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Changes in neighborhood-level socioeconomic disadvantage and older Americans' cognitive functioning

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ABSTRACT

Background: While associations of neighborhood conditions with cognitive functioning at older ages have been established, few studies have investigated with a dynamic perspective if changing neighborhood socioeconomic conditions affect older residents' cognitive declines, and which putative factors mediate this relationship.
Method: Using data from waves 2 (2010–2011) and 3 (2015–2016) of the National Social Life, Health, and Aging Project (NSHAP) survey (n = 1837), ordinary least squares regressions and mediation analyses were conducted, adjusting for multiple confounders and testing eight putative mediators.
Results: Worsening neighborhood socioeconomic circumstances were associated with cognitive declines. Changes in depressive symptoms, sizes of close social networks, and physical activity substantially mediated this relationship.
Discussion: While 18.10% of the total effect occurred through these mechanisms, further pathways may work through contextual- and individual-level variables not assessed in the NSHAP.

1. Introduction

Cognitive functioning is a dimension of health that poses especially large concerns in later life (Langa et al., 2008; Livingston et al., 2017). Declining cognitive functioning includes weakening of memory, attention, and executive functions (Langa et al., 2008), and causes many difficulties for those affected by cognitive impairment, their families and caregivers, and government programs (Alzheimer's Association 2019; Langa et al., 2008; Livingston et al., 2017). Most research on cognitive decline has focused on individual-level risks (e.g. Breteler 2000; Livingston et al., 2017; Norton et al., 2014). Beyond individual-level variables, scholarship has also assessed the effects of features of contexts, including neighborhood characteristics. In fact, the cognitive reserve framework (Stern 2002), originally introduced to explain more effective employment of one's neural networks and heightened capability of utilizing substitute neural pathways that help protect cognitive capacity in later life related to education (Kremen et al., 2019; Singh-Manoux et al., 2011; Stern 2002; Zhang et al., 2015), suggests that neighborhood-level opportunities for cognitive stimulation, such as availability of libraries, can contribute to delaying cognitive decline. There are multiple other neighborhood-level factors relevant to older-age cognitive functioning that will be discussed in what follows. Among the contextual risk factors investigated are neighborhood socioeconomic circumstances (Clarke et al., 2013; Hazzouri et al., 2011; Meyer et al. 2017, 2018; Rej et al., 2015; Sheffield and Peek 2009), infrastructural development, social capital (Clarke et al. 2013, 2015), social disorder (Boardman et al., 2012), and air pollution (Ailshire and Clarke 2015; Ailshire et al. 2017; Andersson et al., 2018; Cerin 2019; Livingston et al., 2020). However, most earlier studies of these neighborhood effects either have been cross-sectional (e.g., Ailshire and Clarke 2015; Ailshire et al., 2017; Clarke et al., 2013) or have examined how neighborhood-level variables from one point in time affected changes in cognitive capacity through time (e.g., Boardman et al., 2012; Clarke et al., 2015; Hazzouri et al., 2011; Meyer et al., 2017, 2018; Rej et al., 2015; Sheffield and Peek 2009). As such, they could not rule out reverse causation; individuals with lower cognitive reserve, based on lower levels of education and less cognitively stimulating and lower status lifetime employment (which increase vulnerability to cognitive declines through time; Kremen et al., 2019; Singh-Manoux et al., 2011; Stern 2002; Zhang et al., 2015), might choose or be forced to live in less affluent neighborhoods. Therefore, the present study's aim to consider both neighborhoods and older residents' cognitive capacity in a

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dynamic context is vital. This study is informed by and adds to the existing literature showing how neighborhood *changes*, in themselves, affect various dimensions of quality of life (e.g., Cho et al., 2011; Christine et al., 2017; DeSena 2006; Kim and Cubbin 2019; Settels, 2020; Wallace et al., 2019). Readers will understand the importance of worsening neighborhood socioeconomic circumstances for cognitive declines and gain insight into relevant mechanisms. The identification of pathways between changes in neighborhood socioeconomic circumstances and changes in cognitive capacities is a central contribution of this study.

