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Neighborhood Age Structure and Cognitive Function in a Nationally-Representative Sample of Older Adults in the U.S

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Abstract

Recent evidence suggests that living in a neighborhood with a greater percentage of older adults is associated with better individual health, including lower depression, better self-rated health, and a decreased risk of overall mortality. However, much of the work to date suffers from four limitations. First, none of the U.S.-based studies examine the association at the national level. Second, no studies have examined three important hypothesized mechanisms - neighborhood socioeconomic status and neighborhood social and physical characteristics - which are significantly correlated with both neighborhood age structure and health. Third, no U.S. study has longitudinally examined cognitive health trajectories. We build on this literature by examining nine years of nationally-representative data from the Health and Retirement Study (2002–2010) on men and women aged 51 and over linked with Census data to examine the relationship between the percentage of adults 65 and older in a neighborhood and individual cognitive health trajectories. Our results indicate that living in a neighborhood with a greater percentage of older adults is related to better individual cognition at baseline but we did not find any significant association with cognitive decline. We also explored potential mediators including neighborhood socioeconomic status, perceived neighborhood cohesion and perceived neighborhood physical disorder. We did not find evidence that neighborhood socioeconomic status explains this relationship; however, there is suggestive evidence that perceived cohesion and disorder may explain some of the association between age structure and cognition. Although more work is needed to identify the precise mechanisms, this work may suggest a potential contextual target for public health interventions to prevent cognitive impairment.

Keywords

cognitive decline; dementia; neighborhood age structure; social cohesion; socioeconomic status; Health and Retirement Study

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1. Background

Nearly 15 percent of Americans over age 70 - approximately 3.8 million people - are currently living with dementia (Hurd et al., 2013). Short of a major medical breakthrough, the number of new dementia cases will only increase with time as the Baby Boomers age. Dementia is also one of the most costly diseases with total costs estimated between 159 to 215 billion dollars, and a projected increase of nearly 80% by 2040 (Hurd et al., 2013). Because individual interventions, in general, have not proven successful to date (Institute of Medicine, 2008), interventions that target factors in the social environment that may be linked to cognitive decline - and ultimately dementia - may provide new opportunities for public health-based interventions.

One potential social mechanism relates to characteristics of one's local geographic environment, with recent research suggesting that neighborhood factors are associated with physical and mental health outcomes, particularly at older ages (for a review see Yen et al, 2009). Neighborhood compositional and contextual factors covering such diverse domains as the economic environment, physical environment, demographics, perceived neighborhood characteristics (both positive and negative), and the social environment have been linked to a variety of health outcomes including mortality, disease prevalence, mental health, and health behaviors (Yen et al, 2009) and, more recently, cognition (Clarke et al., 2012; Clarke et al., 2015; Kovalchik et al., 2015). The significance of the local environment for health may be particularly salient for older adults since they may have greater exposure to their neighborhoods due to limited physical mobility, driving restrictions, and potentially fewer work-related or other motives for frequent travel outside of their neighborhoods (Balfour & Kaplan, 2002; Cagney et al., 2005).

One neighborhood factor that has been largely ignored in the literature is that of neighborhood age structure, although age and age composition are ready markers for any number of social and institutional settings in which we engage. The handful of studies that have examined the age structure of neighborhoods - typically measured as the percent of older adults - are provocative and suggest that there may in fact be protective effects for older adults living in neighborhoods with a larger percentage of older adults (Browning et al., 2006; Clarke et al., 2012; Hybels et al., 2006; Kubzansky et al., 2005; Subramanian et al., 2008; Subramanian et al., 2006; Vogelsang & Raymo, 2014).

1.1 Potential mechanisms linking neighborhood age structure and health

Why should neighborhoods with a greater percentage of older adults be linked to better health? Theoretically, there are several possible explanations, including local socioeconomic conditions, spatial features of neighborhoods and services, and community structure and social capital (Cagney, 2006). Differences in the socioeconomic conditions in neighborhoods with more as compared to fewer older adults, for instance, could explain differences in neighborhood age structure and health, particularly if neighborhoods with a greater percentage of older adults are more advantaged. There is already a large body of work suggesting that neighborhood socioeconomic status (NSES) is linked to a variety of health outcomes, including cognition (Al Hazzouri et al., 2011; Basta et al., 2008; Clarke et al., 2012; Clarke et al., 2015; Shih et al., 2011; Wee et al., 2012; Wu et al., 2015). In addition,

there is some evidence that older adults may live in areas with better NSES. Poverty, for instance, is negatively correlated and affluence positively correlated with the percent of adults 65 and over in the neighborhood (Cagney, 2006). This suggests that socioeconomic factors may be an important mechanism explaining the relationship between neighborhood age structure and health. The age structure of neighborhoods may also affect the local availability of health services and facilities (e.g. urgent care and doctors' offices) and access to social services directly targeting older adults (Glass & Balfour, 2003). While some of this access may be an indirect consequence of the socioeconomic status of neighborhoods, some services may be more directly related to the age structure of neighborhoods. Policy-makers, private companies, or nonprofit organizations may locate key services based on the potential demand for services which are often linked to demographic characteristics of individuals in a neighborhood, such as age.

