Published in final edited form as:

Ann Epidemiol. 2015 November ; 25(11): 849–854. doi:10.1016/j.annepidem.2015.07.001.

Cognitive Decline and the Neighborhood Environment

Philippa J. Clarke, Ph.D.,

Institute for Social Research and Department of Epidemiology, University of Michigan

Jennifer Weuve, Sc.D.,

Rush Institute for Healthy Aging, Department of Internal Medicine, Rush University Medical Center

Lisa Barnes, Ph.D.,

Rush Alzheimer's Disease Center, Department of Neurological Sciences and Department of Behavioral Sciences, Rush University Medical Center

Denis A. Evans, M.D., and

Rush Institute for Healthy Aging, Department of Internal Medicine, Rush University Medical Center

Carlos F. Mendes de Leon, PhD.

Department of Epidemiology, School of Public Health, University of Michigan

Abstract

Purpose—Little research has looked beyond individual factors to consider the influence of the neighborhood environment on cognitive function. A greater density of physical resources (e.g., recreational centers and parks) and institutional resources (e.g., community centers) may buffer cognitive decline by offering opportunities for physical activity and social interaction.

Methods—Using data from the Chicago Health and Aging Project (1993–2011), a prospective cohort study of 6518 adults age 65+, we fit a 3-level growth curve model to examine the role of individual and neighborhood factors (objectively observed at the block group level) on trajectories of cognitive function (composite of East Boston Memory Test, symbol digit test, MMSE) in later life.

Results—Net of individual factors, residence in a neighborhood with community resources, proximity to public transit, and public spaces in good condition were associated with slower rates of cognitive decline, possibly by increasing opportunities for social and physical activities or access to destinations that facilitate engagement in activities.

Conclusions—These results highlight the role of neighborhood environments in buffering cognitive decline among older adults aging in place.

Corresponding Author: Philippa Clarke, PhD, Institute for Social Research, University of Michigan, 426 Thompson Street, Ann Arbor, MI 48103, Tel: 734-647-9611, Fax: 734-936-0548, pjclarke@umich.edu.

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Keywords

cognitive function; neighborhoods; trajectories; longitudinal models; older adults

Dementia is a common and disabling brain disorder among older adults that has consequences for independence, functional decline, institutionalization, and mortality (1, 2). Previous research has identified multiple individual risk factors that are associated with cognitive impairment and decline (3). From a behavioral standpoint, engaging in frequent or vigorous physical activity has been found to be protective against cognitive decline (4–7), potentially through increased cerebral blood flow or reduced inflammation. Social interaction and engaging in cognitively stimulating activities (e.g. reading newspapers, books, playing games such as cards or crossword puzzles) have also been associated with a lower incidence of dementia (8–11) and slower rates of cognitive decline (12, 13), possibly by strengthening processing skills including working memory and perceptual speed, which may help to compensate for age-related declines in other cognitive systems (14) (15, 16).

Recently, a parallel literature has looked beyond individual-level factors to consider the role of the social and built environment for cognition in older adults (17–20). These studies have found significant variation in cognitive function across neighborhoods at a level that is rarely seen for other health outcomes (21). For example, the Epidemiologic Catchment Area Study found that Mini-Mental State Examination scores differed significantly across five study sites (22) suggesting that neighborhood characteristics may be a source of unexplored differences in cognitive function across adults living in different settings. After adjustment for individual socioeconomic resources, living in a more socioeconomically advantaged area (e.g. high household income, high levels of education) has repeatedly been found to be associated with higher cognitive function, particularly among older adults (17, 18), and slower rates of cognitive decline (19).

Authors of these papers have speculated that living in highly educated and socioeconomically advantaged neighborhoods may promote cognitive function and/or buffer cognitive decline in part through their greater density of physical resources (recreational centers, gyms, parks, walking paths) as well as social and institutional resources (libraries, bookstores, community centers) that promote protective health behaviors (e.g., physical activity) and facilitate mental stimulation (e.g., social interaction and cognitive activities such as reading and/or playing games) (11). Clarke et al. (20) found that neighborhood affluence had a net positive association with cognitive function that operated in part through a greater density of institutional resources, including community centers and senior centers, which may provide older adults with the opportunity to engage in cognitively beneficial exercise programs (23, 24). By empirically examining this conceptual sequence, Clarke and colleagues demonstrated how neighborhood resources have the potential to act as a source of “cognitive reserve”(25), particularly for older adults who are aging in place. However, this study was limited to cross-sectional data on levels of cognitive function. Thus, it remains pertinent to investigate whether resource-rich neighborhoods can act as a source of cognitive reserve by stemming declines in cognitive function with age. (26).

