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Research Article

Associations of Neighborhood Walkability and Walking Behaviors by Cognitive Trajectory in Older Adults

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Abstract

Background and Objectives: Lawton's Ecological Model of Aging suggests that associations between environment and mobility differ based on individual factors such as cognitive decline.

Research Design and Methods: Virtual walkability audits were conducted within 1/8 mile of residences of older adults (n = 545; average age = 82; 57% female; 33% Black) who had been enrolled in the Health, Aging, and Body Composition (Health ABC) cohort for 10 years. The primary outcome was self-reported walking in past week and the secondary was mobility disability, self-reported difficulty to walk ¼ mile. Linear mixed models of general cognitive function over the prior 10 years calculated participant-specific slopes; those below 0 were cognitive decliners. Logistic regression models, adjusted for demographics and neighborhood socioeconomic status, tested associations between each walkability variable and each mobility outcome. Interaction terms between walkability and cognitive status were tested and walkability analyses stratified on cognitive status where p for interaction < .2.

Results: In the sample, 57.4% reported walking, 24.2% reported mobility disability, and 51% were cognitive decliners. Sidewalk quality was related to walking in cognitive maintainers; slope was related in decliners. Mixed land use (odds ratio [OR] = 1.61; 95% confidence interval [CI]: 1.12, 2.30) and senior residence (OR = 2.14; 95% CI: 1.27, 3.60) were related to greater walking, regardless of cognitive status. Mixed land use was related to less mobility disability in decliners and abandoned properties were related to greater mobility disability in maintainers.

Discussion and Implications: Policy-level interventions targeted at walkability, including improved sidewalk quality and increasing mixed land use could support walking in older adults, regardless of cognitive status.

Keywords: Cognitive status, Mobility, Person–environment fit, Walkability audit

Background and Objectives

Age-related mobility declines limit an individual's independence and well-being. Environmental barriers are increasingly recognized as barriers to mobility and outdoor walking behaviors. However, several reviews (Barnett et al., 2017; Rosso et al., 2011; Yen et al., 2014) have found that results have been inconsistent, with many studies failing to find associations for both objective and subjective markers of walkability. These inconsistencies may be due, in part, to differences in the underlying health and functional status of samples, as individual characteristics may modify vulnerability to environmental influences (Clarke & Nieuwenhuijsen, 2009; Rosso et al., 2011). If environmental influence is stronger for some subgroups of individuals, analyses that do not take into account this differential vulnerability could obscure any real associations.

Lawton's Ecological Model of Aging posits that as age-related impairments occur, the range of environmental complexity that can be tolerated by an individual narrows (Lawton & Nahemow, 1973). Therefore, consideration of interactions between individual and environmental characteristics, or the person–environment fit, is key to understanding mobility. Cognitive function is likely an important personal characteristic that determines fit with the environment. Community environments present many challenges that require intact cognitive function to successfully navigate them (Patla & Shumway-Cook, 1999). Cognitive decline is associated with risk for mobility declines (Tolea et al., 2016; Verghese et al., 2002, 2007), while Alzheimer's disease and cognitive impairment are associated with reduced out of home mobility (Barnes et al., 2007; James et al., 2011; Wahl et al., 2013; Wettstein et al., 2014, 2015).

Based on the Ecological Model, we aimed to determine whether cognitive function trajectory was a determinant of the association between environmental walkability and community mobility outcomes. We hypothesized that in the presence of cognitive decline, individuals are less equipped to deal with environmental challenges, increasing risk for community mobility limitations. We tested this in a cohort of older adults using measures of neighborhood walkability derived from Google Street View, longitudinal trajectories of cognitive performance, and measures of mobility performance and capacity. Our hypothesis was that associations between greater walkability and higher mobility would be strongest for individuals with declining cognitive function, as according to the Ecological Model, this group would be most vulnerable to environmental influences on mobility.