The safety and physical characteristics of neighborhoods are also related to health (Cohen et al., 2003; Kim, 2010; Krause, 1996; Lawton & Nahemow, 1980; Wu et al., 2015). They also may well be associated with the age structure of neighborhoods such as the level of crime, noise pollution, graffiti and other physical aspects of neighborhoods. Finally, social factors such as social capital and access to social connections may be different for older adults residing in neighborhoods with more seniors and this may in turn influence health. It is well established that social contacts at the individual level are linked to better health, especially for older adults (Berkman et al., 2000; House et al., 1988; Seeman et al., 2010) and that social cohesion in particular is linked to better mental health (Stafford et al., 2011). A greater neighborhood presence of older adults could also influence health through social network formation, information sharing, neighborhood continuity and stability, and increased density of local networks and levels of collective efficacy (i.e., the ability of the community to come together for the common good) (Cagney, 2006). Older adults living alone may especially benefit from the availability of local social capital (Thompson & Krause, 1998). Older adults residing in neighborhoods with fewer other adults in their age group may feel isolated, with the neighborhood unable to promote the same level of social engagement. There is already some evidence that the well-established "widowhood effect" on mortality is lessened for individuals who live among a high concentration of widowed adults (Subramanian et al., 2008) and the authors speculate that this is because neighborhood structural contexts provide opportunities for interacting with others. This may suggest that having local contact with others of a similar age and in similar circumstances could be beneficial for the health of older adults. This may be particularly beneficial to cognitive health as social network access and integration are associated with a lower incidence of dementia (Fratiglioni et al., 2000; Seeman et al., 2001; Seeman et al., 2010).

1.2 Prior Research

To our knowledge, only a handful of studies have examined the relationship between neighborhood age structure and health, and these studies primarily find that a higher percent of older adults is associated with better health. For instance, a greater percent of adults 65 and over in one's census tract (i.e., a statistical subdivision of a county in the U.S., generally comprised of a population between 1,200 to 8,000 people) is cross-sectionally associated with better self-rated health for a sample of men and women 65 and older who lived in New

Haven, Connecticut (Subramanian et al., 2006), is protective against mortality for residents of Chicago ages 60 and over during the 1995 heat wave (Browning et al., 2006), and is cross-sectionally associated with better cognitive function in a Chicago study of adults 50 and over, but only for those individuals with moderate tenure in the neighborhood. It is negatively correlated for those with very long term residence (Clarke et al., 2012). While there is some evidence that it is also protective of mental health among men and women aged 65 years or older (Kubzansky et al., 2005), Hybels et al. (Hybels et al., 2006) find no association between age structure and depressive symptoms among that same age range. Only one study finds an adverse association of living in communities with more older adults – for adults 60 and over in Japan, living among a greater percentage of older adults was related to more difficulties with activities of daily living compare to living in areas with fewer older adults (Vogelsang & Raymo, 2014).

Three of these papers examine mechanisms linking neighborhood age structure to health. Two of them focus specifically on the characteristics of the local service environment. Kubzansky et al. (2005) and Subramanian et al. (2006) both used detailed information from the local *Yellow Pages* to assess a variety of services that could theoretically affect health outcomes, including health services (e.g., hospitals, audiologists), financial services (e.g., banks), social organizations (e.g., churches), recreational facilities, groceries and food outlets, and places of social interaction (e.g., beauty parlors, cafes), and potentially “undesirable” amenities including liquor outlets and pawnbrokers. None of these measures had predictive power for explaining the relationship between age structure and individual-level depressive symptoms or self-rated health and they were not related to these outcomes in individual models. While these papers also examine aspects of neighborhood income and socioeconomic status and its relationship to health, they do not examine the neighborhood factors in the same models as age structure thus limiting our ability to examine the mediating effects of these factors for the relationship between age structure and cognition. Clarke et al. (2012) does examine neighborhood age structure and NSES in the same model; however, this work examines neighborhood age structure as one possible mediator of the relationship between *NSES* and cognition and thus we cannot identify the extent to which *NSES* serves to mediate the relationship between neighborhood age structure and cognition.

The Browning et al (2006) paper examines several neighborhood factors and their relationship to mortality during the Chicago heat wave of 1995 (and in the preceding years for comparison), including age structure. Although this paper adjusts for the socioeconomic characteristics of neighborhoods (i.e., affluence) in the same model as age structure, it does not explicitly explore the potentially mediating role of neighborhood socioeconomic conditions. Thus, it remains unknown whether neighborhood affluence may reduce the association between age structure and mortality. Browning and colleagues did examine the mediating roles of neighborhood social factors (i.e., social networks and social cohesion) and commercial aspects of neighborhoods (i.e., commercial density and decline) to see how these factors might influence the relationship between neighborhood structural factors (including age structure) and mortality. While some of these factors reduce the association between neighborhood affluence and mortality, they have little effect on the relationship between neighborhood age structure and mortality, and the social factors in particular do

very little to explain this relationship. This once again leaves open the question of the mechanisms linking age structure to health.

There are several other limitations in the current literature on this topic. Other than the study by Vogelsang & Raymo (2014), which examined multiple waves of nationally-representative data in Japan, this line of work typically focuses on particular cities and has not yet introduced national data from the US. In addition, the study by Vogelsang & Raymo (2014) is the only one to date to examine trajectories of health using longitudinal data. Also, while age structure is hypothesized to be associated with social and economic conditions and the quality of neighborhoods, none of the studies mentioned above explicitly tests these potential mechanisms.

We use nine years of nationally-representative data from the Health and Retirement Study (HRS) (2002–2010) matched to Census/ACS data to examine the relationship between neighborhood (census-tracts) age structure and cognition. In addition to testing the overall association between the percent of older adults in a census tract and cognitive decline, we also examine three potential mechanisms: NSES and two measures capturing neighborhood social processes (i.e., perceived neighborhood cohesion, and perceived neighborhood safety/physical disorder) which have been theorized to explain the relationship between age structure and cognition but have not yet been explicitly tested. We expect neighborhoods with a greater percent of older adults to have more social cohesion, which should be protective for health by providing social contacts who can help with health information and support and, for cognition in particular, by fostering social engagement which has been linked to cognition. Neighborhood physical disorder captures perceptions of safety and several aspects of the physical disorder of neighborhoods and could work in the opposite direction of social cohesion by preventing older adults from engaging with neighbors and neighborhood resources and thus resulting in a lack of access to the social resources that may come from living in a neighborhood with a greater proportion of older adults. Neighborhoods with a smaller percentage of older adults might also have fewer economic resources which could be linked to a paucity of other spatial resources as well, including social resources and local services that foster better health and cognition. Within this framing, we address the following research questions:

Research Questions

1. Is having a greater percent of adults aged 65+ associated with better cognitive function and slower decline?
2. To what extent can the relationship between age structure and cognition be explained by NSES?
3. To what extent can it be explained by perceived neighborhood social cohesion and physical disorder?

