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Loneliness Moderates the Association between Neighborhood Disadvantage and Cognitive Function Among Older Adults

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Abstract

Objective. Neighborhood disadvantage has been linked to reduced cognitive performance and cognitive decline among older adults; however, potential moderators of this association, such as loneliness, have not been well studied. Therefore, the objective of the study was to examine associations between neighborhood disadvantage and cognitive function, and whether associations are moderated by self-reported loneliness. **Methods.** Data were analyzed from the Healthy Heart and Mind Study, a cross-sectional study with data collection ranging from October 2016 to January 2020 in New Castle County, DE and surrounding areas. The analysis included 136 older adults (36% male) with a mean age of 68.04. Neighborhood disadvantage was assessed using the Area Deprivation Index (ADI), which provided state and national rankings of neighborhood deprivation. Cognitive function was assessed with the Verbal Fluency Test (executive function), the Visual Reproductions Test (short- and long-term visuospatial memory), the Logical Memory Test (verbal memory), and Digit Span Forward and Backward (working memory). Loneliness was measured with the UCLA Loneliness Scale. Descriptive statistics were calculated and linear regression analyses were run, adjusted for age, sex, and education. **Results.** Results showed that higher state and national ADI scores (more disadvantage) were associated with worse short-term visuospatial memory. Loneliness moderated the relationship between national ADI scores and short-term visuospatial memory. **Conclusions.** Overall, our findings suggest that older adults living in more disadvantaged neighborhoods in and surrounding New Castle County, De may be susceptible to poor visuospatial memory performance, and the relationship may vary based on low or high self-reported loneliness. **Policy Implications.** Our findings suggest a need to increase exploration of the role of neighborhood factors in older adult cognitive functioning. Health policies focused on ameliorating individual-level risk factors for cognitive dysfunction and decline may need to be expanded to target neighborhood-level factors and the intersection of neighborhood, loneliness, and social ties.

Introduction

Neighborhood disadvantage, operationalized as poverty, educational level, income level, employment, and housing infrastructure within a neighborhood, has consistently been associated with negative cognitive health outcomes, including poorer cognitive test performance,[1] cognitive decline,[2,3] cortical thinning in Alzheimer's disease signature regions,[2] increased risk for cognitive impairment and dementia,[3] and decreased brain volume (e.g., hippocampal and total brain volume.[4,5] In particular, using the area deprivation index (ADI), a metric of socioeconomic disadvantage within a neighborhood, which includes Census data about income, education, employment, and housing quality,[6] neighborhood disadvantage has been reliably linked to negative cognitive performance outcomes. For example, a cross-sectional study of non-cognitively impaired middle-aged and older adults showed that residing in a disadvantaged neighborhood was associated with worse cognitive performance in the domains of executive function, verbal learning, and delayed recall.[1] Within a population-based cohort study of older adults, researchers observed that higher levels of neighborhood disadvantage (national and state) were associated with greater odds of mild cognitive impairment (MCI).[3] Similarly, higher risk for progression to dementia in cognitively unimpaired participants was associated with every decile increase in national and state ADI.[3]

A guiding theoretical framework for examining neighborhood context as a correlate of cognitive functioning is Bronfenbrenner's socio-ecological model.[7] This model was proposed to help contextualize the various environmental systems that impact human development. Bronfenbrenner posited that it is not only the immediate settings that impact human development, but the larger social contexts in which those settings reside. Moreover, the interaction between a person and the environment is critical to understanding human development. Kilanowski later applied the socio-ecological model to health, wherein she argued that health is affected by the interaction between the characteristics of the individual, the community, and the environment, with the environment encompassing physical, social, and political components.[8] Lastly, this inquiry is guided by the Healthy People's social determinants of health framework, which posits that where people are born, live, learn, work, play, worship, and age affects a wide range of health outcomes and risks.[9] It is from these contextual viewpoints that we consider the role of neighborhood as a distinct and necessary component of understanding manifestations of cognitive function among older adults.