Research Design and Methods

Sample

The Health, Aging, and Body Composition (Health ABC) Study is a longitudinal cohort study that enrolled 3,075 community-dwelling, Black and White adults aged 70–79 in Pittsburgh and Memphis in 1997–1998. Men and Black participants were oversampled in an attempt to recruit equal numbers of men and women and of Blacks and Whites at both sites. The original purpose of the Health ABC was to assess the role of body composition in risk for mobility disability. Therefore, all participants had to be free of self-reported difficulties with activities of daily living (ADL), climbing 10 steps and/or walking ¼ of a mile at baseline. Participants who attended the 2006–2007 clinic visit in Pittsburgh (n = 1,035) and who still lived in the greater Pittsburgh area, including urban and suburban areas, and who had a valid address available (n = 745) were included in the neighborhood substudy. Participants were excluded from analyses if cognitive status could not be calculated (see below; n = 67), or if mobility disability (n = 68) or gait speed (n = 65) were missing. Our analytic sample was n = 545.

Participants in our analytic sample were less likely to be Black (p < .001) and to have lower education (p < .001), diabetes (p < .001), hypertension (p = .04), or mobility disability (p < .001) compared to excluded individuals. Included participants were also more likely to report walking in the past week (p = .002), were on average younger (p = .03), had higher Modified Mini-Mental State (3MS) scores (p < .001), slower decline in 3MS scores (p < .001), faster gait speed (p = .002), and came from neighborhoods with higher socioeconomic status (nSES) (p < .001). There were no differences in gender or marital status. See Supplementary Table 1 for more details.

All participants in Health ABC provided written informed consent at baseline and protocols were approved by local institutional review boards. Data are available upon request.

Neighborhood Walkability

A modified Active Neighborhood Checklist (Hoehner et al., 2007) was applied to Google Street View images of participants' residential neighborhoods (Harding et al., 2020). Items for residence characteristics were added (Clarke, 2014). As mobility disability was assessed for a distance of ¼ mile, virtual audits were conducted for 1/8th mile in either direction from the participants' homes to match a ¼ mile out and back walk. Google Street View images were first collected in 2007; therefore, images from 2007 or the earliest available date were used. The majority (n = 454, 83.3%) of participants had Google Street View images from 2007. Of the remaining participants, most had images from 2008 (n = 40, 7.3%) and the remainder had images from 2009 to 2018 (n = 51, 9.4%).

Walkability variables were chosen based on interrater reliability (Harding et al., 2020), prevalence, and theoretical considerations (Patla & Shumway-Cook, 1999) and included predominant land use, transit stops, visibly abandoned buildings, undeveloped land, street size, presence of a slope, sidewalk quality, steps at home entrance, and type of residence (defined in Table 1). Often, it was impossible to determine level of care present in a senior residence, so this category likely includes a mix of care levels. Given that participants had to attend in-person study visits, this is unlikely to include skilled nursing facilities. Due to lack of visibility on Google Street View, there were missing data for type of home (n = 4) and steps at entrance (n = 65).

Table 1. Definitions of Walkability Variables

Walkability variable	Domain	Definition	Hypothesized impact on walking
Mixed land use	Land use	Nonresidential land uses present	More walking
Transit available	Land use	Transit stop signage present	More walking
Abandoned property	Safety	Visibly abandoned buildings occupying majority of audit and/or any visibly abandoned homes	Less walking
Undeveloped land	Safety	Majority of audit is natural space that is unmaintained	Less walking
Larger street size	Safety	3+ lanes for traffic; excludes turning and parking lanes	Less walking
Slope present	Physical barrier	Steepest slope is moderate-steep; moderate slope would not act as a barrier to most individuals but walking it may increase heart rate, steep slope would be a barrier to individuals who are not active or with physical limitations	Less walking
Less than perfect sidewalk quality	Physical barrier	Sidewalk is absent or is anything other than in perfect condition without bumps, weeds, or cracks	Less walking
Steps at entrance	Physical barrier	Six or more steps at home entrance	Less walking
Type of home			
Single family	Residence	Single family home, including detached or row	Reference
Multifamily	Residence	Multifamily building such as apartments or condominiums	Uncertain
Senior residence	Residence	Indication of a senior residence by signage; includes all levels of care from retirement communities to skilled nursing facilities	Uncertain

Notes: Some definitions adapted from Active Neighborhood Checklist (Hoehner et al., 2007) Protocol, Version 2.0 (https://activelivingresearch.org/active-neighborhood-checklist).