2. Data and Methods

2.1 Data

Data came from the 2002–2010 waves of the Health and Retirement Study (HRS). The HRS is a multi-cohort longitudinal biennial survey of a nationally representative sample of older community-dwelling adults ages 51 and over and their spouses. The study was first launched in 1992 and currently involves six birth cohorts. This includes the “original” HRS cohort of individuals born between 1931 and 1941 (data collections in 1992, 1994, and 1996) and the AHEAD cohort of older adults born before 1924 (data collections in 1993 and 1995). These cohorts were merged in 1998 and two new cohorts were added at this time: the Children of the Depression (CODA) (1924–1930) and the War Babies (1942–1947). A fourth cohort, the Early Baby Boomers (1948–1953), was added in 2004 and a fifth cohort, Mid Boomers (1954–1959), was added in 2010. Data have been collected biennially since 1998. Addresses were geocoded by the HRS to 2000 Census tract boundary definitions and made available in the restricted use HRS Cross-wave file. The HRS coded addresses in 2010 to both the 2000 and 2010 census tract boundary definitions from the US Census Bureau, so this study was able to use the 2000 census tract boundaries for observations across the study period. Across all years there are about 8,000 unique tracts in this study with an average of 8.4 persons per tract (range from 1 to over 400). Annual estimates of age structure for the years 2002 through 2006 were calculated using linear interpolation between the 2000 Census and the first American Community Survey (ACS, 2005–2009) and are selected directly from the ACS 5-year estimates centered on subsequent years using a methodology described and validated elsewhere (Weden et al., 2015). Neighborhood socioeconomic status (NSES) is estimated using a time-invariant latent construct for 2000 through 2010 fit to the 1990 and 2000 Censuses and 2008–2012 ACS.

We began with 20,457 eligible respondents sampled with two consecutive waves of data for the 2002–2010 HRS. We dropped 66 respondents missing census tract information who could not be matched to the neighborhood data. An additional 1,016 respondents were dropped due to incomplete cognition data and another 627 respondents were missing other model covariates. Our final analytic sample included 18,748 HRS respondents aged 51 and over for a total of 67,447 person years, with an average of 3.6 waves of follow up time per individual (Range: 1–5 biennial waves of data).

2.2 Measures

2.2.1 Dependent variable: Cognitive Function—The HRS assessed cognitive function at each wave with the modified Telephone Interview for Cognitive Status, a multidimensional measure of cognitive function, (Brandt et al., 1988) modeled after the Mini-Mental State Exam (Folstein et al., 1975), as described elsewhere (Herzog & Wallace, 1997; Welsh et al., 1993). In sum, respondents were asked a series of questions that include assessments of word recall, working memory, episodic memory, mental processing, vocabulary, and general orientation. Cognitive function is the sum of the component scores and ranges from 0 to 27 for all self-respondents. For respondents who are unable to participate in the study, cognition is assessed through a series of questions to proxy

respondents; however, only self-respondents are included in the cognitive function score provided in the HRS and utilized here.

2.2.2. Neighborhood Age Structure—The primary explanatory factor is neighborhood age structure. In line with prior work, we used census tracts as proxies for neighborhoods and coded age structure as the percent of individuals ages 65 and over in each census tract (Browning et al., 2006; Kubzansky et al., 2005; Subramanian et al., 2006). Because there is some evidence that the relationship between age structure and health may not always be linear (Vogelsang and Raymo, 2014), we compared the continuous version of age structure to one using approximate tertiles, with nearly identical results. We report tertiles here for ease of interpretation. We could not identify a theoretical basis for specific cutpoints so we calculated tertiles using the national data distribution and then rounded to the nearest whole number. The first tertile is for neighborhoods with less than 10% of the population aged 65 and over; the second tertile includes neighborhoods with between 10% and 15% of the population aged 65 and over; and the third tertile includes neighborhoods with 15% or more of the population aged 65 and over. These cutpoints are similar to those used in Vogelsang and Raymo (2014) although they use four categories (<10%, 10–15%, 15–20%, and 20%+). This measure was lagged by one wave (two years) in our models to ensure that we are capturing the effects prior to cognitive status.

2.2.3. Neighborhood Socioeconomic Status—NSES is one potential mediator of the relationship between age structure and health. NSES is a factor score constructed and validated in other work (Miles et al., 2015) from a combination of elements of neighborhood socioeconomic disadvantage, which includes the following tract-level measures: median household income, percentage of female headed households, percentage of adult workers who are unemployed, percentage of households below the poverty line, percentage of persons with a high school degree, and percentage of persons with a bachelor's degree with some of the input measures reverse coded to ensure that all are in the same direction. Higher scores represent lower levels of disadvantage (ranges from –2.95 – 2.03). We used the measure of NSES constructed in Miles et al. (2015) and categorized it into tertiles using the sample of all census tracts in the U.S. We use tertiles for this measure rather than a continuous construction because preliminary analyses showed that the relationship between NSES and age structure was not linear. Specifically, census tracts falling in the middle tertile of NSES had a greater percent of individuals 65 and over than those in the lowest and highest tertiles of NSES. To account for this nonlinearity we categorized NSES into tertiles.