Considering the growing evidence that neighborhood disadvantage influences cognitive performance and promotes cognitive decline, it is critical to understand which variables modify this association. One understudied potential moderator of this relationship is loneliness, a common complaint in older adulthood[10] that independently contributes to cognitive decrements.[11,12] Disadvantaged areas tend to have higher loneliness levels than advantaged areas, although the specific determinants are not well understood. Scant research has shown that increased residential density and reduced walkability of neighborhoods,[13] as well as quantity and quality of green space,[14] partly contribute to greater loneliness among older adults. Interestingly, one study of adults aged 50 and older indicated that loneliness was higher in the most deprived areas independent of individual-level factors such as demographic factors, social engagement and health.[15] A recent analysis and conference proceeding examined the relationship between neighborhood disadvantage, as measured by the ADI, loneliness, and depressive symptoms in a sample of older adults enrolled in the Baltimore Study of Black Aging. Findings showed that higher ADI scores were associated with greater self-reported loneliness and depressive symptoms.[16]

In sum, a growing body of literature suggests that greater neighborhood disadvantage is associated with poorer cognitive functioning, and there is emerging evidence to support the notion that the association may be more pronounced among individuals who self-report loneliness; however, we are not aware of any studies that have examined these linkages together

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among older adults. To address this gap, the current study explored two specific objectives. First, it examined the cross-sectional association between neighborhood disadvantage and domains of cognitive function: executive function, short- and long-term nonverbal and verbal memory, and working memory. It was hypothesized that older adults who reside in neighborhoods with greater disadvantage would perform worse on these measures. The second objective examined whether self-reported loneliness moderates the cross-sectional associations between neighborhood disadvantage and cognitive performance in the same domains. It was hypothesized that the inverse association between neighborhood disadvantage and cognitive function would be more pronounced among lonely older adults.

Methods

Participants

Participants were drawn from a sample of 165 community-dwelling, cognitively normal non-Hispanic Black and White adults aged 60 years and older enrolled in the Healthy Heart and Mind Study between October 2016 and January 2020 in Newark, Delaware, and surrounding New Castle County communities. The overarching aims of the Healthy Heart and Mind Study were to examine associations among subclinical cardiovascular disease, brain pathology, and cognitive functioning in older adults and to determine whether these associations varied by race. Psychosocial, sociodemographic, and behavioral correlates were also assessed. Participants were recruited using community-based strategies, including newspaper advertisements, flyers, email announcements, health fairs, community outreach events, and word-of-mouth referrals. Prospective participants completed an initial telephone prescreening followed by in-person eligibility assessments across two study visits.

Eligibility screening excluded individuals reporting a history of clinical cardiovascular disease (e.g., angina, myocardial infarction, arrhythmias, valvular disease, heart failure, or coronary revascularization), renal, hepatic, pulmonary, hematological, or neurological disease (e.g., stroke, transient ischemic attack, epilepsy, multiple sclerosis, Parkinson's disease), HIV/AIDS, chemotherapy or radiation treatment within the past year, type 1 diabetes or uncontrolled type 2 diabetes (HbA1c > 7), severe hypertension (systolic blood pressure ≥ 180 mmHg or diastolic blood pressure ≥ 110 mmHg), anticoagulant use, severe psychiatric disorder (e.g., schizophrenia), heavy alcohol use (>14 drinks/week), MRI contraindications, severe head injury involving loss of consciousness (>30 minutes), or fewer than eight years of formal education. Further details regarding HHM study participants and exclusion criteria have been previously reported.[5]

Neighborhood disadvantage was operationalized and assessed with the area deprivation index (ADI). The ADI is a scientifically validated, census-based mapping tool that measures neighborhood socioeconomic disadvantage at the census block group level, based on income, education, employment, and housing quality. The ADI is available for customized local-level mapping and free download for every neighborhood in the U.S. through the Neighborhood Atlas, which computes ADI rankings from residential addresses for every neighborhood in the U.S.[6,17] State ADI scores range from 1 to 10 (deciles) and national ADI scores range from 1 to 100 (percentiles) with higher scores indicating greater neighborhood disadvantage.