The above-mentioned studies on the links between neighborhood characteristics at one point in time and cognitive capacity in older residents inform our analyses. If more disadvantaged neighborhoods hold negative consequences for older residents' cognitive capacities, it is plausible that improving (or worsening) neighborhood socioeconomic circumstances slow down (or speed up) rates of cognitive declines. Beyond allowing for stronger causal inferences by limiting the influence of possible selection bias, studying the role of changing neighborhood socioeconomic circumstances for cognitive capacities through time potentially leads directly to policy implications; policies and programs that improve neighborhood socioeconomic circumstances or slow down neighborhood socioeconomic declines might be beneficial for maintaining older residents' cognitive capacities. Studies showing how neighborhood changes through time lead to changes in various dimensions of quality of life suggest likely effects upon changing cognitive capacities.

1.1. Potential mediators

Scholarship proposes various mechanisms potentially mediating between neighborhoods and cognitive functioning. We focus on neighborhood-level percentage of persons with incomes below the poverty line, households on public assistance, and adults unemployed, and we address eight putative mediators in the neighborhood-cognition relationship. Much of the scholarship cited below that supports the testing of our various putative mediators is based on cross-sectional investigations of the effects of socioeconomically disadvantaged neighborhoods. Our study expands on this by suggesting and testing mediators through which effects of improving or worsening neighborhood socioeconomic circumstances on changes in cognitive functioning occur.

Firstly, we discuss community social capital. The social disorganization theory proposes that as a consequence of poverty, socioeconomically disadvantaged communities face declines in the institutions and informal social networks that regulate residents' behavior while furthering their ability to collectively address their common dilemmas (Ansari 2013; Bursik 1988; Sampson and Groves 1989). This suggests that changing neighborhood socioeconomic circumstances might lead to concomitant changes in community social capital. Furthermore, worsening neighborhood socioeconomic circumstances lead to increased criminal and delinquent activity (Bursik 1988), and generalized distrust (Ross et al., 2001). Because older adults' high fearfulness of violence and crime can prevent them from exiting their homes and engaging in physical and cognitively stimulating social activity (Foster and Giles-Corti 2008; Fried and Barron 2005; Piro et al., 2006), worsening neighborhood socioeconomic circumstances can cause cognitive declines.

Secondly, mediation might occur through decreased community involvement. Beyond leading to declining community institutions (Clarke et al., 2013), worsening neighborhood socioeconomic circumstances cause sentiments of fear and lack of trust that limit residents' community participation (Aneshensel 2010; Aneshensel et al., 2011). Clarke et al. (2013) found that involvements in community groups and activities help safeguard older persons' cognitive functioning.

Thirdly and fourthly, changes in sizes of close social networks and social support are potential mediators. Worsening neighborhood socioeconomic circumstances can hamper keeping and gaining close and supportive social ties as they cause apprehension and lack of trust (Ross et al., 2001), stress and mental health problems (Kim 2010; York Cornwell and Behler 2015), and waning of community institutions that connect people (Clarke et al., 2013). This distress and generalized distrust can prevent the acquisition and maintenance of social relationships with both community residents and non-residents (Aneshensel 2010). Both local and nonlocal social ties are further impeded since community institutions and social gathering places attract both neighborhood residents and non-residents (van Eijk 2010). Close ties both within and outside of one's local area are important in later life since older adults are likely to have some social relationships with friends and family members living outside of their neighborhoods. According to the socioemotional selectivity theory of aging, reduced time horizons in later life lead older persons to prioritize present-moment emotional satisfaction over future socioeconomic success (Carstensen 1992; Charles and Carstensen 2010). Older adults are thus likely to shed their weaker social ties in favor of more frequent and close interactions with their stronger social connections (Carstensen 1992; Charles and Carstensen 2010). Therefore, for many older persons, the cognitive stimulation and social support obtained from close confidants might be especially beneficial for cognitive capacity. In fact, studies show that social networks (Ali et al., 2018; Amieva et al., 2010) and support (Amieva et al., 2010; Ellwardt et al., 2013) benefit older persons' cognitive health.

Fifthly, research connecting older adults' personal financial circumstances with cognitive functioning (Chen and Cao 2020) suggests that individual-level poverty is another possible mediator.

