segregation is associated with cognitive trajectories of residents, particularly when NSES is considered. Often, NSES is included as a covariate in segregation studies or as an effect modifier/moderator in an interaction term with other individual-level variables. However, as Ward et al. point out, there has been an over-reliance on interaction terms in health disparities research,[20] and this is important given that both segregation and NSES clearly vary by race. The goal of this study is to examine the associations of neighborhood segregation and NSES with baseline cognition and cognitive decline over time in a well-characterized cohort of NHW and Black older adults. We add to the literature by considering the combined influence of segregation and NSES on cognition. In the United States, these measures are often highly correlated (e.g., neighborhoods with an overrepresentation of minoritized residents are more likely to have low NSES) but do not perfectly predict one another. Thus examining segregation and NSES simultaneously may reveal important nuances that have not been evaluated in prior, similar studies to date. We also hypothesized that these two neighborhood characteristics affect Black and NHW individuals differently due to person–environment fit.[21] In this study, we speculate that Black and NHW participants respond differently to their neighborhood given the social, historical, and varied life course experiences that make up the social construction of race.[22]

2 | METHODS

We obtained data on 327 participants with residential address data available from the University of California, Davis (UCD) Alzheimer's Disease Research Center (ADRC). Participants were recruited primarily through community outreach, but also through referrals to memory clinics, and completed clinical evaluations approximately annually. Participants were required to speak English or Spanish. Exclusion criteria included unstable major medical illness, such as severe heart disease, major psychiatric disorders, active cancer with chemotherapy, and active substance abuse and dependence disorders, all assessed through a clinical exam. Additional details regarding ADRC recruitment methods are published elsewhere.[23] The parent study was approved by the UCD institutional review board and all participants provided informed consent. For this study, we restricted the sample to individuals who were NHW or Black (n = 806), who had at least two visits in which they completed neuropsychological testing (n = 586), who had neighborhood level data (n = 331), and who had non-missing data for at least one cognitive domain (N = 327).

2.1 | Clinical evaluations

All participants received standardized multidisciplinary diagnostic evaluations at each visit including a detailed medical history, neuropsychological testing, and physical and neurological exams. Family members or other close informants rated the individual's level of independent functioning. Standardized diagnostic criteria using the current Alzheimer's Disease Centers Uniform Data Set guidelines were used to determine the presence of a cognitive syndrome (normal cognition, mild cognitive impairment: MCI, and dementia).[24,25] For all visits, each individual was diagnosed via consensus conference by the clinical team and reviewed at adjudication conferences. All diagnoses were determined blind to the neuropsychological assessment measures used in the current study.

2.2 | Cognitive outcomes

The Spanish and English Neuropsychological Assessment Scales (SENAS) was administered at all evaluations. Item response theory was employed to develop psychometrically matched measures across different scales in both English and Spanish and that are appropriate for diverse education levels. Four SENAS domains were captured: executive function, semantic memory, episodic memory, and spatial ability. The composite measure of executive function is constructed from category fluency (number of animals named in 60 s), phonemic (letter) fluency (words beginning with the /f/ sound, words beginning with the /l/ sound), and working memory tasks (digit-span backward, visual-span backward, list sorting). The composite of semantic memory is based on highly correlated verbal (object-naming) and nonverbal (picture-association) tasks. The composite of episodic memory is derived from a multi-trial word-list-learning test (Word List Learning 1).[26] The three alternate forms of the word list learning task were alternated over time to account for practice effects. The composite of spatial ability was based on the Spatial Localization scale, which assesses ability to perceive and reproduce increasingly complex two-dimensional spatial relationships. SENAS scores are presented in z-score like units (derived from a larger sample), where a score of zero corresponds to the mean and differences from the mean are expressed in standard deviation (SD) units. Measure development and psychometric characteristics are described further elsewhere.[26–29]

2.3 | Neighborhood variables

At baseline, individual participant addresses were geocoded using QGIS and the MMQGIS plug-in along the US Census Bureau's road network.[30–32] Given that study participants were seen at two sites—one in the Bay Area and one in Sacramento—most neighborhoods were located in the Northern California vicinity. Similar to previous research and to be judicious with participant privacy, we defined neighborhoods based on census tracts.[33] Geocoding was checked for quality assurance (e.g., addresses that appeared unusual were checked in google maps for location accuracy).