Mobility

Mobility was conceptualized in two ways (Glass, 1998). The primary outcome was enacted mobility via self-reported outdoor walking behaviors. The secondary outcome was mobility capacity, or self-assessed ability, via self-reported mobility disability. Outdoor walking behaviors are reliant on environmental factors (Barnett et al., 2017) and disability measures reflect environmental as well as individual characteristics (World Health Organization, 2001). Further, walking behaviors are a determinant of risk for mobility disability (Gill et al., 2012). Mobility outcomes were taken from the 2006–2007 visit to match the timing of the Street View audits.

Walking behavior

Participants were asked "did you walk for exercise, or walk to work, the store, or church, or walk the dog, at least 10 times, in the past 12 months?" If they answered "yes" to this question, they were asked "in the past 7 days, did you go walking?" Participants were categorized as those who reported walking in the past week compared to those who did not.

Mobility disability

Participants were asked if they had any difficulty walking a ¼ mile, about two or three blocks, due to a health or physical problem. Presence of any difficulty was considered mobility disability.

Cognitive Status

In late life, cognitive function is typically either maintained or declines over time. Here, these two trajectories were calculated using previously reported methods (Yaffe et al., 2009). Briefly, a linear mixed model with random intercepts and slopes estimated participant-specific slopes of 3MS (Teng & Chui, 1987) scores. The 3MS was administered in 1997–1998, 1999–2000, 2001–2002, and 2006–2007. A subset of participants also completed the 3MS in 2003–2004 and 2005–2006. Models utilized scores from all available time points. 3MS slopes were not calculated if the 3MS was missing or <80 at baseline or if there were no follow-up measures (Yaffe et al., 2009). Cognitive maintainers were defined by predicted slopes of 0 or greater (no change or small improvements) and cognitive decliners as having predicted slopes less than 0. As decline can range from small to severe declines, in sensitivity analyses, decliners were further categorized as minor or major decliners (Yaffe et al., 2009). Minor decliners had predicted slopes less than 0 but greater than 1 *SD* below the slope mean and major decliners had predicted slopes greater than 1 *SD* below the slope mean (Yaffe et al., 2009).

Covariates

Age, gender, race, and educational attainment were self-reported at study baseline. All other covariates came from the 2006–2007 visit. Marital status was recorded. Participants reported if they were currently driving, at least once in a while. Body mass index was calculated by the standard formula (weight in kilograms)/(height in meters)^2. Diabetes was determined by self-report, use of hypoglycemia medication or insulin, a fasting glucose of ≥126 mg/dl, or a 2-hr glucose tolerance test >200 mg/dl. Hypertension was by self-report or current medication use. Depressive symptoms were reported by the short form Center for Epidemiological Studies-Depression scale (Andresen et al., 1994). Date of the clinic visit was coded by season to account for potential seasonal effects on mobility (Clarke et al., 2015).

Gait speed was measured at usual pace over 6 m and is reported as m/s. As gait speed was an important potential confounder and to limit the number of missing observations, gait speed from 2007 to 2008 was used when available for those with missing data from 2006 to 2007 (n = 33).

nSES (Rosso et al., 2016) was calculated from 2010 census data by z-scores for median individual income, median household income, median value of housing units, percentage of households receiving interest/dividend/net rental income, percentage of adults with high school education, percentage of adults with a bachelor's degree, and percentage of adults in managerial/professional occupations with higher values indicating better nSES. Median age of residents was also from the 2010 census. Population density was obtained from the United States Department of Agriculture (United States Department of Agriculture Economic Research Service, 2016).

Length of residence was calculated from residential history data obtained from Lexis Nexis (Wheeler & Wang, 2015) as the duration of time between the first observed date of the address until 2007. Sensitivity analyses limited analyses to those with duration of residence ≥3 years.

Statistical Analyses

Demographic and health variables were compared by mobility outcomes using t tests for continuous and chi-square tests for categorical variables.