Perceived loneliness was assessed using the UCLA Loneliness Scale (Version 3), a 20-item measure of perceived loneliness and satisfaction with one's social relationships Participants rated

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how often each statement described their experience (e.g., “How often do you feel alone?”) on a 4-point scale ranging from 1 (never) to 4 (often). Positively worded items (1, 5, 6, 9, 10, 15, 16, 19, and 20) were reverse-scored, and all items were summed to create a total loneliness score. Scores ranged from 20 to 80, with higher scores indicating greater loneliness.[18]

Cognitive Performance Measures

The Visual Reproduction Test, a subtest of the Wechsler Memory Scale-IV (WMS-IV), measured visuospatial memory.[19] Participants were shown a total of five printed cards with geometric designs of increasing complexity for 10-seconds each. The final two cards were the most complex with two designs printed on each card. After each 10- second exposure, the geometrical designs were covered, and participants were asked to immediately draw what they remembered of the design(s) on the card for immediate recall. Delayed recall of the figures was obtained after approximately 30 minutes. During the delayed task, participants were not shown the cards again but had to draw the card designs from memory. Scores were based on the number of correctly drawn figures, and total correct responses were generated for both immediate and delayed recall, such that higher scores reflected better recall.

Logical Memory I and II, subtests of the Wechsler Memory Scale-IV (WMS-IV), measured short-term and long-term verbal memory using immediate and delayed recall conditions.[18] During the Logical Memory I immediate condition, a story was narrated aloud. The participant then recalled verbatim what they remembered to the examiner. Participants then listened to a longer second story then recalled verbatim what was remembered. The Logical Memory II delayed condition was administered approximately 20 minutes later. During the delayed condition, participants were instructed to recall verbatim details of the two stories from the immediate condition. The total number of correct responses was recorded for each condition, such that the higher scores reflected better recall.

The Digit Span subscale from the Wechsler Adult Intelligence Scale-IV (WAIS-IV) measured memory span and working memory.[20] The test consists of two parts: Digit Span Forward and Digit Span Backward. During these tasks, random number sequences of increasing length are presented verbally to the participant at the rate of one number per second. In Digit Span Forward, the participant repeated the same number sequence after the examiner. In Digit Span Backward, the number sequences were repeated in reverse order. The tasks were discontinued when the participant failed both sequences of any given set. The number of correct sequences from each task was scored. Higher scores reflected better memory span and working memory performance.

The Verbal Fluency subtest from the Delis-Kaplan Executive Function System (D-KEFS) measured executive functioning.[21] During the Letter Fluency condition, participants were instructed to generate as many words as possible beginning with the letters F, A, and S, with 60 seconds allotted for each letter. During the Category Fluency condition, participants generated as many words as possible belonging to the categories of animals and boys' names, with 60 seconds allotted for each category. During the Category Switching condition, participants alternated between naming fruits and furniture items for 60 seconds. Responses were recorded and scored according to standardized administration procedures. Total correct responses were recorded for each condition, with higher scores reflecting better cognitive flexibility and executive functioning.

For analysis, we utilized raw scores (i.e., total correct responses) for each cognitive performance

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measure and its conditions/tasks (e.g., immediate/delayed, forward/backward). Raw scores were used in the analyses as continuous variables.