We analyzed longitudinal data from the Chicago Health and Aging Project (CHAP), a prospective, population based cohort study of adults age 65 and older in the city of Chicago who were surveyed up to six times over a period of 18 years (1993–2011). In addition to being a longitudinal study on cognition, the project also collected objectively measured, detailed data on environmental features relevant for engaging in physical and cognitively stimulating activities in later life (e.g., presence of community centers, continuous sidewalks, pedestrian amenities, public transit). As such, the data provide an excellent opportunity to examine the possible role of neighborhood environments in modifying the rate of cognitive decline among urban-dwelling older adults.

MATERIALS AND METHODS

The Chicago Health and Aging Project (CHAP) is a longitudinal population-based study of Alzheimer's disease in older adults that has been ongoing since 1993 (11, 27). Details of the study have been published elsewhere (27). Briefly, CHAP is conducted in three adjacent neighborhoods on the south-side of Chicago (Morgan Park, Beverly, and Washington Heights), which together encompass 82 census block groups within an area spanning 20 census tracts. The study population was identified on the basis of a census of all study area residents in 1993, and every person aged 65 and older was invited to participate. Of the 7,813 eligible residents, 6,158 (78.9%) were enrolled and administered a baseline interview (62% black and 38% white).

Baseline interviews in participants' homes were conducted from 1993 to 1996, with follow-up in-person interview cycles at approximately 3-year intervals to 2011, with participation rates of 80–85%. Beginning in the third data collection cycle (2000–2003), the sample was supplemented with residents from the same study area who had turned 65 since the beginning of the study, with an identical set of assessment methods fully integrated with those in the original cohort. As of 2011, CHAP completed a total of six data collection cycles for those who enrolled originally (1993–96) and up to four for those who first enrolled in the third or later data collection cycles (2000–2003).

Interviews included standardized questions on medical history, lifestyle factors, demographic and psychosocial characteristics, as well as standardized tests of physical and cognitive function. Data for these analyses come from 6518 individuals who completed at least one assessment of cognitive function. Written informed consent was obtained from all study participants, and all study procedures were approved by the institutional review board at Rush University Medical Center.

Individual Measures

The primary outcome of interest, cognitive function, was assessed at each interview using four tests including the East Boston Memory Test of immediate and delayed recall (28), the symbol digit modalities test as measure of perceptual speed (29), and the Mini Mental State Examination (MMSE) as a measure of general cognitive orientation and function (30). As described previously, scores on each test were first standardized by converting raw scores to z-scores based on the baseline distribution in CHAP, and then averaged across tests to produce a summary score of global cognitive function (11).

Through social selection processes over the life course, individuals at greater risk for cognitive decline (e.g., racial minority, lower educated, and those with multiple health problems) may be more likely to live in neighborhoods with fewer resources in later life. Analyses therefore controlled for key sociodemographic and health factors that aim to minimize selection bias in the results. *Sociodemographic factors* capture underlying behaviors and resources that are associated with cognitive function over the adult life course. Data for these individual-level demographic characteristics come from the first CHAP interview including gender, race (African American or White/other race), educational attainment (less than a high school diploma, high school diploma but less than college, or college degree or higher), and baseline annual household income (less than US\$15,000 per year, US\$15,000 – \$30,000 per year, and greater than US\$30,000 per year).

On the other hand, time-varying variables capture the dynamics of changing social and physical risk factors for cognitive impairment over late adulthood. We focus on physical health status, physical activity, marital status and social support over time. *Physical health status* was assessed according to nine self-reported, physician-diagnosed chronic medical conditions, including myocardial infarction, cancer, hypertension, stroke, diabetes, thyroid disease, shingles, Parkinson's disease, and hip fracture. Individual conditions were summed to create a total score of chronic health conditions. *Physical activity* was assessed according to the frequency of walking for exercise during the past 2 weeks using questions derived from the 1985 Health Interview Survey (31). A summary measure of the total minutes of walking in the past two weeks (in 10 minute units) was used in analyses. *Marital status* was captured by a binary indicator contrasting currently married or living with a partner vs. not married (including widowed, divorced, separated, and never married). The size of each participant's *social support* network was summarized as the total number of children, relatives, and friends seen at least monthly.