Main effects of walkability and mobility associations and effect modification by cognitive status were tested with logistic regression models. First, covariate models were constructed to determine the most parsimonious models to preserve power and limit collinearity. For both outcomes, the covariate model started with age, gender, race, educational attainment, nSES, and usual pace gait speed. As health variables could be either confounders or mediators in the pathway, they were not considered. Backwards elimination at $p < .1$ trimmed the model. For walking behavior, models include gender, race, and gait speed. For mobility disability, models include age, gender, nSES, and gait speed. Second, each walkability measure was added separately to test the main effect. Third, a multiplicative interaction term for each walkability measure and cognitive status was included in separate models and $p < .2$ was considered suggestive of effect modification. We used a liberal p value to indicate likely effect modification as we were likely underpowered for tests of interaction. Finally, for any model with a suggestion of effect modification, analyses of walkability measures with walking outcomes were stratified on cognitive maintainer status and effect sizes between strata were compared. Effect modification by cognitive status was only considered to be present when there was a $p < .2$ and a difference in the associations of walkability measures with walking outcomes between cognitive strata was observed. All models utilized robust standard errors to account for possible correlations from clustering within census blocks. Analyses were conducted in SAS 9.4.

Results

The analytic sample was on average 82 years old and was 57% female and 33% Black (Table 2). Participants who reported walking in the past week were 57.4% of the sample and those with mobility disability were 24.2%. Of those with mobility disability, 28.0% reported walking in the past week compared to 66.8% of those without mobility disability ($p < .0001$). Being a nonwalker and having mobility disability were both associated with being female, being Black, having no more than a high school education, and having a poorer health profile (Table 2). Gait speed was strongly related to both mobility outcomes. Season of interview was not associated with either outcome. Of the neighborhood sociodemographic factors, only lower nSES was associated with worse mobility. Cognitive maintainers made up 49.0% of the sample and were more likely to be walkers and not have mobility disability (Table 2). At the 2006–2007 visit, the mean 3MS score was 89.4 (SD = 6.0) for decliners and 97.1 (SD = 2.2) for maintainers.

Walking Behavior

In adjusted models in the full sample (Table 3), mixed land use, better sidewalk quality, and living in a senior residence were related to a greater likelihood of walking in the past week. There was effect modification for abandoned properties, presence of a slope, and sidewalk quality. Stratified analyses indicated an association of slope with lower likelihood of walking among cognitive decliners (odds ratio [OR] = 0.51; 95% confidence interval [CI]: 0.29, 0.90) but with no association among maintainers (OR = 1.05; 95% CI: 0.63, 1.73). Lower sidewalk quality was related to lower odds of walking in both groups, but the association reached statistical significance in cognitive maintainers (OR = 0.38; 95% CI: 0.19, 0.76) but not decliners (OR = 0.81; 95% CI: 0.46, 1.40). Presence of abandoned properties did not reach significance in either cognitive group. There was no effect modification for mixed land use or senior residence, indicating that these associations did not differ by cognitive status.

Table 2. Characteristics for the Total Analytic Sample of Older Adults, by Self-Reported Walking in the Past Week and by Presence of Mobility Disability (*n* = 545)