Procedure

The Healthy Heart and Mind Study protocol included a telephone pre-screening to determine initial eligibility, followed by two in-person study visits completed within a 14-day period. During Visit 1, participants completed a comprehensive health screening conducted by a nurse practitioner at the University of Delaware's Nurse Managed Primary Care Center in Newark, DE. Next, participants completed self-report demographic questionnaires; residential addresses were collected as part of these questionnaires and used to derive state and national ADI scores. Participants also completed psychosocial and health behavior measures, including the UCLA Loneliness Scale, which were administered by trained research staff. A neuropsychological test battery was then administered by trained research staff to assess cognitive domains including attention, executive functioning, and memory. Visit 2 consisted of a fasting blood draw, vascular imaging, and magnetic resonance imaging; however, those data were not included in the current analysis. Participants received a $50 gift card upon completion of each study visit. Following completion of all study procedures, participants were debriefed. The study protocol was approved by the Institutional Review Board at the University of Delaware, and all participants provided written informed consent prior to participation.

Statistical Analyses

Descriptive statistics used to characterize the sample (frequencies, means, standard deviations, and ranges) were computed using IBM SPSS Statistics Version 30. Linear regression analyses were conducted using Hayes' PROCESS macro for SPSS (Version 5.0), Model 1, to examine whether loneliness moderated the association between ADI and cognitive outcomes. Age, sex, and educational attainment were included as covariates in all moderation models.

Results

Descriptive Statistics

The analytic sample consisted of 136 participants who completed both study visits and had complete data for study variables of interest. Of the original HHM Study sample (N = 165), 29 participants were excluded due to missing or incomplete address data required for ADI determination. No significant differences were observed between included and excluded participants with respect to age, sex, race, or educational attainment. Within the analytic sample, participants had a mean age of 68.04 years (SD = 5.97), and 36% were male. Approximately 45% identified as Black or African American. The sample had a high level of secondary and post-secondary educational attainment, with 78.6% (n =107) of participants having attained at least a high school diploma, and 52.9% (n = 72) having attained at least a partial college education, a college degree, or specialized professional training. Mean self-reported loneliness, as assessed by the UCLA Loneliness Scale, was 35.66 (SD = 10.49) reflecting a moderate degree of perceived loneliness. Descriptive statistics for cognitive measures and all other variables are included in Table 1.

Table 1. Distribution of Sample Characteristics (N=136)

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	N (%)	Mean	SD	Range
Age, years	136 (100%)	68.04	5.97	60 - 94
Sex				
Female	87 (64%)			
Male	49 (36%)			
Education				
some college or higher	72 (52.9%)			
high school grad	35 (25.7%)			
less than high school	29 (21.3%)			
ADI state score	136 (100%)	3.96	32.69	1 - 10
ADI national score	136 (100%)	28.49	19.34	4 - 94
UCLA Loneliness Scale	91 (66.91%)	35.66	10.49	21 - 62
Logical Memory I	136 (100%)	31.68	7.01	16 - 46
Logical Memory II	136 (100%)	19.25	0.56	3 - 34
Visual Reproduction I	133 (97.80%)	33.04	5.02	23 - 43
Visual Reproduction II	135 (99.26%)	25.54	8.09	0 - 43
Digit Span forward	136 (100%)	10.76	2.39	5 - 16
Digit Span backward	136 (100%)	8.48	2.27	4 - 14
Letter Fluency	136 (100%)	40.68	10.63	18 - 71
Category Fluency	136 (100%)	39.51	8.08	22 - 58
Category Switching	136 (100%)	12.96	2.58	7 - 20

The mean state ADI decile score was 3.96, indicating that participants, on average, lived in neighborhoods characterized by relatively lower levels of socioeconomic disadvantage at the state level. However, 25% of participants had a state ADI score of 5 or greater, indicating that their neighborhoods were among the most disadvantaged within the state. The map in Figure 1 illustrates the distribution of neighborhood disadvantage within Delaware. The mean national ADI percentile score for participants' neighborhood disadvantage at the national level was 28.49, which reflects even less relative disadvantage when participants' neighborhoods are compared to all U.S. neighborhoods versus Delaware neighborhoods.