Neighborhood Measures

Based on the high density of participants in the CHAP study area we were able to define neighborhoods according to the census block group. A block group consists of clusters of contiguous city blocks within the same census tract that are delineated by local participants in the Census Bureau's Participant Statistical Areas Program. Block groups typically contain between 600 and 3,000 people and capture the more compact spaces in which older adults travel and spend their time (32, 33). Our study sample (N=6518) was nested within 82 block groups, with an average of 79 participants per census block group (range 20–302).

In the third CHAP cycle (2000–2003) an objective neighborhood assessment was conducted for residential blocks in the study area. The assessment was conducted on the ground by trained raters and included a detailed neighborhood audit of each street within the study area using a set of structured questions on specific neighborhood features and conditions derived from previous research (34–36). For our purposes, we focused on those neighborhood characteristics hypothesized to be related to cognitive function by providing opportunities for physical activity or cognitively stimulating activities in the local environment. For example, the presence of *community centers* in the block group could provide residents opportunities for recreational activity and social interaction. Access to *public transit* (public

transit stop in the block group) may facilitate social integration and access to destinations, particularly for older adults who are unable to drive. We also captured **neighborhood walkability** based on observations about the presence of sidewalks (whether there are any discontinuous sidewalks in the block group) and pedestrian amenities (any cross walks). Raters also evaluated the **quality of public spaces** in each audit by indicating whether any of the public spaces were in poor or deteriorating condition. For each feature, block group level summaries were created by aggregating across all streets observed in each block group.

Because the neighborhood audit was only conducted at a single assessment in the CHAP study, we treated these neighborhood characteristics as time invariant under the assumption that there was little meaningful change over time in the types of neighborhood resources at the focus of this study (37, 38). However, we adjust for participants' **years of residence** in the neighborhood to account for duration of exposure to these characteristics. As an additional marker of the extent of exposure to the immediate neighborhood, we also account for an individual's self-reported **tendency to drive** to places they need to go (often vs. sometimes, rarely or never).

Statistical Analyses

We examined trajectories of cognitive function over the 18-year study period using growth curve models (39). Growth curve models belong to a general class of mixed models that take into consideration the clustering of observations (within persons and neighborhoods) and also have the capacity to handle unbalanced designs (varying number of observations per person) (40). We analyzed a three-level linear model with multiple observations nested within persons, who were nested in neighborhoods. Age was used as the indicator of time, centered at age 65 for analyses. We used the MIXED procedure in SAS (Version 9.2, Cary, NC) to estimate linear models using full information maximum likelihood. Cognitive function scores were normally distributed justifying the use of a Gaussian model.

RESULTS

Table 1 outlines the sociodemographic characteristics of the study participants at baseline (study entry). The majority (61%) were between the ages of 65 and 75 (mean age = 74 years) and over half (62%) were female. A large majority (72%) was African American and just over half of the participants (53%) had a high school degree. Household income was distributed across the three analytic categories, with almost 40% reporting an annual income between \$15,000 and \$30,000 at baseline. Most (60%) of the sample was not married at baseline, largely due to being widowed (47%). On average, participants reported just over 1 medically diagnosed health condition (range 0–6), and walked on average for 120 minutes (2 hours) per two week period. Participants reported an average of 6 individuals in their social network that they saw at least monthly. These were generally long term residents, residing in their neighborhood for an average of 33 years. Most reported (61%) that they usually drove to get to places that they needed to go.

Only 5% of study participants lived in a block group where there was a community center (Table 1). However, public transit and cross walks were relatively plentiful, with just under half (40%) of the study population living in a neighborhood with a public transit stop on the

block group, and over half (57%) living in an area with cross walks in their block group. However, the quality of public spaces in these urban neighborhoods was relatively poor. Almost half (42%) of respondents lived in a block group where the general condition of public spaces was poor or deteriorated, and 11% lived in an area without sidewalks on at least one of the streets in the block group.

Table 2 presents the results from a series of linear growth models of cognitive function over time. The variance components from an unconditional model (not shown) indicate that most (63%) of the variance in cognitive function lies between persons (level 2), but there is also significant variation between neighborhoods (8% at level 3). Model A presents the results for the unconditional growth model, showing the coefficients for the intercept and rate of change (linear slope) in cognition by age. At the first CHAP assessment (age 65) the mean score on the global cognitive function measure was 0.705, and declined at a rate of 0.046 standardized units per year (rate of change, Model A). (Adjusting for year of study entry was not statistically significant and was not included in the model.)