2.2.4 Perceived Neighborhood Social Cohesion and Physical Disorder—

Perceptions of neighborhood social cohesion and physical disorder are the other potential mediators we examine here. These measures came from eight items that were part of the Psychosocial and Lifestyle Questionnaire in the HRS. This questionnaire was introduced in 2006 and was restricted to a 50% random sample each year with the same sample of respondents re-interviewed in alternate waves. Respondents rated the extent of perceived neighborhood physical disorder on four items (i.e., vandalism/graffiti, cleanliness/garbage, vacant/deserted houses, and perceived safety walking alone at night). We follow the HRS naming convention and call this measure “physical disorder” although it arguably captures

both physical disorder and perceptions of safety. Social cohesion is an index based on four items (i.e. feeling part of the area, trusting people, friendliness of people, and the availability of help if in trouble). Both social cohesion and physical disorder measures use a reference area of a 20 minute walk or about 1 mile from one's home. The range for both neighborhood cohesion and disorder is 1 to 7, where 7 indicates the strongest agreement to statements indicating neighborhood cohesion or neighborhood disorder. Because these measures are available only for half the sample in each wave and unavailable prior to 2006 (i.e., included for 2006–2010 only), sample sizes are smaller for analyses using these measures (n=13,162 unique individuals).

2.2.5 Other covariates—Other covariates measured at the individual or household level include birth cohort, age, gender, race/ethnicity, individual socioeconomic status (i.e., wealth and education), health conditions, functional limitations, and mental health. Birth cohort indicates which of the five HRS birth cohorts individuals fell into based on year of birth. Age is time-varying and coded as a continuous variable and race/ethnicity is a time-invariant indicator categorized as non-Hispanic white, non-Hispanic black (hereafter referred to as white and black, respectively), and Hispanic/Other. Wealth is time-varying and captures total net assets of the household. It is parameterized as a categorical measure due to both the skewness of the wealth distribution and to account for negative wealth. The first category captures negative wealth and the other four approximate quartiles, specifically: (1) negative wealth, (2) \$0 to \$49,999, (3) \$50,000 to \$149,999, (4) \$150,000 to \$399,999; and (5) \$400,000 or greater. Highest attained education is time-invariant, coded in years, and centered at a value of 12 indicating high school attainment. We also included controls for three health factors that are known to be related to cognition: whether the respondent, respectively, ever had a diagnosis of hypertension, diabetes, or heart disease. These measures were each coded as indicator variables: 1 if respondents reported that they had ever received a doctor's diagnosis of the condition and 0 otherwise, and all are time-varying. We controlled for disability status at each wave using a scale of activities of daily living (ADLs) and a scale of instrumental activities of daily living (IADLs). The scales are the sum of binary indicators for activities reported as being somewhat difficult or very difficult. The total ADL score includes 5 activities: bathing, eating, dressing, walking across a room, and getting in or out of bed. IADLs include 5 instrumental activities: using a phone, handling money, taking medications, shopping for groceries, and preparing meals. Both scales range from 0 to 5 where higher scores indicate having more difficulty with activities. Finally we also control for time-varying depressive symptoms using the Center for Epidemiologic Studies -Depression Scale (CES-D). The CES-D score is the sum of eight binary indicators for when a respondent indicated certain feelings all or much of the time over the week prior to the interview. The binary indicators include questions asking whether everything is an effort, sleep is restless, the respondent felt alone, felt sad, could not get going, was depressed, happy (reverse coded), and enjoying life (reverse coded). Values ranged from 0 to 8, where higher scores indicate the respondents' feelings in the past week were more negative.

2.3 Statistical Analyses

Multilevel linear regression growth models were used to examine the relationship between neighborhood age structure and trajectories of cognitive function. All model variables, with the exception of age structure, were modeled as concurrent with the assessment of cognitive function. Thus, we captured cognition and most of the other covariates from 2002–2010. We lagged age structure by one wave so that, for example, the 2002 cognitive assessment is regressed on the 2000 observation of age structure. This lag is necessary because the ACS data are provided in five-year estimates, and lagging by one wave (two years) ensures appropriate temporal ordering between neighborhood age structure and cognition (i.e. that we are capturing age structure at a time point *before* the measure of cognitive function). Because there are up to five observations per person and individuals are clustered within census tracts, we employed three-level growth curve models. This included person-level random intercepts and linear age slopes to account for repeated measures within individuals and census tract-level random intercepts to account for individuals within tracts. Models also included all individual covariates mentioned above. All covariates other than birth cohort, gender, education and race were time-varying. Models were weighted using time-invariant HRS sampling weights from the year respondents entered the HRS study. Analyses were performed using Stata 13 software.

Age was the time scale for the models. To determine the best parameterization of age, we fit several specifications and compared Bayesian Information Criterion (BIC), which is based, in part, on the likelihood function and used as a criterion for model selection (the model with the lowest BIC is preferred). Specifically, we parametrized age in four ways: (1) linear, (2) quadratic, (3) 10-year splines, and (4) 5-year splines. The first panel of Appendix Table 1 shows the BIC statistics for each of the four age parameterizations. Model 1a shows the BIC for our full model with all controls and a linear measure of age. Model 1b shows the BIC for the same model but with a quadratic for age, Model 1c includes age in 10-year splines, and Model 1d includes age in 5-year splines. The model that fit the data best was a quadratic (age and age²); therefore, age and age² are included in all models.

We similarly compared the model fit using the BIC statistic for several other models. The second panel of Appendix Table 1 compares the neighborhood percent 65+ in tertiles to the continuous version included in the age parameterizations in panel 1. Age structure in tertiles fit the data slightly less well but fairly similar to the continuous version of this measure (BIC=357,347 for tertiles Model 1e vs. 357,339 for continuous Model 1b). As mentioned above, we report our findings in tertiles for ease of interpretation, but we also ran the models with a continuous version of age structure and results were similar.

The third panel adds in individual interactions with all model covariates in Model 1e by cohort, age, and gender, respectively, to see if these fully interacted models improve the model fit. None of these models fit the data better than the simpler model without interactions (Model 1e).