Neighborhood-level residential segregation was assessed using both global and local spatial clustering measures. Spatial clustering diagnostics of the data on race was performed using global spatial autocorrelation measures including the Getis-Ord General G[34] and global Moran's I.[35,36] Diagnostic tests indicated significant spatial clustering, and thus we used the local Getis-Ord Gi* statistic, a widely accepted measure of spatial clustering, also known as hotspot analysis.[34,37] The measure was computed in ArcGIS using the Hot Spot Analysis Tool.[38] We focused on Black clustering specifically due to the focus on historical racism and segregation. The proportion of Black residents in a census tract was compared with the mean proportion of Black residents in the surrounding area. A spatial weight accounted for composition of each tract compared with neighboring tracts. The Gi* statistic produces a z-score representing how much, in SD units, the racial composition of one's tract differs from the greater surrounding area. The more positive the Gi* statistic, the greater the clustering (i.e., overrepresentation) of Black residents in the census tract and surrounding neighborhoods compared with the larger surrounding area (i.e., within a search threshold of 12.4 mi/20 km). The more negative the Gi* statistic, the lower the clustering (i.e., underrepresentation) of Black residents compared to the surrounding area. Gi* statistics near zero indicate no racial clustering.

NSES was derived from six US Census tract variables: percentage of individuals with a high school diploma, percentage who owned their own home, percentage not on public assistance, percentage employed, median household income, and median number of rooms in home. These variables were z-score standardized and then averaged together to create a single NSES variable (range: –1.67 to 1.76, where a larger positive value indicates a higher NSES).

Our primary neighborhood measure of interest was a four-category composite measure based on the Gi* statistic for Black segregation and NSES. We first determined the median value of each variable for NHW and Black participants separately in order to dichotomize the Black segregation and NSES measure. Medians were calculated separately because the values were significantly and meaningfully different by race (i.e., significantly lower NSES for Black participants). The dichotomized measures were then combined into the four-category segregation-NSES measure: (1) higher segregation-lower NSES; (2) lower segregation-higher NSES; (3) lower segregation-lower NSES; and (4) higher segregation-higher NSES. We chose to create a single composite measure because it allowed for an easy-to-interpret and a conceptually distinct measure that provides insight beyond previous studies that examine segregation or NSES separately.

2.4 | Covariates

Covariates in multivariable models included age, sex, education in years, cognitive status at the baseline visit (normal, MCI, or dementia), number of visits, recruitment source (clinic or community, as most MCIs come from clinic), clinic site (East Bay versus Sacramento, as 90% of Black participants came from the East Bay), and population density (people/mi^2). Time was calculated as years from baseline evaluation and captures annualized rate of change.

2.5 | Statistical analyses

Descriptive statistics were used to describe the sample stratified by the four-category segregation-NSES measure. Unadjusted linear and logistic regression were used to test differences in the sample demographic and clinical characteristics by neighborhood segregation-NSES type. Mixed-effects regression models including random intercepts and random slopes examined associations between the segregation-NSES measure and cognitive outcomes. Few census tracts were represented by more than one participant; thus, similar to previous research,[18,39,40] we treated the NSES and Gi* statistic variables as person-level factors in a contextual analysis rather than modeling their effects in a multilevel model. As mentioned earlier, we hypothesized that segregation and NSES affect individuals differently depending on race, and thus, our models were a priori stratified by race (Black, NHW).

Although the combined segregation-NSES measure was of primary interest, we also ran similar models to determine race-stratified associations between the segregation and NSES measures considered separately and the cognitive outcomes. A prior study using the same sample presented associations between segregation and all cognitive domains in this paper except spatial ability.[39] Thus only the association between segregation and spatial ability is presented here. In sensitivity analyses, we removed individuals with dementia at baseline to ensure that associations were not skewed by their differential cognitive trajectories.

In all models, we used inverse probability weighting (IPW) to account for potential attrition/selection bias that may be due to the exclusion of participants with only one visit and those with missing addresses (excluded 821 participants from the original cohort due to our focus on those with: at least two time points, address-level data, and were Black or NHW). We calculated IPWs in logistic regression using the participant's age at baseline, sex, education level, race, site, and diagnosis at baseline (1 = in analytic sample, 0 = not in analytic sample). These weights were then applied in the mixed-effects regression models focused on our analytic sample to reduce bias in the estimates. All analyses were conducted using SAS v9.4.[41]