		Walking behavior			Mobility disability		
	Total sample (*n* = 545)	Walkers (*n* = 313)	Nonwalkers (*n* = 232)		Nondisabled (*n* = 413)	Disabled (*n* = 132)	
Variable	Mean (*SD*) or *n* (%)	Mean (*SD*) or *n* (%)	Mean (*SD*) or *n* (%)	*p* Value	Mean (*SD*) or *n* (%)	Mean (*SD*) or *n* (%)	*p* Value
Age (years)	82.2 (2.7)	82.2 (2.7)	82.1 (2.8)	.7	82.0 (2.6)	82.6 (3.0)	.03
Female	310 (56.9)	152 (48.6)	158 (68.1)	<.0001	221 (53.5)	89 (67.4)	.005
Black race	178 (32.7)	79 (24.7)	99 (42.9)	<.0001	122 (29.5)	56 (42.4)	.006
Education							
<HS	56 (10.3)	31 (9.9)	25 (10.8)	.05	38 (9.2)	18 (13.6)	.01
HS grad	193 (35.5)	98 (31.4)	95 (40.9)		136 (33.0)	57 (43.2)	
>HS	295 (54.2)	183 (58.7)	112 (48.3)		238 (57.8)	57 (43.2)	
Married	260 (47.7)	161 (51.4)	99 (42.7)	.04	200 (48.4)	60 (45.5)	.6
Driving	397 (72.8)	232 (74.1)	165 (71.1)	.4	324 (78.5)	73 (55.3)	<.0001
BMI[a]	27.7 (4.6)	27.0 (4.0)	28.6 (5.3)	.0003	26.8 (4.0)	30.4 (5.4)	<.0001
Diabetes	125 (23.0)	63 (20.1)	62 (26.8)	.07	84 (20.3)	41 (31.3)	.009
Hypertension	386 (70.8)	208 (66.5)	178 (76.7)	.009	272 (65.9)	114 (86.4)	<.0001
CES-D score[b]	7.2 (6.1)	6.4 (5.6)	8.2 (6.6)	.002	6.8 (5.9)	8.4 (6.7)	.02
Gait speed (m/s)	1.04 (0.29)	1.11 (0.26)	0.95 (0.31)	<.0001	1.13 (0.22)	0.79 (0.34)	<.0001
3MS score[c]	93.2 (6.0)	93.7 (5.9)	92.6 (6.0)	.04	93.5 (5.8)	92.3 (6.4)	.04
Cognitive maintainer	267 (49.0)	174 (55.6)	93 (40.1)	.0003	214 (51.8)	53 (40.2)	.02
Duration of residence (years)	19.9 (16.9)	19.5 (17.1)	20.6 (16.6)	.4	19.8 (16.9)	20.4 (16.9)	.7
Season							
Winter	123 (22.6)	63 (20.1)	60 (25.9)	.2	88 (21.3)	35 (26.5)	.3
Spring	138 (25.3)	76 (24.3)	62 (26.7)		103 (24.9)	35 (26.5)	
Summer	149 (27.3)	94 (30.0)	55 (23.7)		121 (29.3)	28 (21.2)	
Fall	135 (24.8)	80 (25.6)	55 (23.7)		101 (24.5)	34 (25.8)	
nSES	0.62 (5.10)	1.31 (5.00)	−0.32 (5.10)	.0002	1.10 (5.12)	−0.88 (4.75)	<.0001
Population density (persons/mi^2)	8165.2 (7565.3)	8534.3 (7631.3)	7667.0 (7462.7)	.2	8197.0 (7557.5)	8065.4 (7617.6)	.9
Population median age (years)	39.5 (7.8)	39.1 (7.9)	40.2 (7.7)	.1	39.8 (7.6)	38.6 (8.4)	.1

Notes: BMI = body mass index; CES-D = Center for Epidemiological Studies-Depression; HS = high school; 3MS = Modified Mini-Mental State Examination; nSES = neighborhood socioeconomic status.
[a]*n* = 530. [b]*n* = 506. [c]*n* = 530.

Mobility Disability

In adjusted models in the full sample (Supplementary Table 2), there were no significant associations between walkability and mobility disability. However, there was effect modification by cognitive status for mixed land use, abandoned properties, undeveloped land, and transit. Stratified analyses revealed a significant association between mixed land use and a lower odds of mobility disability among cognitive decliners (OR = 0.54; 95% CI: 0.33, 0.91) but not among maintainers (OR = 1.45; 95% CI: 0.67, 3.16). Abandoned properties were related to greater likelihood of mobility disability, but associations were significant in cognitive maintainers (OR = 3.54; 95% CI: 1.17, 10.73), but not among cognitive decliners (OR = 1.87; 95% CI: 0.78, 4.49). Neither undeveloped land nor transit was significantly associated with mobility disability in stratified analyses.

Minor and Major Decliners

Seventy-two participants (13.2%) were defined as minor decliners and 206 (37.8%) as major decliners. Major decline was defined by those with a slope greater than −0.52 points/year. In sensitivity analyses comparing cognitive maintainers to both minor and major decliners, results were largely the same as for the combined decliner group. In stratified analyses, the findings for minor decliners were more similar to those for major decliners than they were for maintainers (data not shown).