Finally, the fourth panel adds a cross-level interaction of age by age structure to Model 1e. This interaction of neighborhood age structure by individual age captures changes in the slope of age structure over time. Once again, this model does not improve the fit of the data.

Sensitivity Analyses—We ran two sensitivity analyses to examine whether the results were sensitive to (1) migration or (2) differential attrition from the sample. The first sensitivity analysis examined the extent to which the inclusion of individuals who move between census tracts during the study period might bias the results. For this analysis, we used the same models described above but individuals were censored if/when they moved. A move was defined as a change in census tract from the prior wave.

The second sensitivity analysis examined potential bias due to selective attrition. One concern in a study such as this one is that our sample may become selectively cognitively healthy over time, with the less healthy respondents leaving the study sample due to nonresponse or death. Because we do not include proxy respondents (i.e. family members who sometimes respond on behalf of an ill or incapacitated respondent), the self-report respondents who are retained in the study might differ from those at baseline. To account for this possibility, we employed attrition weights to weight the sample in each follow-up wave back to the characteristics of the full sample at entry year in our analytic dataset. The attrition weight was calculated from covariate-balancing propensity score models that were designed to reweight the data to account for differential attrition due to nonresponse or death, as described in Kovalchik et al. (2015). Analyses using attrition weights are identical to those described above except for the use of a weight combining the survey weight with the attrition weight instead of using only the HRS provided survey weight.

3. Results

Descriptive Statistics

Table 1 shows weighted descriptive characteristics for the two samples upon entry into the study (for most respondents this is the 2002 wave): (1) the full sample, and (2) the subsample of respondents for whom we have information on social cohesion and physical disorder from the Psychosocial Questionnaire. The average age of the full sample is 64. Approximately 82% of the sample is predominately non-Hispanic white; the mean years of education is 12.79 years (a little more than a high school degree), and 17 percent has negative wealth (i.e., debt). The average percent of individuals 65 and older for all census tracts in this study was 14% (not shown, ranges 0–92% across neighborhoods in this study). The average cognitive function score is 16 (range: 0–27). About half the sample has hypertension, 21% has heart disease, and 16% percent has diabetes upon entry to the sample. The average score on social cohesion is 5.5 (range: 1–7) and physical disorder is 2.4 (range: 1–7). The subsample with complete information on physical disorder and social cohesion is fairly similar to the main sample, although it does differ in a few important ways. The subsample is more likely to be non-Hispanic white, more educated, and more likely to live in a neighborhood with a higher percentage of adults 65 and older. The subsample with information on neighborhood cohesion and disorder is also somewhat older. This is because this subsample is first collected in 2006 as opposed to 2002 so it is less representative of the youngest age groups.

Association Between Age Structure and Cognitive Function

Table 2 displays the results of two regression models predicting cognitive function over the 2002–2010 time period. Both models control for age, age², birth cohort, gender, race/ethnicity, education, wealth, diagnosed heart disease, diabetes, hypertension, ADLs, IADLs, and CES-D score. The first model examines the baseline association between neighborhood age structure and cognitive status without controls for changes in the slope over time. The second model adds in an interaction between age by neighborhood age structure to examine changes in the slope of neighborhood age structure over time. The results of Model 1 indicate that living in neighborhoods with the highest tertile of adults 65 and over is associated with better cognitive function. Specifically, living in a neighborhood with a high percentage of older adults is associated with a 0.139 higher cognitive score than living in a neighborhood with a low percentage of older adults. We do not see a significant difference between living in a neighborhood with a medium percent of older adults (middle tertile) compared to a low percent (lowest tertile). Model 2 adds an interaction between the age variables and neighborhood age structure to examine the relationship between neighborhood age structure and cognition over time. These interactions are not statistically significant and the coefficients are very small suggesting that while living in a neighborhood with a high percent of older adults is associated with better cognition at baseline, there is no statistically significant difference in this association over time. Because we do not see differences in the association over time (and because the model fit statistics in Appendix Table 1 indicate that this was not the best fitting model), we do not include this interaction in the models for the mediation analyses discussed below.

Testing How Age Structure Operates Through Social and Economic Mechanisms

As discussed above, we examined three mechanisms potentially driving the relationship between age structure and cognitive function: (1) NSES, (2) perceived social cohesion, and (3) perceived physical disorder. The results are depicted in Tables 3 and 4. The first model in Table 3 is identical to that depicted in Table 2 but is restricted to the subsample of respondents with complete information on NSES. The second model in this table adds to the first model by adjusting for NSES. In preliminary results, we also ran this model with the addition of an interaction term between NSES and age structure but the interaction was not statistically significant suggesting that there are no added effects of the treatment by NSES. By comparing the two models we find that the addition of NSES makes very little difference for the relationship between age structure and cognitive function. The coefficient for the highest tertile of the percentage of older adults ages 65 and over is statistically significant in both models and changes by less than 1% between the two models for the highest tertile (from 0.140 to 0.146). As we saw in Table 2, the coefficient for the middle tertile of age structure is close to zero and not statistically significant. This suggests that even though NSES is itself strongly and significantly related to cognitive function it does little to mediate the relationship between age structure and cognition.

Table 4 is similar to Table 3 but examines the second set of mechanisms: social cohesion and physical disorder. Model 1 shows the coefficients for the basic model depicted in Table 2 but using the smaller sample size for this subsample. Models 2 and 3 show the results for these models upon the addition of social cohesion and physical disorder, respectively. Model 4

includes both social cohesion and physical disorder. Once again, we explored the possibility of including interactions for social cohesion and physical disorder with neighborhood age structure but the interactions were not statistically significant.