Sixthly, in addition to fears concerning exiting one's home (Foster and Giles-Corti 2008; Fried and Barron 2005; Piro et al., 2006), various consequences of worsening neighborhood socioeconomic circumstances might prevent regular engagement in physical activity. Indeed, residents of more socioeconomically disadvantaged neighborhoods were less likely to engage in physical activity partly through lower neighborhood aesthetic appeal, more constrained community social networks (Kamphuis et al., 2009), poorer neighborhood structural design, and more required police surveillance, monitoring, and control (van Lenthe et al., 2005). All these concomitants of worsening neighborhood socioeconomic circumstances discourage physical activity within one's community. Physical activity protects cognitive capacity (Buchman et al., 2019; Sofi et al., 2011; Toohey et al., 2013) through improved cerebrovascular and broader hemodynamic health, increased release of neurotrophins, and reduced stress through decreased levels of cortisol (Sofi et al., 2011).

Seventhly, neighborhood disadvantage is associated with higher consumption of alcohol (Barr 2018; Crawford et al., 2018) and cigarettes (Crawford et al., 2018; Miles 2006). Cigarette smoking (Ott et al., 2004) and excessive alcohol consumption (Kim et al., 2012) have been linked with older adults' cognitive declines. This suggests that worsening neighborhood socioeconomic circumstances might lead to rising alcohol and cigarette consumption, which might hold negative consequences for older residents' cognitive capacities.

Lastly, neighborhood disadvantage causes distress and depression (Kim 2010; Santiago et al., 2011), which are associated with older adults' cognitive declines (Aggarwal et al., 2014; Dotson et al., 2010; Gulpers et al., 2016; Livingston et al., 2017; Norton et al., 2014). For example, the higher home foreclosure rates and rising broader housing instability within neighborhoods undergoing worsening socioeconomic circumstances have been linked with distress and higher depressive symptomatology (Burgard and Kalousova 2015; Cagney et al., 2014). Furthermore, worsening neighborhood socioeconomic circumstances raise levels of criminal and delinquent activity, which are potent sources of apprehensiveness, distress, and depressive symptoms (Aneshensel 2010; Leonard and Murdoch 2009). Declines and improvements in neighborhood socioeconomic circumstances might thus lead to increases and reductions in distress and depression, respectively. Both midlife and later life distress and depression predict later life cognitive

declines (Livingston et al., 2020). In addition to the effects of chronic depression, depressive episodes are risk factors for cognitive declines (Livingston et al., 2020). Depression leads to neurological changes that increase extents of glucocorticoids circulating within the bloodstream and lead to protracted activation of the hypothalamic-pituitary-adrenal axis, which cause neuronal harm (Sachs-Ericsson et al., 2005). Furthermore, the lethargy and fatigue associated with depression among older persons (Moreh et al., 2010; Valentine et al., 2009) can hamper activities beneficial for older adults' cognitive functioning (Baer et al., 2013; Lindwall et al., 2012).

1.2. Potential moderation

These impacts of worsening neighborhood socioeconomic circumstances might vary by education. Education has been associated with older persons' cognitive health (Kremen et al., 2019; Singh-Manoux et al., 2011; Zhang et al., 2015), due to greater accumulation of cognitive reserve over the course of their lives (see Singh-Manoux et al., 2011; Stern 2002). The lower cognitive reserve accrued by less educated older adults might increase their dependence upon their communities as facilitators of healthy behaviors, social integration, and cognitive stimulation (Clarke et al., 2013).

1.3. Aims and hypotheses

This study's first aim is to examine how worsening neighborhood socioeconomic circumstances affect older residents' cognitive declines. The second aim is to assess if respondents' levels of education moderate this relationship. The third aim is to investigate mediation of this focal relationship through the eight putative mediators discussed above.

We hypothesize that worsening neighborhood socioeconomic circumstances are associated with stronger declines in older residents' cognitive functioning over time, that this relationship is stronger for residents without university degrees, and that this effect is mediated to some extent through each of the eight putative mechanisms.