3 | RESULTS

The analytic sample (N = 327) had a mean age of 75 years (SD = 7.0), had 15.2 years of education (SD = 3.1); 64% percent were women; 64% were NHW, and 36% were Black (Table 1). Most participants had normal cognition (62%) and MCI (31%) at their baseline visit, and, on average, participants had completed 5.2 visits (SD = 2.9). Black participants lived in neighborhoods with higher mean levels of Black segregation and lower NSES (mean Gi* = 10.5 [SD = 4.6], range = –3.0, 21.7; mean NSES = –0.11 [SD = 0.66]; range = –1.67, 1.30) than White participants (mean Gi* = 7.6 [SD = 7.6], range = –6.4, 22.3; mean NSES = 0.35 [SD = 0.63], range: –1.26, 1.76). The continuous neighborhood segregation and NSES measures were weakly correlated (r = 0.32). Compared to individuals living in higher segregation-lower NSES areas, those in lower segregation-lower NSES areas reported fewer years of education, and those in higher segregation-higher NSES reported more years of education. Tables S1 and S2 show characteristics by NHW and Black participants, respectively (results not discussed).

Figure 1 shows the tracts that study participants live in, and the percentage of Black residents in the tract. Figures 2 and 3 show the spatial distribution of neighborhood types (by level of segregation and NSES) in Sacramento and the Bay Area. Unadjusted regression findings are provided in Table S3. In race-stratified, adjusted models (Table 2), for Black individuals, living in lower segregation-lower NSES neighborhoods (estimate = 0.052, 95% confidence interval [CI] = 0.018, 0.086) and higher segregation-higher NSES neighborhoods (estimate = 0.059, 95% CI: 0.009, 0.108) was associated with slower decline in episodic memory over time, versus living in higher segregation-lower NSES neighborhoods. For NHW individuals, living in lower segregation-higher NSES neighborhoods was associated with faster decline in spatial ability over time versus living in higher segregation-lower NSES neighborhoods (estimate = –0.073, 95% CI: –0.146, –0.000). No other associations were observed between the neighborhood segregation-NSES categories and baseline cognition or change in cognition over time. Tables S4 and S5 present individual associations between the segregation and NSES measures and cognitive outcomes. Greater neighborhood segregation was associated with faster spatial ability declines over time among NHW but not Black participants, and no other segregation-cognition associations were observed. NSES was not associated with baseline spatial ability or in change in spatial

TABLE 1 Sample characteristics ($N = 327$)

		Neighborhood Black segregation-neighborhood SES category			
Characteristic at baseline	Total	Higher segregation-lower NSES	Lower segregation-higher NSES	Lower segregation-lower NSES	Lower segregation-higher NSES
Sample size, *n*	327	75	76	88	88
Age, mean (SD)	75.1 (7.0)	76.2 (7.3)	73.2 (7.1)*	76.6 (7.0)	74.3 (6.5)
Female, *n* (%)	209 (63.9%)	54 (72.0%)	47 (61.8%)	49 (55.7%)*	59 (67.1%)
Education (years), mean (SD)	15.2 (3.1)	15.0 (2.9)	15.7 (2.9)	14.0 (3.2)*	16.3 (3.0)*
Race/ethnicity, *n* (%)					
White	209 (63.9%)	46 (61.3%)	47 (61.8%)	58 (65.9%)	58 (65.9%)
Black	118 (36.1%)	29 (38.7%)	29 (38.2%)	30 (34.1%)	30 (34.1%)
Cognitive status, *n* (%)[a]					
Normal	199 (62.2%)	51 (69.9%)	42 (57.5%)	50 (56.8%)*	56 (65.1%)
MCI	98 (30.6%)	20 (27.4%)	23 (31.5%)	27 (30.7%)*	28 (32.6%)
Dementia	23 (7.2%)	2 (2.7%)	8 (11.0%)	11 (12.5%)*	2 (2.3%)
Neighborhood population density, mean (SD)	4625 (1648)	4573 (1515)	4996 (1956)	4264 (1271)	4709 (1747)
Neighborhood SES, mean (SD)[b]	0.18 (0.68)	-0.34 (0.37)	0.57 (0.33)*	-0.35 (0.47)	0.83 (0.47)*
Neighborhood Black segregation (vs others), Gi* statistic, mean (SD)	8.64 (6.83)	12.63 (4.27)	3.22 (4.54)*	3.71 (4.21)*	14.84 (4.61)*
Cognitive z-score, mean (SD)					
Episodic memory	-0.03 (0.94)	0.14 (0.90)	-0.06 (0.91)	-0.36 (0.92)*	0.18 (0.94)
Semantic memory	0.51 (0.70)	0.52 (0.67)	0.56 (0.70)	0.27 (0.69)*	0.72 (0.67)
Executive function	0.12 (0.61)	0.19 (0.61)	0.15 (0.60)	-0.15 (0.57)*	0.31 (0.57)
Spatial ability	0.28 (0.69)	0.29 (0.60)	0.37 (0.71)	0.10 (0.77)	0.37 (0.66)
Clinic sample (vs community), *n* (%)	69 (23.0%)	11 (15.7%)	15 (20.8%)	22 (25.9%)	21 (28.8%)
Number of visits, mean (SD)	5.2 (2.9)	5.7 (2.9)	4.8 (2.7)*	5.7 (2.9)	4.7 (2.9)*