It is noteworthy that the coefficients for age structure are no longer statistically significantly associated with cognition in these models – even before the inclusion of the mediators. The coefficient for the highest age tertile for this subsample is also only about half the size of that for the full sample (0.016 as compared to 0.14 in Table 2, Model 1). The smaller sample size and demographic differences may explain why the beta for neighborhood age structure is smaller and no longer statistically significant. As noted in the discussion of Table 1 above, the two samples have some demographic differences that arise because this subsample is only available starting in 2006.

With regard to the mediators in these models, both social cohesion and physical disorder are statistically significantly associated with cognitive function when investigated separately (i.e., in Models 2 and 3), with social cohesion positively associated with cognition and physical disorder showing a slightly stronger negative relationship. Upon including both factors into the same model concurrently (Model 4), only physical disorder retains a statistically significant relationship with cognitive function. We can also see from Model 4 that the strength of the relationship between age structure and cognition is reduced upon inclusion of social cohesion and physical disorder into the model. Although the coefficient for age structure is not statistically significant, there is a large reduction in the size of the coefficient once social cohesion and disorder are added in Model 4. The coefficient for the highest tertile of age structure drops from 0.065 to -0.034 between Model 1 and Model 4 – a reduction of 48%.

Sensitivity analyses

We conducted sensitivity analyses to account for two potential sources of bias to the estimates above: (1) migration and (2) differential attrition. Supplemental Appendix Tables 2 and 3 show the results of the first sensitivity analysis. The vast majority of the sample remained in the same tertile of age structure between waves. About 13% of observations are in neighborhoods that became one or more tertiles older or younger between waves. Nonmovers' neighborhoods changed very little between waves. Even among movers, only 22% end up moving to a neighborhood with a different age structure. We also reanalyzed the basic model excluding movers. The results of these models are in Supplemental Appendix Table 3. The coefficients from this analysis are slightly larger but comparable to what we saw in the analyses that include the full sample of respondents. Similar to the Table 2 results, only the highest tertile of neighborhood age structure was associated with cognitive function.

To examine selection due to differential attrition, we weighted the data using a weight that combines the survey weight (provided by the HRS) with an attrition weight that reweights the data to account for differential attrition due to nonresponse or death. Results using the HRS survey weights did not differ substantively from those using a combined weight that incorporates the attrition weight. In addition, the coefficient for the age structure tertiles is nearly identical to what we report above (see Supplemental Appendix Table 4).

4. Discussion

In this nationally-representative sample of U.S. adults aged 51 and over, living in a neighborhood in the highest tertile of the percent of adults 65 and older was associated with significantly better cognitive function. Specifically, going from the lowest to highest tertile of age structure is associated with 0.139 points higher cognitive function. This association is statistically significant. To put this in perspective, having a hypertension diagnosis is associated with a similar change in cognitive function in these models (albeit a decrease of functioning) of 0.140. This association is moderate: based on the fully adjusted model, the size of the association is equivalent to approximately one year difference on the TICS. Accompanying this overall level difference, however, there were no significant differences in the rate of cognitive change over time (i.e., decline) for respondents who resided in neighborhoods with an older age structure. The lack of differences in cognitive trajectories by neighborhood age structure over time is consistent with other work examining socioeconomic context and cognition using longitudinal data (Al Hazzouri et al., 2011; Rosso et al., 2016) and could be for any of a number of reasons. One possibility could be that differential mortality would select a healthier sample over time, a pattern that has been shown, for example to produce cross-overs in health and mortality by race and socioeconomic status (Goldman, 1993; Palloni & Ewbank, 2004; Vaupel et al., 1979; Zajacova & Burgard, 2013). Although our sensitivity analyses that accounted for differential attrition due to nonresponse or death cannot eliminate the possibility that mortality selection is occurring, they shed doubt on the likelihood that this is a major driver. Alternatively, it is possible that natural aging processes become more relevant than environmental factors as older adults age.

Our work adds to the growing body of research showing that the sociodemographic characteristics of neighborhoods – specifically, their age structure - can have implications for one's own health (Browning et al., 2006; Clarke et al., 2012; Hybels et al., 2006; Kubzansky et al., 2005; Subramanian et al., 2008; Subramanian et al., 2006; Vogelsang & Raymo, 2014) and cognition (Clarke et al., 2011). But one of the outstanding questions in the current literature on age structure and health that remains is: what explains this relationship? We argue here that living in neighborhoods with a greater proportion of older adults may serve to improve cognitive health by facilitating more active social ties and engagement. Social interactions are a well-established mechanism for improving and maintaining cognitive well-being. There is already a vast literature on individual social relationships and health, including cognitive health (Berkman et al., 2000; House et al., 1988; Seeman et al., 2010), and the neighborhood social context and health (Kawachi & Berkman, 2000). There is also evidence that neighborhood physical disorder has the opposite relationship with health (Cohen et al., 2003; Kim, 2010; Krause, 1996; Lawton & Nahemow, 1980; Wu et al., 2015), and this may occur because neighborhoods that are unsafe or have high levels of disorder may impede utilization of neighborhood resources.

We build on this work by testing whether the social and economic local environment explains the relationship between age structure and cognitive health by examining three theorized mechanisms and whether they mediate the relationship between age structure and cognitive function: NSES, and perceived neighborhood social cohesion and physical

disorder. Of the mechanisms examined here, social cohesion and physical disorder appear to be two possible factors for explaining the relationship between the neighborhood percent of adults 65 and over and cognitive function, although our study can only provide suggestive evidence to this effect due to our smaller and more selective sample for this analysis. We theorize that cohesion and disorder may be the means through which the health benefits of age structure on cognition are realized. Thus, community-level interventions that increase local social ties and safety may help older adults take advantage of the benefits that come from having a greater proportion of older adults in the neighborhood. If anything, our findings suggest that higher levels of perceived physical disorder is even more detrimental to maximizing the benefits of living in an older neighborhood than social cohesion is beneficial. We find that the association with NSES, on the other hand, had an independent association with cognitive function that was essentially unchanged whether or not considered in conjunction with neighborhood age structure.