2. Methods

2.1. Dataset and sample

Respondent-level variables were obtained from the National Social Life, Health, and Aging Project (NSHAP). The NSHAP is a longitudinal panel study of a representative sample of older Americans employing a complex multi-stage area probability sampling strategy and focusing on health, well-being, and interpersonal relationships. We employed waves 2 (2010–2011) and 3 (2015–2016) because they include the reliable and valid Chicago Cognitive Function Measure (CCFM) (further explained below).[1] 3005 respondents from 57 to 85 years of age were interviewed at wave 1. Wave 2 included newly interviewed respondents, wave 1 respondents, and partners of wave 1 interviewees. This second wave included 3377 respondents from 36 to 99 years of age, with a response rate of 74%. Because age-related cognitive declines begin as early as age 45 (Singh-Manoux et al., 2012), nine younger respondents were excluded. Among the remaining wave 2 respondents, 70.13% (n = 2362) were interviewed for wave 3. To ensure assessment of normal age-related cognitive declines, further excluded were 180 respondents who reported at wave 2 having had a first cancer that started in the brain, a stroke in the previous five years, Alzheimer's disease, or dementia. The timing of these two NSHAP waves locates this study in the recovery period following the 2007–2009 Great Recession.

[1] The NSHAP's first wave employed the Short Portable Mental Status Questionnaire to measure cognitive functioning. This measure's ceiling effect constrains its ability to assess variability in cognitive functioning throughout the sample (Shega et al., 2014). Therefore, we did not employ the first wave.

Information concerning the sampling design for the NSHAP's first wave is presented in Suzman (2009) and O'Muircheartaigh et al. (2009). Further details concerning the wave 2 sampling strategy are presented in O'Muircheartaigh et al. (2014). Approval for the NSHAP was obtained from the Institutional Review Boards of the National Opinion Research Center (NORC) and the University of Chicago. All NSHAP interviewees submitted written statements of their informed consent.

In congruity with other researchers (e.g., Estabrooks et al., 2003), we employed census tracts as proxies for neighborhoods. Census tracts are "small, relatively permanent statistical subdivisions of a county or equivalent entity …. Census tracts generally have a population size between 1200 and 8000 people, with an optimum size of 4000 people" (United States Census Bureau 2012). Based on their residential addresses, NSHAP respondents were associated with their census tracts and census tract-level variables by means of protected geodata procured from NORC via special contractual arrangements. This study included 598 census tracts. The average census tract included 3.07 respondents. While the minimum number of respondents within a census tract was 1, the maximum was 25.

While multilevel modelling is common within studies of contextual effects, this study's low numbers of respondents per census tract prohibited use of this technique. In fact, 269 of the 598 census tracts included only one respondent; individual and contextual effects and variance cannot be disentangled within level 2 units that include only one level 1 unit. Furthermore, Clarke (2008) has shown how a two-level model should have an average of at least five level-1 units per level-2 unit in order to produce reliable and valid estimates (this study's average was 3.07). Nonetheless, we report that intraclass correlations (ICC) of the empty model revealed that only 3.29% of the variation in our outcome was based on differences between census tracts, rather than within census tracts. Both the low numbers of respondents per census tract and the low ICC suggest refraining from multilevel modeling. To reduce bias based on correlations among respondents within the same census tract, all models here studied clustered standard errors by wave 2 census tract.

Wave 2 and wave 3 census tract-level data were obtained from the 2006–2010 and 2011–2015 American Community Surveys (ACS), respectively. For both waves, data over five years were averaged because individual years included too few respondents per census tract, and each census tract was studied across all five years. The 2010 Decennial Census could not be employed for wave 2 because it does not include this study's census tract-level socioeconomic variables (see below). The 2006–2010 and 2011–2015 ACSs were the most effective datasets for waves 2 and 3 of the present study since there are no alternative census tract-level data that do not extend beyond 2010 and 2015, respectively, two upper limits that should be maintained to avoid associating outcomes (at the individual level) with causes (at the census tract level) from later points in time (Holland 1986; Pötter and Blossfeld 2001; VanderWeele 2015).