Figure 1. Neighborhood Atlas Area Deprivation Map for the State of Delaware

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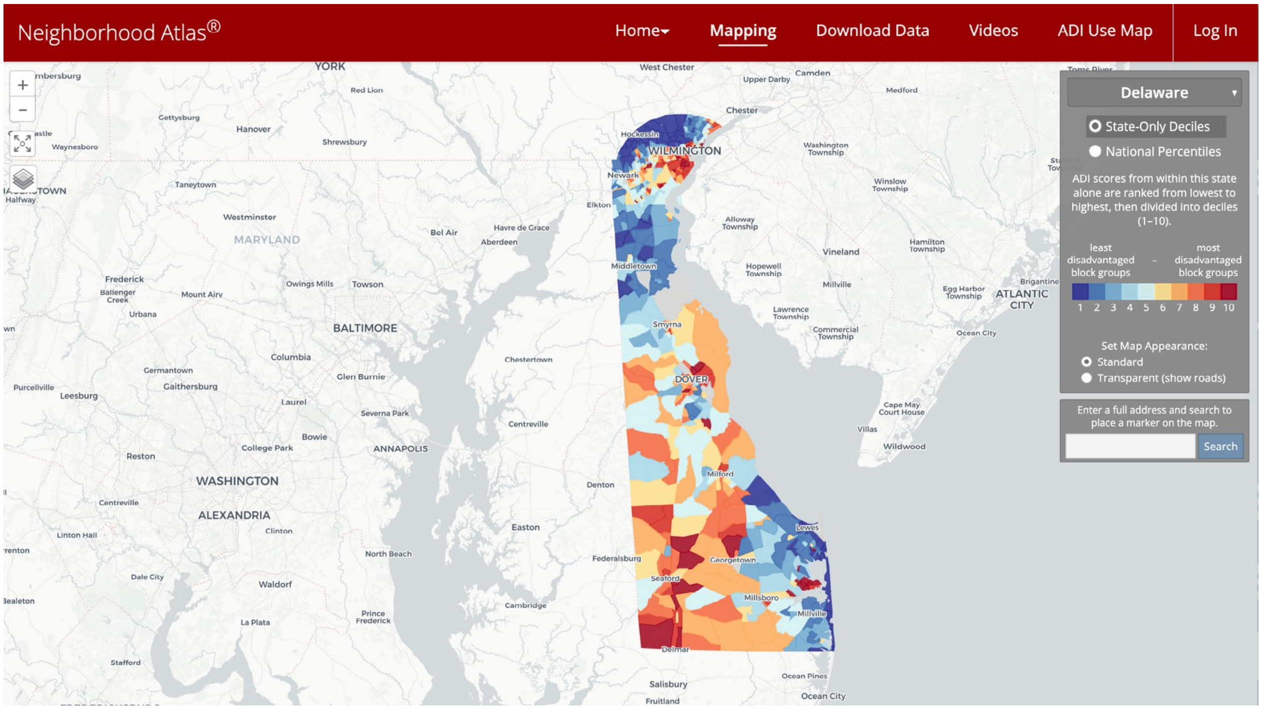

ADI State, Loneliness, and Cognitive Function Associations

Regression analyses indicated that the overall model predicting Visual Reproduction II (delayed recall) from state ADI scores and loneliness scores was significant, $F(6, 83) = 3.89$, $p = .002$, explaining 21.9% of the variance ($R^2 = .22$). State ADI was a significant predictor of Visual Reproduction II (delayed recall) performance ($b = -1.97$, $SE = 0.94$, $p = .039$), indicating that higher neighborhood disadvantage was associated with poorer delayed visual reproduction performance within this memory domain. The state ADI × loneliness interaction was also significant ($b = 0.05$, $SE = 0.02$, $t = 2.07$, $p = .042$, 95% CI [0.002, 0.098]), suggesting that the association between ADI state and Visual Reproduction II (delayed recall) performance varied as a function of loneliness. However, probing of the interaction showed that state ADI scores were not significantly associated with Visual Reproduction II (delayed recall) performance at low, moderate, or high levels of loneliness (all $p > .05$), and Johnson–Neyman analyses indicated no regions of significance within the observed range of the moderator. No other overall models predicting cognitive performance in the remaining domains were significant. Likewise, no other state ADI × loneliness models yielded significant relationships with cognitive measures.