Abbreviations: NSES, neighborhood socioeconomic status; SD, standard deviation; SES, socioeconomic status
[a]Comparisons employed using ordinal logistic regression with cognitive status as the outcome.
[b]Higher score, higher neighborhood SES.
*$p < 0.05$ in unadjusted logistic/linear regression (compared to higher segregation, lower SES neighborhoods).

ability over time. In sensitivity analyses removing those with dementia, the findings remained similar except that there was no longer an association between lower segregation-higher NSES neighborhoods and faster decline in spatial ability over time among NHWs (Table 6).

4 | DISCUSSION

We found that distinct combinations of neighborhood clustering of Black residents and NSES were associated with changes in episodic memory, although in nuanced ways, for Black study participants. Compared to Black individuals living in higher segregated-lower NSES neighborhoods, Black participants living in lower segregated-lower NSES neighborhoods and higher segregated-higher NSES neighborhoods had slower declines in episodic memory over time. Thus Black individuals living in higher segregated-lower NSES neighborhoods appeared to be at a disadvantage in episodic memory over time. These findings partially mirror those of Pohl et al., who examined cross-sectional associations between three segregation indices and memory, language, and visuospatial.[43] They found that Black participants living in segregated neighborhoods scored worse on language and memory. Irrespective of the participant's race/ethnicity, living in neighborhoods that were desegregated was associated with higher scores on the three cognitive domains. In the MESA cohort, Besser et al. also found that Black participants in segregated neighborhoods had steeper declines in processing speed.[19]

Our study findings indicate that Black participants benefited from living in neighborhoods with higher clustering of Black residents if NSES was high, or if there was a low clustering of Black residents and NSES was low. This speaks to the complicated and nuanced relationship between individual race, a proxy for social and life-course contextual experiences, residential segregation, and NSES. The complex fit between a person and their environment is part of Bronfenbrenner's social ecological theory.[21] Some individuals thrive in certain environments and others do not. In the case of our sample, Black participants