As with all studies, there are several limitations that should be noted. While we extend prior work in several ways: by longitudinally examining the associations between neighborhood age structure and cognition in a nationally representative sample, we still encountered smaller sample sizes and a somewhat different demographic breakdown for the mediation analyses of social cohesion and disorder. For the subsample, the association between age structure and cognitive function without the mediators is not statistically significant making it difficult to justify a formal mediation analysis. Given the smaller sample sizes for individuals who report on social cohesion and disorder in the HRS by study design, future work is needed to examine their impact in larger samples in other datasets. In addition, given that we use self-reported perceptions of neighborhood social measures, it is possible that cognitive status could influence differential reporting of these measures. Also, our measure of social cohesion may not capture the same underlying factors as social capital or networks. These other facets of the neighborhood social environment could be examined in other work. Another potential mechanism that could not be examined using the HRS is access to health, medical and caregiving resources, which may be more abundant in older neighborhoods. We speculate that the consequences of this data limitation is small however to the elucidation of mechanisms since other work did not find a significant mediating association between local resources and health (Kubzansky et al., 2005; Subramanian et al., 2006).

Consistent with other work, we use census tracts to capture neighborhoods. Census tracts are a useful proxy for neighborhoods as they were created by the Bureau of the Census to represent homogeneous groupings of residents. However, there is evidence that individuals may view their neighborhood quite differently from conventional boundaries (Coulton et al., 2001). Neighborhoods may not follow census tract boundaries, may vary from person to person, and, for some older adults, residential locations may not capture the full extent of the neighborhoods to which they are exposed. Relatedly, there has been a recent move in the neighborhoods literature toward investigating “activity spaces” – places where adults spend their time as opposed to focusing solely on residential areas (Browning & Soller, 2014; Cagney et al., 2013; Jones & Pebley, 2014). Future work is needed to examine whether these concepts are applicable to older populations who may spend most of their times close to home either due to functional limitations, driving restrictions, or for other reasons.

In sum, our study is the first to analyze age structure and cognitive function and decline in a national sample of the U.S. showing that older neighborhood age structure – specifically living among a higher proportion of adults 65 and over – is linked to better cognitive health among older adults, independent of individual-level demographics and health status. While interventions targeting individual-level factors have achieved limited and inconsistent effects to prevent cognitive decline (Daviglus et al., 2010; Plassman et al., 2010), our study suggests that public policies that seek to retain a high concentration of older adults in neighborhoods may be a public health measure worth exploring to protect cognitive health in late life.

This is also one of only a few studies to explore the mechanisms underlying the association between age structure and cognitive health. Given the reduced sample for the social cohesion and physical disorder measures examined here, our work provides only suggestive evidence that the social and physical aspects of older neighborhoods may explain the relationship between age structure and health. Nonetheless, if the effects of neighborhood age structure operate, in part, through increased social cohesion, programs that increase social cohesion for older adults in older neighborhoods -- for example through community centers, age-friendly initiatives, and services offered through senior villages (AARP, 2016) -- could improve not only physical health but also cognitive health. Similarly, improving the physical conditions of neighborhoods may enable older adults to better access the health benefits older neighborhoods provide. Deeper investigations into how neighborhoods with higher concentrations of older adults can promote social relationships and whether mitigating the effects of neighborhood crime, garbage, and vacant housing can further bolster the benefits of living in an older neighborhood could be promising avenues for future research.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Research Highlights

- Neighborhood age structure is related to cognitive function among adults over 50.
- Neighborhood social factors explain some of this relationship.
- Neighborhood socioeconomic status does little to explain this relationship.
- Neighborhood social factors may be a policy lever for improving cognitive health.

Table 1

Descriptive Characteristics of the Analytic Sample in Year of Entry into Sample

		Full Sample (n=18,748)	Cohesion and Disorder Subsample (n=13,162)
Cognitive function score (mean, sd)		15.95 (4.48)	15.89 (4.24)
Age in years (mean, sd)		64.69 (9.93)	66.21 (9.80)
Birth cohort (%)	HRS	27.26	27.31
	AHEAD	12.27	6.76
	CODA	13.63	11.63
	War babies	22.33	23.60
	Early Baby boomers	24.52	30.69
Race/Ethnicity (%)	Non-Hispanic White	81.81	84.36
	Non-Hispanic Black	9.41	7.92
	Hispanic/Other	8.77	7.72
Gender (%)	Female	56.10	56.14
Education in years (mean, sd)		12.79 (3.05)	13.06 (2.89)
Total wealth	Negative wealth	17.18	15.66
	\$ 0 – < \$50,000	19.6	18.75
	\$ 50,000 – <\$150,000	20.28	20.28
	\$ 150,000 – < \$400,000	21.69	22.03
	\$400,000+	21.15	23.28
Heart disease		21.17	23.32
Hypertension		49.62	54.75
Diabetes		16.06	18.91
Neighborhood % age 65+	Low (<10%)	26.99	22.90
	Medium (10–15%)	37.39	38.96
	High (15%+)	35.62	38.13
Neighborhood socioeconomic status in tertiles	Low	26.66	24.62
	Medium	37.56	37.73
	High	35.78	37.65
CES-D Score (mean, sd)		1.50 (1.99)	1.38 (1.94)
ADLs (mean, sd)		0.25 (0.74)	0.25 (0.75)
IADLs (mean, sd)		0.19 (0.62)	0.19 (0.63)
Perceived social cohesion (mean, sd)			5.51 (1.33)
Perceived physical disorder (mean, sd)			2.41 (1.33)

Notes: All measures except for cohort, race-ethnicity and gender are time-varying although descriptive statistics reported here are for year of entry into the sample. Weighted using HRS survey weights. Abbreviations: sd=standard deviation.