It should be noted that United States census tracts' boundaries changed between 2000 and 2010. The ACS 2006–2010 census tract-level data were based on the 2000 census tract boundaries. As such, respondents were associated with ACS 2006–2010 census tract-level information based on their wave 2 residential addresses' locations according to the 2000 census tract boundaries. One of NORC's wave 2 census tract-level variables identified which respondents were located at wave 2 within census tracts whose boundaries had changed between 2000 and 2010. According to this variable, 31.46% of this study's respondents (n = 578) at wave 2 were located within census tracts (n = 192) whose boundaries had changed between 2000 and 2010.

There are notable differences between wave 2 respondents retained and not retained within wave 3. Those retained were more likely to be women and tended to be younger, be more educated, be in better health, be more involved in the community, have more close confidants, have better personal finances, and receive more social support. They also were more frequently engaged in rigorous physical activity and smoked

fewer cigarettes (as well as being less likely to currently smoke). Furthermore, they were more likely to be employed, be married, and have one or two children, and less likely to be childless or have three or more children. Moreover, they were less likely to have taken part in wave 1. Those re-interviewed resided in neighborhoods with more social capital, lower population densities, and better socioeconomic circumstances. In all other regards, they did not significantly differ from those not re-interviewed. There is a general trend of those re-interviewed being more advantaged in their personal and neighborhood characteristics.

2.2. Dependent variable

This study employed the CCFM, an adjustment of the widely used Montreal Cognitive Assessment. The CCFM is a multi-question comprehensive assessment of cognitive functioning spanning "executive function, visuo-construction skills, naming, memory, attention, language, abstract thinking, and orientation" (Tallon et al., 2017:103) with high validity and reliability (Kotwal et al., 2015). Scores on this index potentially spanned from zero to twenty. This study's dependent variable was change in cognitive functioning, created through subtracting wave 3 scores by wave 2 scores.

2.3. Independent variable

This study's central predictor was change in census tract-level socioeconomic disadvantage. In accordance with Ailshire and Clarke (2015), census tract-level socioeconomic disadvantage was operationalized through percentage of persons with incomes below the poverty line, households on public assistance, and adults unemployed. At each wave, these measures were standardized and then averaged (Cronbach's alphas: wave 2: 0.75, wave 3: 0.77). Change in neighborhood-level socioeconomic disadvantage was developed through subtracting wave 3 scores by wave 2 scores.

2.4. Potential moderator

We tested whether a respondent had a university degree as a potential moderator of the focal relationship.

2.5. Potential mediators

Community social capital was assessed through eleven questions. The first three questions, how often do people in this area visit? how often do people in this area do favors? and how often do people in this area ask advice? were answered on the following scale: (0) never, (1) rarely, (2) sometimes, or (3) often. The latter eight questions asked respondents for their agreement with the following statements: this is a close-knit area, people around here are willing to help, people in this area don't get along, people in this area don't share same values, people in this area can be trusted, people in this area are afraid at night, there are places where 'trouble' is expected, and you're taking a big chance walking alone at night. Possible answers were: (0) strongly disagree, (1) disagree, (2) neither agree nor disagree, (3) agree, or (4) strongly agree. Answers to negative statements were reverse coded. Within each wave, all measures were standardized and then averaged (Cronbach's alphas: wave 2: 0.78, wave 3: 0.80). A measure of change in community-level social capital was developed through subtracting wave 2 scores from wave 3 scores.

Community involvement was studied through frequency of volunteer work in the past year, attendance at meetings of organized groups in the past year, and attendance at religious services. At both waves, respondents reported for the former two variables: (0) never, (1) less than once a year, (2) about once or twice a year, (3) several times a year, (4) about once a month, (5) every week, or (6) several times a week. Similarly, frequency of attendance at religious services was on the following scale: (0) never, (1) about once or twice a year, (2) several times a year, (3) about once a month, (4) every week, or (5) several times a week. Three change scores were developed through subtracting wave 3 scores by wave 2 scores.

Sizes of close networks were obtained through the question, "Looking back over the last 12 months, who are the people with whom you most often discussed things that were important to you?" Respondents listed up to five confidants. If not included, their partners were added as sixth close network members. Respondents were then asked if they were close with anyone else, serving as a seventh potential confidant. Networks of close ties thus ranged from zero to seven. Wave 3 sizes were subtracted by wave 2 sizes to create a measure of change in close network size.