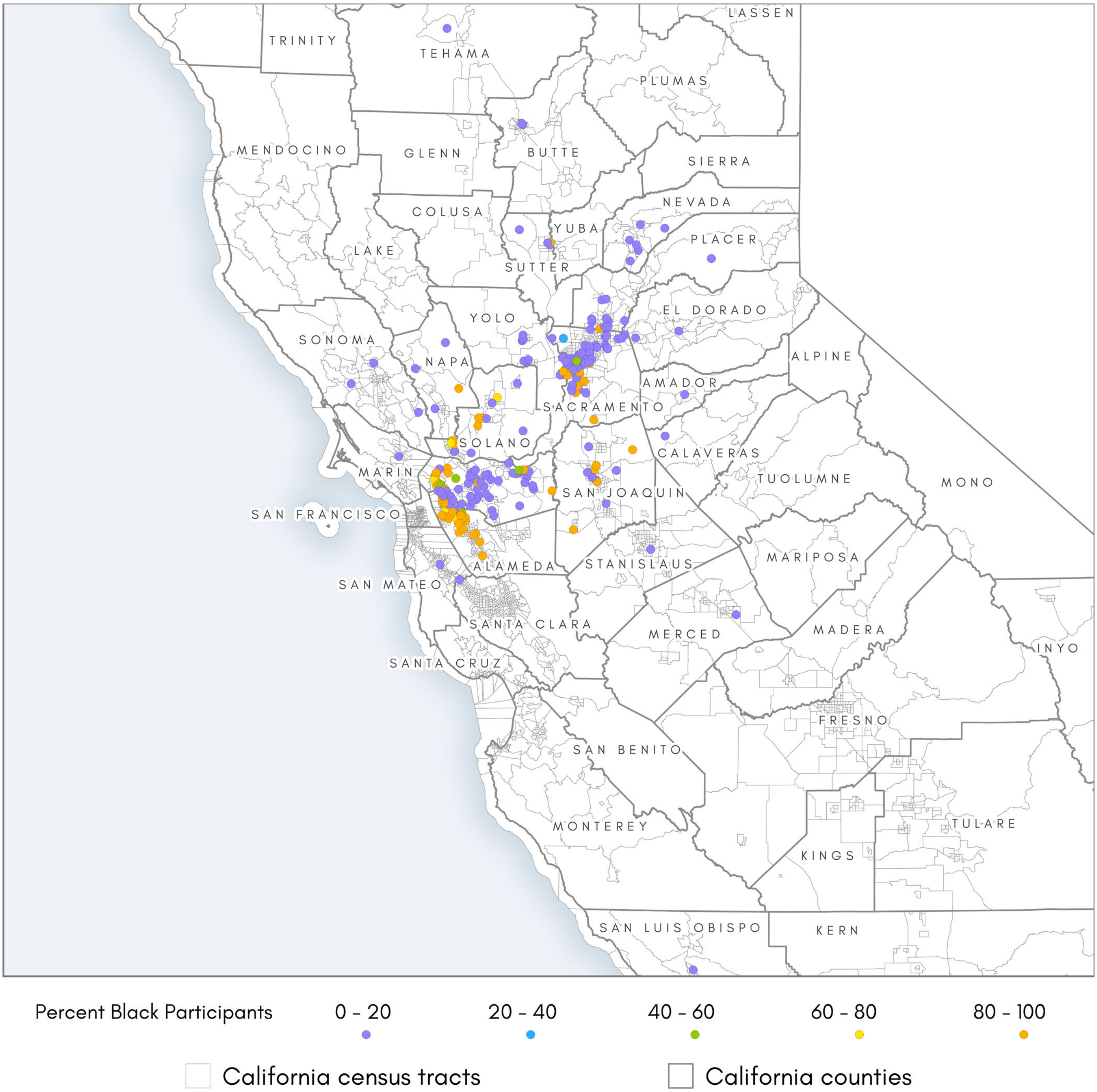

FIGURE 1 Percentage of Black residents in the census tract (points represent %).

surrounded by Black residents have better episodic memory over time if NSES is high.

This finding may partially be explained by the *density hypothesis*—that racially similar neighborhoods provide their residents with social capital and support and resources that may be associated with certain protective features for cognition.[44,45] Ethnic communities have been theorized to protect its members from social isolation, marginalization, discrimination, and prejudice, as well as put its residents in a better position to access social support and community resources. The theory may help us better understand the findings for Black participants in neighborhoods with a high clustering of Black residents. This may especially be the case when neighborhoods (and the individuals who live in them) have greater resources (NSES) to counterbalance the potentially negative aspects of segregated neighborhoods (e.g., higher policing). Using data from the Health and Retirement Study (HRS), Aneshensel and colleagues[46] showed that late middle-aged adults living in highly segregated Black communities had poor cognitive function at baseline; however, this was the case only if they had low education. In contrast, the highest level of cognitive functioning was among highly educated persons who lived in predominantly Black neighborhoods. Hutchinson and colleagues showed that Black mortality was lower among residents of predominantly Black neighborhoods in Philadelphia with high