Table 2

Coefficients and 95% Confidence Intervals Associated with Cognitive Function, Growth Curve Models 2002–2010

Cognitive Function at baseline Model 1			Cognitive Function with interactions over time Model 2		
	β	95% CI	β	95% CI	
Neighborhood % age 65+	Low	reference		reference	
	Medium	-0.008		0.003	(-0.125, 0.131)
	High	0.139 *	(-0.108, 0.092)	0.161 *	(0.025, 0.297)
Age		-0.178 ***		-0.181 ***	(-0.192, -0.170)
	Age Squared	-0.003 ***	(-0.186, -0.169)	-0.003	(-0.004, -0.002)
(Neighborhood % age 65+) $\times$ Age	Low $\times$ Age			reference	
	Med $\times$ Age			0.004	(-0.006, 0.014)
	High $\times$ Age			0.004	(-0.007, 0.015)
(Neighborhood % age 65+) $\times$ Age Squared	Low $\times$ Age Squared			reference	
	Med $\times$ Age Squared			<0.001	(-0.001, 0.001)
	High $\times$ Age Squared			<0.001	(-0.001, 0.001)
Race/Ethnicity	White	reference			
	Black	-2.183 ***	(-2.335, -2.030)	-2.184 ***	(-2.336, -2.031)
Gender	Hispanic/Other	-0.984 ***	(-1.167, -0.801)	-0.985 ***	(-1.168, -0.802)
	Female	0.991 ***	(0.904, 1.078)	0.991 ***	(0.904, 1.0778)
Education in years		0.439 ***	(0.422, 0.457)	0.439 ***	(0.422, 0.456)
	Total wealth	-0.705 ***	(-0.835, -0.574)	-0.704 ***	(-0.835, -0.574)
Diagnosed hypertension	\$ 0 – < \$50,000	-0.185 ***	(-0.288, -0.083)	-0.186 ***	(-0.288, -0.083)
	\$ 50,000 – <\$150,000	reference			
	\$ 150,000 – < \$400,000	0.187 ***	(0.095, 0.278)	0.186 ***	(0.095, 0.278)
	\$ 400,000+	0.376 ***	(0.267, 0.48)	0.376 ***	(0.267, 0.484)
Diagnosed diabetes		-0.140 **	(-0.221, -0.059)	-0.140 ***	(-0.221, -0.059)
		-0.159 **	(-0.258, -0.060)	-0.159 **	(-0.258, -0.060)
Diagnosed heart disease		-0.099 *	(-0.188, -0.010)	-0.099 *	(-0.188, -0.010)

	Cognitive Function at baseline Model 1		Cognitive Function with interactions over time Model 2	
	β	95% CI	β	95% CI
CES-D Score	-0.091***	(-0.109, -0.072)	-0.091***	(-0.109, -0.072)
ADLs	-0.102***	(-0.156, -0.047)	-0.102***	(-0.156, -0.047)
IADLs	-0.622***	(-0.690, -0.554)	-0.622***	(-0.689, -0.554)
Number of unique individuals			18,748	
Biennial person years			67,447	

Notes: Weighted using HRS Survey weights. All models also control for birth cohort.

I Medium and high tertile differ significantly at $p<0.05$

* $p<0.05$
** $p<0.01$
*** $p<0.001$

Table 3

Coefficients and 95% Confidence Intervals Associated with Cognitive Function Net of Neighborhood SES, Growth Curve Models 2002–2010

Full model for the subsample with neighborhood SES information			Net of Neighborhood SES		
	β	95% CI	β	95% CI	
Neighborhood % age 65+					
Low		reference			
Medium ^I	−0.009	(−0.109, 0.091)	−0.003	(−0.103, 0.097)	
High	0.140 [*]	(0.032, 0.248)	0.146 [*]	(0.038, 0.255)	
Neighborhood socioeconomic status					
Low		reference			
Medium			0.145 [*]	(0.026, 0.264)	
High			0.308 ^{***}	(0.179, 0.438)	
Number of unique individuals	18,744		18,744		
Biennial person years	67,428		67,428		

Notes: Weighted using HRS Survey weights. Neighborhood cohesion and disorder were available for a sub-sample for only the 2006–2010 waves. All models also control for birth cohort, gender, race, education, wealth, whether doctor diagnosed heart disease, hypertension, diabetes, CES-D score, ADLs and IADLs.

^I Medium and high tertile differ significantly at $p < 0.05$

^{*} $p < 0.05$

^{**} $p < 0.01$

^{***} $p < 0.001$

Growth Curve Model Coefficients and 95% Confidence Intervals Associated with Cognitive Function, 2006–2010

Table 4

	M1 Subsample with data on neighborhood social cohesion and disorder		M2 Adjusted for perceived neighborhood social cohesion only		M3 Adjusted for perceived neighborhood physical disorder only		M4 Adjusted for perceived neighborhood social cohesion and disorder	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Neighborhood % age 65+								
Low		reference		reference		reference		reference
Medium	0.016	(-0.147, 0.179)	-0.001	(-0.162, 0.165)	-0.008	(-0.171, 0.155)	-0.008	(-0.171, 0.155)
High	0.065	(-0.106, 0.236)	-0.048	(-0.124, 0.219)	0.034	(-0.137, 0.205)	0.034	(-0.137, 0.205)
Neighborhood Social Cohesion			0.097	(0.053, 0.141)			-0.011	(-0.046, 0.068)
Neighborhood Physical Disorder					-0.148***	(-0.193, -0.103)	-0.141***	(-0.199, -0.103)
Number of unique individuals							13,162	
Biennial person years							17,662	

Notes: Weighted using HRS Survey weights. All models also control for birth cohort, gender, race, education, wealth, whether doctor diagnosed heart disease, hypertension, diabetes, CES-D score, ADLs and IADLs.

I_1 Medium and high tertile do not differ significantly at $p < 0.05$

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$