Model B in Table 2 adds the individual sociodemographic and health characteristics. At baseline (age 65) cognitive function scores were significantly lower for African Americans than for whites ($\beta = -.255$, $p < .001$), for those with less than a college education, and for adults with annual household incomes of \$15–30,000 per year compared to those with over \$30,000 per year. Women had significantly higher cognitive function scores than men, while married individuals had significantly lower scores than the unmarried at age 65. Not surprisingly, individuals who often drive as means to get around report higher cognitive function than those who drive less often. Individuals with a larger social network, and those engaging in more physical activity (walking) showed no difference in cognitive function at age 65. The number of underlying physical health conditions was also not related to cognitive function at age 65, net of the other sociodemographic characteristics.

However, physical health conditions, network size, and walking for exercise were associated with the rate of change in cognitive function over this 18 year period (bottom half of Model B, Table 2). Engaging in more frequent physical activity (walking), having a larger social network, and being married were associated with a slower rate of cognitive decline over late adulthood. Slower rates of cognitive decline were also seen among older adults who report driving more frequently. Conversely, a greater number of chronic health conditions and very low income (less than \$15,000 per year) were associated with more rapid rates of decline in cognitive function.

Model C (Table 2) adds the neighborhood characteristics hypothesized to influence cognitive function, net of individual risk factors. There were no significant associations of neighborhood resources with cognitive function at age 65, but the presence of neighborhood resources was significantly associated with the rate of decline in cognitive function over this period in later life. Residence in a block group with a community center and a public transit stop was associated with a slower rate of cognitive decline over time (0.010 and 0.007 standardized units slower, respectively, per year of age). In a similar vein, residents of neighborhoods in which public spaces were in poor condition had a faster rate of cognitive

decline over time (0.05 standardized units faster per decade than those with public spaces in good condition).

DISCUSSION

The World Health Organization has identified dementia as a public health priority (41). The projected growth in the world's population age 60 years and over will lead to an explosion in the number of people with dementia in the United States and around the world. While recent therapeutic advances show promise for reducing the dementia burden (42), the most optimal approach is likely to include pharmacological, nutritional and behavioral factors (43). A growing body of work has demonstrated the importance of health or lifestyle behaviors for cognitive function including higher levels of physical activity (44, 45), a healthy diet (especially vegetable consumption(46, 47)), not smoking (48), and engaging in leisure or social activities (49–51). However, little attention has been paid to the extent to which the surrounding residential context supports these behaviors by offering opportunities for physical activity, a healthy diet and social/leisure activities.

This study analyzed an array of environmental and individual data collected on a racially diverse population of community dwelling older adults to examine the moderating role of neighborhood physical and social resources on trajectories of cognitive function over an 18 year period. We found that neighborhood resources were not related to initial levels of cognitive function at study entry. However, net of well-known individual risk factors, neighborhood resources were related to the rate of decline in cognitive function over time. Specifically, local community centers and proximity to public transit were associated with slower rates of cognitive decline, possibly due to increased opportunities for social and physical activities or ease of access to destinations to facilitate engagement in activities. Results also highlight the importance of maintaining public spaces in good condition, which may support physical, social and leisure activities for older adults by maintaining barrier-free walkways (52, 53).

The associations of neighborhood resources with rates of cognitive decline were statistically significant, but small. To put these results in context, the benefits for those residing in areas with public transit is about a third of that shown for vegetable consumption (47). However, making changes to local built environments (e.g. adding community centers or public transit stops) may be easier to implement than efforts to change individual behaviors in the absence of resources.

This study has a number of strengths including a large bi-racial community-dwelling population of older adults, followed repeatedly over almost two decades. The use of direct, objective measures of neighborhood features observed on the ground is also a strength. We acknowledge that our study also has several limitations. Our results are based on a global measure of cognition using a screening tool and we are not able to investigate the relationships with specific domains of cognitive function. The neighborhood audits were conducted from 2000–2003 while cognitive function was assessed from 1993–2011, raising the possibility that changes in neighborhood resources over the assessment periods could introduce error in our results. However, neighborhood features tend to be relatively stable

across periods of 5 to 10 years (54), and are unlikely to change substantively over the time period observed in this study (38). The study was also limited to older adults in the Chicago area, constraining the generalizability of the findings. However, by focusing on a small but dense area it was possible to gather detailed, objective observations of neighborhood environments by trained raters in the field. Finally, longitudinal data were unavailable on the individual activities hypothesized to mediate the pathway between neighborhood resources and cognitive function/decline (e.g. physical activity and cognitively stimulating activities). However, descriptively, the data suggest that the self-reported activities of participants at baseline did reflect their neighborhood resources (e.g., participants living in neighborhoods with public transit reported going to the library more frequently, results not shown). Future research should explicitly test whether residents of different areas actually engage in activities facilitated by their community resources.