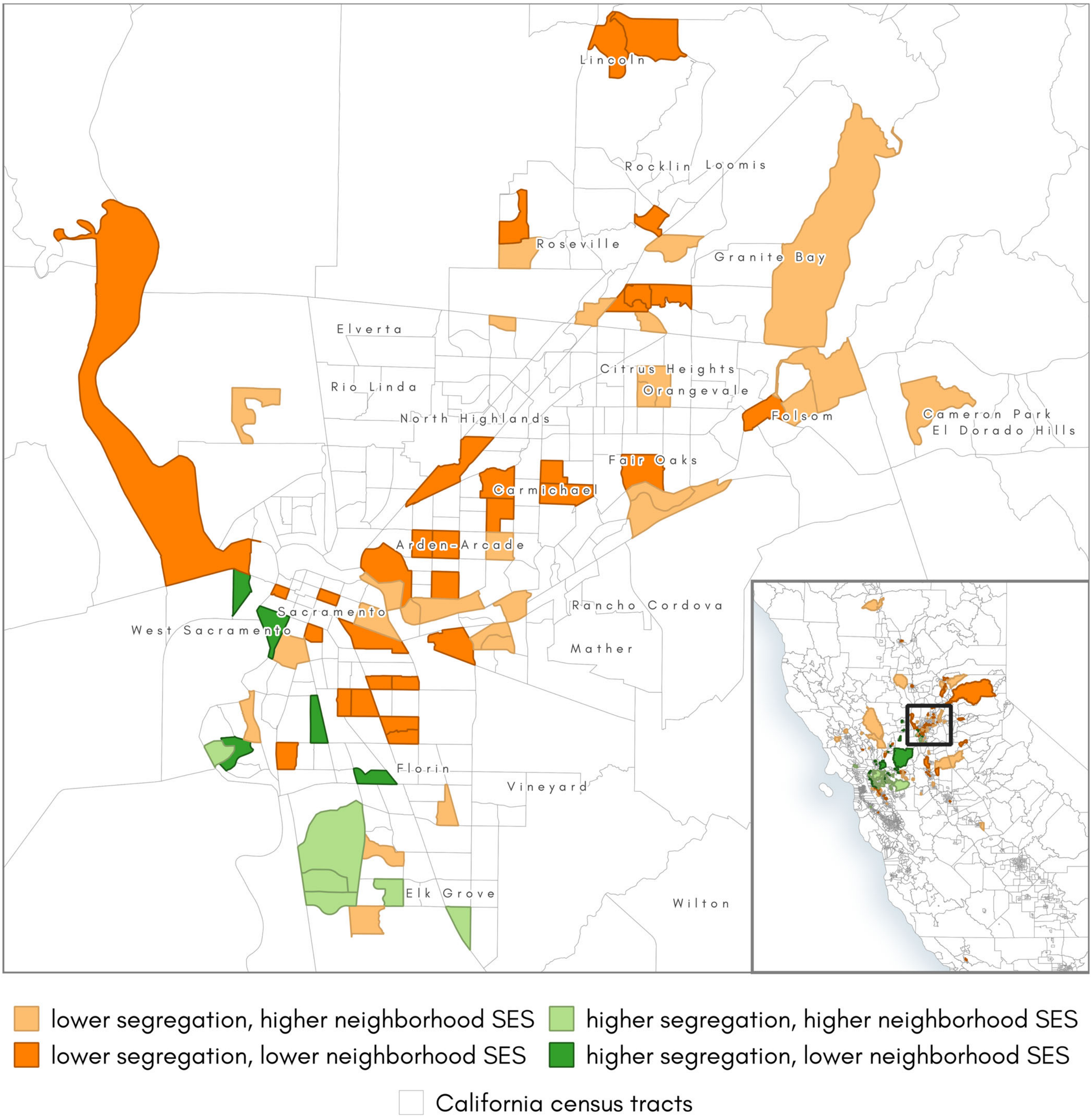

FIGURE 2 Spatial distribution of Sacramento neighborhood types according to level of Black segregation and neighborhood socioeconomic status. SES, segregation and neighborhood socioeconomic status

neighborhood social capital in comparison to Black residents living in predominantly White neighborhoods.[47] However, more research is needed to understand and replicate our results.

We found that when NSES was low, Black individuals who live in less segregated (e.g., more diverse) environments have slower episodic memory declines over time. Some research suggests that older adults may benefit from living areas that are racially/ethnically diverse. Although these neighborhoods may have lower SES and fewer resources, they may be characterized by diversity in race/ethnicity that provide opportunities for interacting with individuals from a variety of backgrounds and life experiences, which can be cognitively and socially stimulating. Population-based studies have shown that individuals in racially/ethnically diverse neighborhoods had lower risks for metabolic syndrome,[48] which is linked to cognitive outcomes and may serve as an underlying mechanism.

For our NHW participants, compared to those living in higher segregation-lower NSES neighborhoods, living in lower segregation-higher NSES areas was associated with faster decline in spatial