Table 3. Multivariable Models of Associations Between Neighborhood Walkability and Self-Reported Walking in the Past Week in Older Adults

Walkability variable	Adjusted[a] model without interaction (n = 545) OR (95% CI)	p for interaction	Adjusted[a] model in cognitive maintainers (n = 267) OR (95% CI)	Adjusted[a] model in cognitive decliners (n = 278) OR (95% CI)
Land use/destinations				
Mixed land use	**1.61 (1.12, 2.30)**	.8		
Transit available	0.95 (0.65, 1.40)	.4		
Safety				
Abandoned property	0.82 (0.52, 1.30)	.16	0.54 (0.23, 1.26)	1.07 (0.56, 2.02)
Undeveloped land	0.87 (0.57, 1.33)	.8		
Larger street size	1.23 (0.66, 2.31)	.3		
Physical barrier				
Slope present	0.70 (0.47, 1.04)	.05	1.05 (0.63, 1.73)	**0.51 (0.29, 0.90)**
Less than perfect sidewalk quality	**0.61 (0.38, 0.96)**	.05	**0.38 (0.19, 0.76)**	0.81 (0.46, 1.40)
6+ steps at entrance[b]	1.06 (0.67, 1.68)	.8		
Residence				
Type of home[c]				
Single family	Ref	Ref		
Multifamily	1.41 (0.96, 2.08)	.8		
Senior residence	**2.14 (1.27, 3.60)**	.3		

Notes: CI = confidence interval; OR = odds ratio. Multiplicative interactions with cognitive maintainer status and analyses stratified by cognitive maintainer status where p for interaction < .2 are shown. Bolded values indicate significant associations.
[a]Adjusted for gender, race, usual gait speed; robust regression accounting for clustering at census block level. [b]n = 480; [c]n = 541.

Length of Residence

The average duration of residence was 19.9 (*SD* = 16.9; median = 17.3) years. There were 107 participants (20.2%) who had lived at their residence for fewer than 3 years. In sensitivity analyses that removed these individuals, results were consistent with those for the full sample with one exception; there was no interaction between sidewalk quality and cognitive status for self-reported walking (p for interaction = .4) but there was a main effect (OR = 0.55; 95% CI: 0.33, 0.93).

Discussion and Implications

We found that four measures of walkability from Google Street View audits were associated with walking behaviors in a sample of older adults. The influence of cognitive status on these findings was mixed. In general, environmental factors were more strongly related to walking than mobility disability. Mixed land use and living in a senior residence were related to greater likelihood of walking, regardless of cognitive status. Presence of a slope was related to less walking in cognitive decliners and lower sidewalk quality was related to less walking in cognitive maintainers. Mixed land use reduced likelihood of mobility disability among cognitive decliners and abandoned properties increased likelihood among cognitive maintainers.

Mixed land use provided some of the most consistent results, likely indicating that presence of walking destinations is an important determinant of whether older adults walk and, consequently, their ability to avoid mobility disability (Rosso et al., 2011). Land use and presence of destinations have been well studied previously, with fairly consistent findings in line with our results (Rosso et al., 2011; Yen et al., 2014). We also identified that those living in senior residences were more likely to report walking in the past week. We were unable to determine level of care of these facilities, but these were likely retirement communities or assisted living as study participants had to attend in-person study visits. Higher levels of walking in senior residences may be related to a greater availability of structured and social activity opportunities within these communities, which seem to benefit cognitive decliners as well as maintainers.

We identified poorer sidewalk quality and presence of visibly abandoned properties as related to lower mobility among individuals maintaining their cognitive function over time. Sidewalk quality has been identified as a barrier by older adults living in both urban (Gallagher et al., 2010) and suburban (Mitra et al., 2015) neighborhoods. Audited sidewalk quality has also been related to outdoor walking behaviors in older adults (Christman et al., 2020). Presence of abandoned properties in our study likely represents a visual indication of disorder in the neighborhood which influences feelings of safety. Neighborhood disorder has been linked to lower levels of physical activity (Mooney et al., 2017) and reduced muscle strength (Duchowny et al., 2020) in older adults. Neighborhood disorder is also associated with persistent mobility limitations, with likely pathways through physical activity and psychosocial processes (Latham & Williams, 2015). However, not all studies have found associations of sidewalk quality and measures of neighborhood disorder with mobility outcomes (Rosso et al., 2011), possibly due to not accounting for individual characteristics that may modify these associations, such as cognitive function.