In spite of these limitations, this work emphasizes the importance of considering urban design for the cognitive health of older adults who are aging in place. Although people with dementia may be concentrated in institutions, the majority of older adults with dementia live in the community (55). Our research stresses the importance of intelligent design of community environments for individuals at risk for cognitive decline (56, 57).

Acknowledgments

This work was supported by National Institute on Aging Grant R03-AG42956. The authors would like to thank Todd Beck for data management support.

List of Abbreviations

CHAP Chicago Health and Aging Project

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TABLE 1

Descriptive Statistics for Study Sample: Chicago Health and Aging Project (N=6518)

	Percent or Mean ($\pm$ s.d.)
<i>Individual Characteristics (at Baseline)</i>	
Age (years)	74.1 (7.4)
Gender	
Female	62.2
Male	37.8
Race	
African American	71.6
White or Other race	28.4
Education	
<HS Education	28.5
HS Degree	52.8
College Degree	18.7
Household Income	
Income < \$15K	23.6
Income \$15K to \$30K	39.9
Income > \$30K	36.5
Marital Status	
Married	40.1
Not married	59.9
Number of Chronic Health Conditions	1.2 (1.0)
Walking for Exercise (minutes per 2 weeks in 10 minute units)	12.2 (25.7)
Social Network size	6.3 (5.7)
Usually drives for transit	60.6
Residential tenure (years)	32.7 (25.2)
<i>Neighborhood Characteristics</i>	
Community Center	4.8
Public Transit	40.3
Cross Walks	57.3
Discontinuous Sidewalks	11.3
Public Spaces in Poor Condition	42.2

s.d. = standard deviation

TABLE 2

Regression Coefficients from a Three-Level Linear Growth Curve Model of Trajectories of Cognitive Function in Later Life: Chicago Health and Aging Project (N=6518)

	Unconditional Growth	+ Individual Factors	+ Neighborhood Factors
	Model A	Model B	Model C
Intercept (at age 65)^d	.705***	.849***	.868***
<i>Neighborhood Factors</i>			
Community Center			-.054
Public Transit			-.075
Cross Walks			-.020
Discontinuous Sidewalks			-.060
Public Spaces in Poor Condition			.026
<i>Individual Factors</i>			
Female ^b		.159***	.146***
African American ^c		-.255***	-.259***
<HS Education ^d		-.418***	-.409***
HS Degree ^d		-.138***	-.143***
Income < \$15K ^e		-.074	-.074
Income \$15K to \$30K ^e		-.084**	-.085**
Married ^f		-.096***	-.098***
Chronic Conditions		-.007	-.005
Walking for Exercise (10 minute units)		-.0002	-.0002
Social Network size		-.002	-.002
Usually drives for transit		.214***	.207***
Duration of residence (years)			.001
Rate of Change (Age)	-.046***	-.047***	-.051***
<i>By Neighborhood Factors</i>			
Community Center			.010*
Public Transit			.007**
Cross Walks			.003
Discontinuous Sidewalks			.005
Public Spaces in Poor Condition			-.005*
<i>By Individual Factors</i>			
Female ^b		.001	.003
African American ^c		-.002	-.001
<HS Education ^d		.004	.002
HS Degree ^d		.006	.006
Income < \$15K ^e		-.013***	-.013***

	Unconditional Growth	+ Individual Factors	+ Neighborhood Factors
	Model A	Model B	Model C
Income \$15K to \$30K ^e		-.001	-.006*
Married ^f		.009***	.009***
Chronic Conditions		-.002*	-.002**
Walking for Exercise (10 minute units)		.0001***	.0001***
Social Network size		.001***	.001***
Usually drives for transit		.007***	.007***
Duration of residence (years)			-.000

*
p<.05

**
p<.01

p<.001 (two tailed tests)

^a Age is centered at age 65

^b Reference group is Male

^c Reference group is white

^d Reference group is college degree

^e Reference group is income >\$30,000

^f Reference group is Unmarried (Separated/Divorced, Widowed, or Never Married)