National ADI, Loneliness, and Cognitive Function Associations

Regression analyses also indicated that the overall model predicting Visual Reproduction II (delayed recall) from national ADI scores and loneliness scores was significant, $F(6, 83) = 4.19$, $p = .001$, explaining 23.3% of the variance ($R^2 = .23$). National ADI score was a significant predictor of Visual Reproduction II performance ($b = -0.27$, $SE = 0.11$, $p = .019$), indicating that higher national-level neighborhood disadvantage was associated with poorer delayed visual reproduction performance. No other overall models predicting cognitive performance in the

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remaining domains were significant. While loneliness scores did not have a significant main effect (b = -0.16, SE = 0.12, p = .169), the national ADI x loneliness interaction was significant (b = 0.007, SE = 0.003, t = 2.42, p = .018, 95% CI [0.001, 0.013]), indicating that the association between national ADI scores and Visual Reproduction II (delayed recall) performance also varied as a function of loneliness.

Probing of the interaction for conditional effects showed that the relationship between ADI national and Visual Reproduction II (delayed recall) performance differed across levels of loneliness. Specifically, at lower levels of loneliness (loneliness score = 26), the association between national ADI and Visual Reproduction II (delayed recall) performance was negative and approached significance (b = -0.089, SE = 0.048, t = -1.87, p = .065, 95% CI [-0.185, 0.006]). At moderate levels of loneliness (loneliness score = 32), the association was weaker and non-significant (b = -0.047, SE = 0.038, t = -1.24, p = .218, 95% CI [-0.123, 0.028]). At higher levels of loneliness (loneliness score = 48.44), the association shifted toward a positive direction but remained non-significant (b = 0.069, SE = 0.047, t = 1.45, p = .150, 95% CI [-0.025, 0.163]).

Johnson–Neyman analyses further clarified this interaction by identifying regions of significance. The association between national ADI and Visual Reproduction II (delayed recall) performance was statistically significant when loneliness was low (i.e., loneliness scores ≤ 23.98; b = -0.104, SE = 0.052, p = .05) and again when loneliness was high (i.e., loneliness scores ≥ 58.87; b = 0.142, SE = 0.071, p = .05), but not statistically significant across moderate levels of loneliness (approximately 23.98 < loneliness scores < 58.87). Specifically, greater neighborhood disadvantage was significantly associated with worse delayed recall, among older adults with lower levels of loneliness and significantly associated with better delayed recall among older adults with higher levels of loneliness. This indicates that the relationship between neighborhood disadvantage and Visual Reproduction II (delayed recall) performance is not constant, but instead emerges primarily at the extremes of loneliness. These findings are illustrated in the Figure 2 interaction plot. No other moderation models yielded significant effects on cognitive performance.

Figure 2. Interaction Plot Illustrating National ADI x Loneliness Predicting Visual Reproduction II Performance