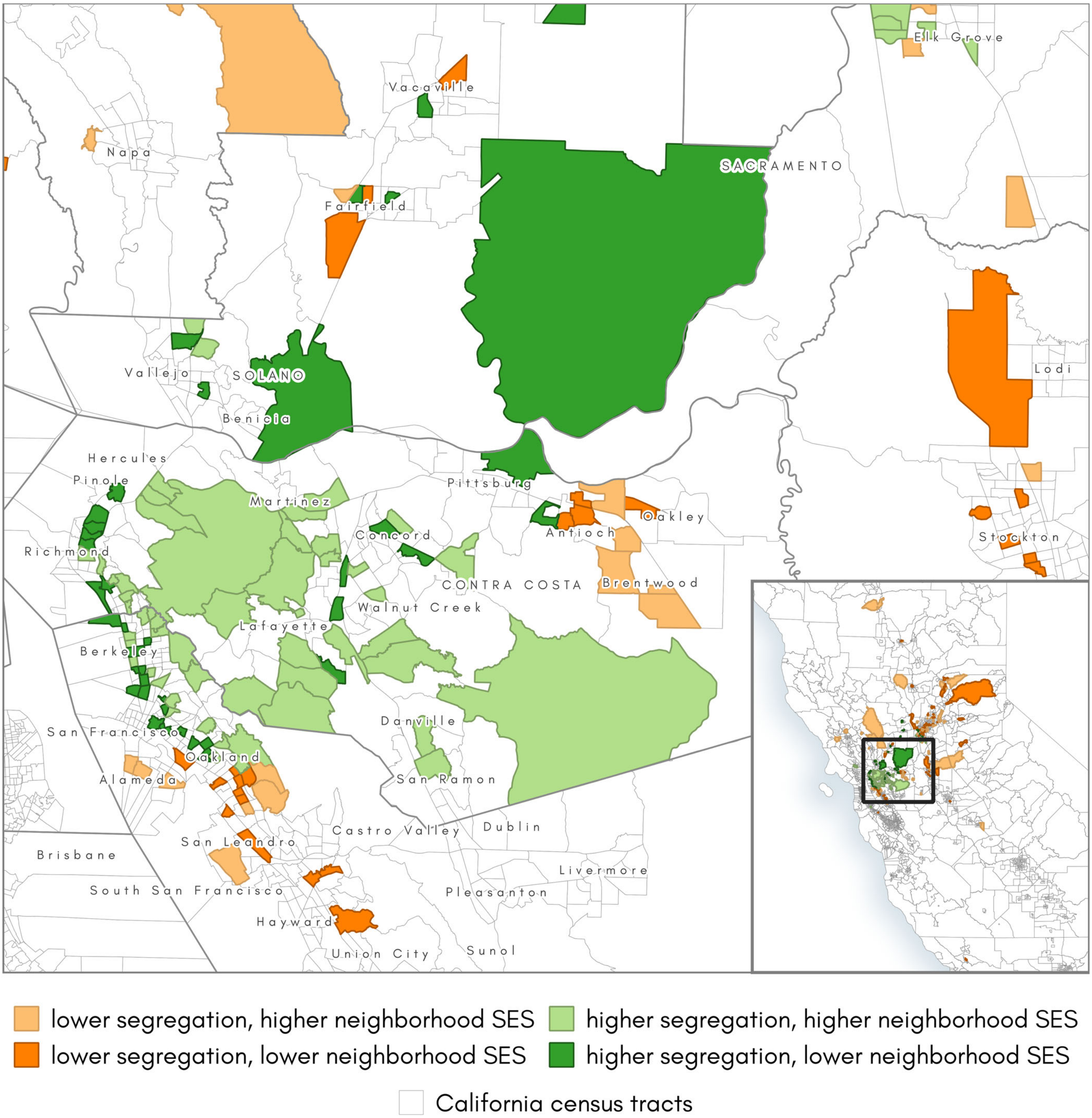

FIGURE 3 Spatial distribution of Bay Area neighborhood types according to level of Black segregation and neighborhood socioeconomic status. SES, segregation and neighborhood socioeconomic status

ability. One possibility is that the results are related to the test characteristics of the cohort shown in a previous study, indicating minimal racial/ethnic differences in baseline cognition, but steeper decline over time for NHWs.[49] The current study's results add more nuance to that work and suggest there is a complicated relationship between race, segregation, and NSES. It is not clear why this finding would be present only for spatial ability, however, and future work with a large study sample should replicate these results.

Study limitations include the possible lack of generalizability to other regions of the country and to individuals from other racial/ethnic minority groups (e.g., Latinos, Asian Americans). Differences in historical redlining, de jure and de facto discrimination, as well as immigration policies influence city growth and neighborhood characteristics. These factors change over time and are unique to every city/region contributing to present day differences in the East Bay and Sacramento, although we controlled for site in all analyses to address as much of the difference as possible.[50] Results from this study should be interpreted

TABLE 2 Association between neighborhood Black segregation and neighborhood socioeconomic status and cognition, stratified by race