Finally, presence of a slope near the residence was related to lower likelihood of walking among cognitive decliners, but not maintainers. One previous study found that incident walking difficulties were more frequent among those living in neighborhoods considered hilly by objective measurement, but did not consider the cognitive status of participants (Keskinen et al., 2018). Hills pose a particular barrier to individuals with a number of impairments, including joint pain, fatigability, and cardiorespiratory difficulties. Possibly, these impairments are more common in those with cognitive decline and/or those with cognitive decline lack the needed motivational capacity to overcome impairments in the face of a physical barrier such as a hill.

Counter to our hypothesis, we found that neighborhood environmental factors were generally not more strongly related to mobility among cognitive decliners than among maintainers. It may be the case that cognitive maintainers have fewer intrinsic risk factors for mobility declines and may be more likely to interact with their neighborhood environments. However, while we did see that cognitive maintainers were more likely to report walking and less likely to report mobility disability than decliners, there was still a large percentage of decliners who reported good mobility. It is possible that those experiencing cognitive decline were simply poorer at reporting mobility and as a result, misclassification could have masked any true associations in this group. One previous study found no significant interactions between memory impairment with neighborhood perception for ADL and instrumental activities of daily living outcomes (Nguyen et al., 2016), indicating that neighborhood perception was equally related to disability, regardless of memory impairments. Another study found that better perceived neighborhood characteristics were related to greater physical activity, with findings stronger in those with lower cognitive function (Cheval et al., 2019). Both of these prior studies relied on neighborhood perception, which can be shaped by level of mobility through exposure to the neighborhood and by cognitive function.

Collectively, these results suggest that cognitive function, at least among individuals without overt dementia, is not a strong modifier of the association between neighborhood walkability characteristics and mobility or disability outcomes. This is counter to the Ecological Model of Aging on which this study was predicated. There are several reasons why this may be the case, though we are unable to test these with the existing data. First, the model may simply be inaccurate. While the model has face validity, there are an insufficient number of experimental studies that have directly tested it to comment on its likely validity. Alternatively, older individuals who have lived in their communities for a long period of time, as in this study sample, may have become accustomed to the difficulties in their environment such that they no longer have a strong impact on mobility or they may have developed compensatory strategies to deal with them. Finally, the model may simply not apply to the types of environmental and individual measures used in this study. For example, the Ecological Model of Aging may be more applicable for immediate residential environmental conditions than it is for neighborhood ones.

Our study had several limitations. Our study was cross-sectional which does not allow for detection of temporality. However, the average time in home was 20 years and analyses which excluded participants who lived in their home for fewer than 3 years did not substantially differ from results presented here. This indicates that these results were not driven by individuals moving to different environments after the onset of mobility problems. Second, audits of Google Street View images can be limited by missing images and visual obstructions. For example, we were not able to view entrance characteristics of all participant homes, resulting in some missing data. However, we had high interrater reliability for all measures used here (Harding et al., 2020).

Our study had several notable strengths. We included participants across a range of neighborhoods, including urban and suburban locations with a range of nSES in both private and senior residences. We also included a large number of Black participants. Finally, we had a very well characterized sample with a number of individual- and neighborhood-level covariates measured. We also had cognitive function measured over the prior 10 years, so we were able to determine a decline or maintenance trajectory, rather than relying on a single cognitive assessment.

We identified a number of neighborhood characteristics which were related to greater mobility of older adults. Namely, these were mixed land use, senior living, absence of visibly abandoned properties, higher sidewalk quality, and lack of slopes. In general, the findings were stronger for those who were maintaining cognitive function over time or did not differ by cognitive status. Some of these factors are modifiable given community-level interventions and policy initiatives. Even for factors such as land use, which may be difficult to modify, or slopes, which are essentially unmodifiable, identification of these as barriers or facilitators of mobility allows for targeted modifications. For example, strategic placement of benches along steep slopes could assist those for whom slopes are too physically demanding. Interventions to encourage walking in residential neighborhoods without natural walking destinations could also be implemented, with the potential to adapt models currently used in senior living facilities.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

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Conflict of Interest

None declared.

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