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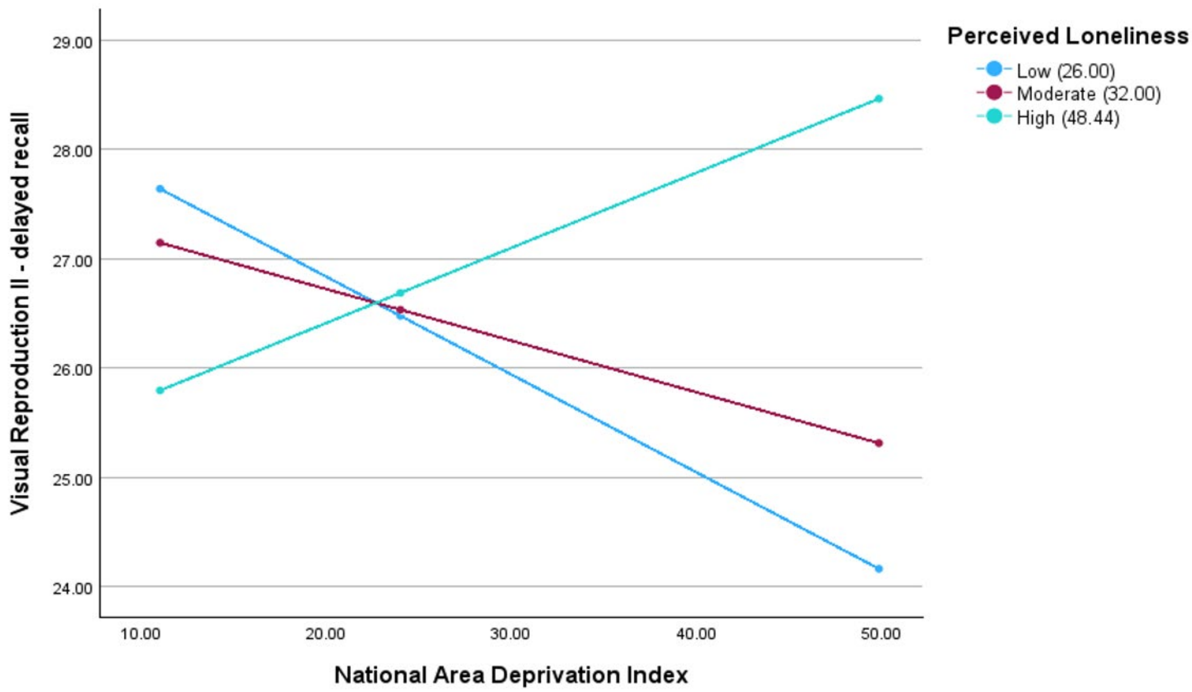

Discussion

The objectives of this study were 1) to examine cross-sectional associations between neighborhood disadvantage, as operationalized by state and national ADI scores, and cognitive performance in the domains of visuospatial memory, verbal memory, working memory, and executive function, and 2) to examine whether self-reported loneliness moderates these associations. Analyzing data from 136 older adults residing in the New Castle County, DE area, results showed that greater neighborhood disadvantage at both the state and national levels was associated with poorer delayed visuospatial memory. There were no significant associations between neighborhood disadvantage and immediate visuospatial memory, immediate and delayed verbal memory, working memory, or executive function. Additionally, self-reported loneliness moderated the association between neighborhood disadvantage at the national level and delayed visuospatial memory. That is, the relationship between neighborhood disadvantage and delayed visuospatial memory was significant when loneliness was low, non-significant at moderate levels of loneliness, and significant when loneliness was high.

Significant, positive associations between state- and national-level neighborhood disadvantage and delayed visuospatial memory are consistent with prior research with older adults, which showed that area-level deprivation is associated with lower cognitive performance, even after adjusting for individual-level socioeconomic variables such as education.[22,23] Other studies have reported a similar pattern of findings with other domains of memory,[2,24] wherein verbal memory typically yields significant findings; in our study, only visuospatial memory was significant. Visuospatial memory is the ability to retain and process an object's identity and spatial location, and is a critical ability needed for many daily tasks. It is complex, incorporating mechanisms such as perceptual processes and working memory functions,[25] If living in a disadvantaged

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neighborhood negatively influences this cognitive domain, reduced ability to remember and identify an object and its spatial location could be very problematic in under-resourced or unsafe neighborhoods. Further research is needed to determine whether this domain in particular is particularly sensitive to deprived environments and whether reduced visuospatial memory performance affects older adults' ability to navigate problematic built environments. Furthermore, it is plausible that null findings for the remaining cognitive domains were due to lack of sensitivity of the other cognitive performance measures to detect any influence of neighborhood disadvantage. Also potentially driving null findings is the reality that, while there was variability in disadvantage within the sample, most participants had relatively low levels of neighborhood disadvantage as 75% did not reside in deprived neighborhoods.