Estimate and 95% CI[a,b]			Neighborhood Black segregation, neighborhood SES category (reference group: Higher Black segregation-lower NSES)		
Cognitive domain	**Race**	**Time period for estimate**	**Lower segregation-higher NSES**	**Lower segregation-lower NSES**	**Higher segregation-higher NSES**
Episodic memory	White	Baseline	0.04 (-0.36, 0.29)	-0.23 (-0.53, 0.08)	0.12 (-0.18, 0.41)
		Change over time[c]	-0.035 (-0.097, 0.026)	0.000 (-0.040, 0.041)	-0.009 (-0.055, 0.038)
	Black	Baseline	0.20 (-0.14, 0.54)	0.09 (-0.21, 0.38)	-0.08 (-0.43, 0.26)
		Change over time[c]	0.035 (-0.008, 0.079)	**0.052 (0.018, 0.086)**[**]	**0.059 (0.009, 0.108)**[*]
Semantic memory	White	Baseline	-0.08 (-0.38, 0.23)	-0.00 (-0.30, 0.29)	0.20 (-0.07, 0.46)
		Change over time[c]	-0.024 (-0.070, 0.022)	-0.002 (-0.043, 0.039)	-0.010 (-0.075, 0.055)
	Black	Baseline	0.25 (-0.06, 0.57)	0.00 (-0.30, 0.31)	-0.02 (-0.30, 0.26)
		Change over time[c]	-0.006 (-0.037, 0.025)	-0.003 (-0.028, 0.021)	0.013 (-0.012, 0.038)
Executive function	White	Baseline	-0.06 (-0.28, 0.17)	-0.20 (-0.43, 0.04)	0.04 (-0.18, 0.25)
		Change over time[c]	-0.048 (-0.104, 0.008)	0.007 (-0.039, 0.052)	-0.031 (-0.083, 0.022)
	Black	Baseline	0.28 (0.005, 0.54)	0.21 (-0.07, 0.49)	0.06 (-0.19, 0.31)
		Change over time[c]	-0.026 (-0.064, 0.001)	-0.020 (-0.46, 0.007)	-0.005 (-0.026, 0.017)
Spatial ability	White	Baseline	0.09 (-0.19, 0.36)	-0.04 (-0.31, 0.24)	0.00 (-0.27, 0.27)
		Change over time[c]	**-0.073 (-0.146, -0.000)**[*]	-0.000 (-0.043, 0.043)	-0.052 (-0.122, 0.018)
	Black	Baseline	0.26 (-0.18, 0.71)	-0.00 (-0.44, 0.43)	-0.00 (-0.36, 0.36)
		Change over time[c]	-0.052 (-0.127, 0.023)	0.024 (-0.047, 0.094)	0.028 (-0.035, 0.090)

Abbreviations: NSES, neighborhood socioeconomic status.
[a]Model controlled for age at baseline, sex, education (years), cognitive status at baseline, neighborhood population density, recruitment source, number of visits (to control for practice effects), and site.
[b]Model employed inverse probability weights to account for attrition/selection bias.
[c]That is Segregation-SES × time.
*$p < .05$.
**$p < .01$.
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with caution given that the mean education in our sample was quite high (15 years). There is a possibility that our findings are affected by self-selection, in which individuals with a certain level of cognition choose to live in a particular area. Moreover, we were unable to compare those who enrolled in the study versus those who did not, given the rolling enrollment of our cohort. Although we accounted for participant education and a variety of potential confounders in our models, it is possible that our findings are due to early life SES or place of birth, variables not measured in this study but that would be an important next step. Furthermore, we had addresses from one time point and could not account for residential tenure or longer-term exposures to residential segregation or NSES. In addition, we did not have data on neighborhood factors that could help explain our observed associations, including access to resources, social cohesion, crime, and safety, and these factors will be important to explore as potential mediators in future studies. Finally, census tracts as neighborhoods may not adequately capture how residents perceive and experience their "neighborhood." Future research on segregation and NSES should include other geographies (e.g., census block) as well as qualitative perceptions of neighborhoods. Studies with larger samples and that define neighborhoods using alternate boundaries (e.g., ½-mile around residence) might be able to further characterize segregation and its impact on cognitive trajectories.

Our study contributes to the literature in this area by including neighborhood level data (e.g., geocoding addresses and linking to U.S. Census data) on a well-characterized cohort followed up over a long period of time, using a psychometrically robust neuropsychological battery that encompasses several domains of cognition, and by incorporating a well-established, formal measure of segregation. In addition, we examined the combined influence of both segregation and NSES, variables that are related but also distinct. We controlled for a number of important potential confounders, including individual-level education. Given that certain neighborhoods, particularly in certain parts of the state and country, continue to be segregated, it is imperative that we understand the impacts it has on cognitive impairment for our growing older and diverse population. Neighborhood studies like the current one can inform interventions and policies to help redress the impacts of structural racism on historically disadvantaged and segregated neighborhoods.

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CONFLICT OF INTEREST STATEMENT

Author disclosures are available in the supporting information.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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