Social support from family members was assessed through the questions "How often can you open up to members of your family if you need to talk about your worries?" and "How often can you rely on family for help if you have a problem?" For each question, respondents answered (0) never, (1) hardly ever or rarely, (2) some of the time, or (3) often. At each wave, these two scores were averaged (Cronbach's alphas: wave 2: 0.60, wave 3: 0.74). Change in social support from family members was developed through subtracting wave 2 scores from wave 3 scores. Social support from friends was identically assessed through these two questions based on friends (Cronbach's alphas: waves 2 and 3: 0.73).

Regarding personal finances, respondents reported their total household assets, including all forms of wealth subtracted by all forms of debt, in dollars. Wave 2 amounts were adapted for inflation between waves 2 (based on 2010) and 3 (based on 2015). In accordance with the United States Bureau of Labor Statistics – Consumer Price Index Inflation Calculator (2020), they were increased by a factor of 1.086. To correct its right skew, this variable was natural logarithm transformed at each wave (the value of 0.01 was added beforehand to prevent values of zero from becoming 'undefined'). Wave 3 scores were subtracted by wave 2 scores to create the measure of change in total household assets. Assets become more important than income for quality of life in the later years (Willson et al., 2007; Robert and House 1996). Furthermore, because the value of the primary residence forms a large part of the typical American family's overall wealth (De Nardi et al., 2012), community socioeconomic declines that reduce the values of neighborhood homes indirectly affect Americans' total household assets. We did not emphasize changes in household incomes because they are not clearly linked with changing neighborhood circumstances, especially among older adults who are less dependent on local circumstances for their incomes.

Respondents reported their rigorous physical activity on the following scale: (0) never, (1) less than 1 time per month, (2) 1–3 times per month, (3) 1–2 times per week, (4) 3–4 times per week, or (5) 5 or more times per week. A measure of change in physical activity was created through subtracting wave 3 scores by wave 2 scores.

Change scores for numbers of alcoholic drinks per week and cigarettes per day were developed through subtracting wave 2 amounts from wave 3 amounts.

Depressive symptoms were assessed through the 11-item short form version of the 20-item Center for Epidemiologic Studies Depression Scale. In response to how often in the past week they "did not feel like eating," "felt everything was an effort," "felt lonely," "felt sad," etc., respondents answered (1) rarely or none of the time, (2) some of the time, (3) occasionally, or (4) most of the time. Two items denoting happiness were reverse coded. At each wave, these eleven scores were averaged (Cronbach's alphas: wave 2: 0.79, wave 3: 0.78). Wave 2 scores were subtracted from wave 3 scores to create a measure of change in depressive symptoms.

2.6. Control variables

Aside from whether a respondent changed census tracts between the two waves, all control variables were from wave 2. No further wave 3

variables were controlled to avoid blocking causal pathways (other than the putative mediators) between change in neighborhood-level socioeconomic disadvantage and cognitive declines.

At the census tract level, log-transformed (to reduce right skew) population density (persons per square mile) was controlled, as was situation within a metropolitan statistical area (MSA), a commonly used designation for urban location.

Numerous individual-level demographic variables were controlled, including gender, age, race/ethnicity (white, black, Hispanic (non-black), other), marital/relationship status (married or living with a partner, separated or divorced, widowed, never married), parental status (no children, one or two children, three or more children), and workforce status (employed, retired, not employed for reasons other than retirement). Except when serving as a moderator, education was controlled (university degree, high school diploma, less than a high school diploma).

Self-rated physical health (poor, fair, good, very good, excellent) was controlled. Additionally, an index of functional health was controlled, based on questions concerning seven daily living activities (walking across a room, walking one block, bathing, dressing, getting in or out of bed, eating, using toilet), answered on the following scale: (0) no difficulty, (1) some difficulty, (2) much difficulty, or (3) unable to do. These seven scores were averaged (Cronbach's alpha: 0.84). This measure is a previously validated index and physical disability potently predicts future health outcomes and risk of mortality (Smith et al., 1986).