Regarding the counterintuitive finding that lesser loneliness may strengthen the positive relationship between neighborhood disadvantage and long-term visuospatial memory, and greater loneliness may reduce the positive relationship, the rationale is not clear. The nascent literature on neighborhood disadvantage and loneliness among older adults has shown trends for a positive association between the two variables, such that individuals living in more deprived neighborhoods are more likely to self-report a lonely existence.[13,14] Our study results support the counternarrative that being lonely in a disadvantaged neighborhood may be protective. In the absence of a body of literature to support this finding, it is possible that remaining isolated from surrounding deprivation may have some protective influence. Inversely, having social ties and/or support in a deprived neighborhood may be harmful for some individuals if those ties are not safe or beneficial. Recent work in the area has confirmed that social factors can reduce or eliminate the observed associations between deprived neighborhood conditions and poor health outcomes,[26,27] but our findings suggest there may be nuance to this relationship. Adding further complexity, patterns of social ties and support that may influence these relationships vary by race/ethnicity. Past research shows that Black and White adults are similar with regard to proximity of social networks, but Black adults have smaller networks, more contact with network members, and more family members in their networks.[28] While we did not measure social ties or support in this study, we did not find racial differences in self-reported loneliness. Indeed, future work that examines these relationships should consider the nature of individuals' relationships within the neighborhood, whether those relationships are protective or harmful, and perceived benefits of social ties and support. Moreover, future studies should incorporate measurement of subjective perceptions of the neighborhood Indeed, future work that examines subjective perceptions of the neighborhood to promote understanding of the influence of neighborhood disadvantage.

This study has several strengths. Primarily, this study contributes to the early stages of literature exploring the moderating role of loneliness as it relates to neighborhood disadvantage and cognitive functioning. Second, this study leveraged data from participants from the Delaware area, which is particularly important as it is projected that by 2030, Delaware's older adult population, aged 60 and older, will make up 28.4% of the state's population.[29] Third, this study included a comprehensive battery of neuropsychological measures tapping into a breadth of cognitive domains. Lastly, our sample included a relatively diverse sample of older adults (36% male, 45% Black/African American) which increases the generalizability of our findings to other Delawareans.

Study Limitations

Although our study revealed interesting findings about cross-sectional associations between neighborhood disadvantage, loneliness, and cognitive function among older adults, a few study limitations should be noted. This study explored objective neighborhood disadvantage with a single index of deprivation. Additional studies should examine other objective characteristics of the neighborhood as well as subjective perceptions of neighborhood quality and other characteristics (e.g., physical built disorder, social cohesion, etc.). Inclusion of both objective and subjective characteristics of the neighborhood has implications for improved understanding of neighborhood-related loneliness and cognitive performance. Next, this study was cross-sectional with a limited sample size. Longitudinal research with larger sample sizes is needed to confirm the reliability of these linkages. Lastly, due to the composition of our sample (relatively well educated) and the geographic setting (urban/suburban), findings would not generalize to more diverse, severely disadvantaged, or rural settings within or outside of the U.S.

Policy Implications and Conclusions

As loneliness is increasingly recognized as a public health issue, particularly among older adults, understanding the influential role of loneliness on the relationship between neighborhood and cognitive function will be critical to disentangling its impacts on healthy aging. For example, research points toward the investment in policy level mental health and welfare programs that support health behaviors, activity patterns, and social engagement that protect health and well-being.[30] Further research is warranted exploring the associations among neighborhood, loneliness, and cognitive function, to support the development of interventions, resources, and policies that can help reduce loneliness and encourage neighborhood-based social ties among older adults.

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