Further controlled were respondents' years of residing in their local areas (0–5 years, 6–20 years, over 20 years) and whether they changed census tracts between the two waves.

We controlled whether a respondent took part in wave 1 since experience with the wave 1 cognitive functioning assessment, the Short Portable Mental Status Questionnaire, might have yielded practice effects. Repeated cognitive testing can result in higher scores as respondents come to learn the typical structure of questions and the types of answers being sought (Rabbitt et al., 2008; Singh-Manoux et al., 2011). Furthermore, these practice effects vary based on intelligence and education (Rabbitt et al., 2008; Singh-Manoux et al., 2011), increasing the need to control this variable.

2.7. Analysis

The first part of the analysis employed two ordinary least squares (OLS) regressions that revealed how census-tract level socioeconomic disadvantage is associated with cognitive functioning. The first model only adjusted for gender and race/ethnicity to uncover the full association. The second model included all control variables to assess effects net of preceding census tract- and individual-level circumstances. Unstandardized coefficients are reported. The second part repeated these two models with census tract-level socioeconomic disadvantage in interaction with whether a respondent had a university degree.

The third phase employed structural equation modelling (SEM) for mediation analyses. We followed the recommendations of VanderWeele and Vansteelandt (2014) for analyses of multiple mediators. Accordingly, the central equation regressed (OLS) cognitive functioning upon census tract-level socioeconomic disadvantage, the mediators, and all control variables. The remaining equations, one for each mediator, regressed (OLS) each mediator upon census tract-level socioeconomic disadvantage and all control variables. Therefore, model 3's dependent variable was cognitive functioning. The subsequent three models had as dependent variables this study's focal mediators (the only three that substantially mediated the central relationship): depressive symptoms (model 4), size of close network (model 5), and physical activity (model 6). Because the central equation adjusts for the mediators, this modelling strategy is effective even when the mediators are interdependent (see VanderWeele and Vansteelandt 2014).

These three mediators are pertinent to activities that benefit older persons' cognitive capacities. They thus aggregate in their salubrious effects. Accordingly, we use these three mediators in a joint analysis to check for possible "clustering" among them, thereby not overestimating their role in the association. Physical activity and depression furthermore present direct biological mechanisms, including neurodegenerative, cardiovascular, and broader physical health processes, through which cognitive functioning either declines or is maintained. In fact, physical activity builds up cognitive reserve that can sustain older persons' cognitive capacities even through the onset and accumulation of neurological declines and diseases; however, the precise molecular bases of this cognitive reserve have yet to be identified (Buchman et al., 2019). The key importance of social activity within close social networks for older persons is emphasized in the socioemotional selectivity theory of aging (Carstensen 1992; Charles and Carstensen 2010). Interactions and joint activities with close social contacts often have cognitively stimulating components that help build up cognitive reserve; however, this is difficult to disentangle empirically (Scarmeas and Stern 2003). There are thus strong reasons to expect that these three variables might serve as mediators. Furthermore, they are most apt to translate the more distant cause of worsening neighborhood socioeconomic circumstances into more proximal causes of older residents' cognitive decline over time.

We used Stata's 'nlcom' (nonlinear combinations of estimators) postestimation command to assess the proportions (along with statistical significances) of the total effect of census tract-level socioeconomic disadvantage upon cognitive functioning that were mediated through each of the following sets of potential mediators, presented in Table 1 (while all eight were investigated, this study focused on the above three substantial mediators).

For each potential mediating variable, the coefficient of the association of census tract-level socioeconomic disadvantage with the mediator was multiplied by the coefficient of the relationship between the mediator and cognitive functioning (see Baron and Kenny 1986). Concerning the above sets of mediators including multiple variables, 'nlcom' permits the addition of multiple mediating pathways. Accordingly, 'nlcom' was further used to compute the total effect of census tract-level socioeconomic disadvantage upon cognitive functioning through adding the direct effect to all mediated effects.

To reduce potential bias in results through selective attrition between the two waves (causes for attrition include institutionalization, inability to locate or re-interview a respondent, and death), we employed the inverse probability weighting technique recommended by Hawkley et al. (2014). Many wave 2 demographic and health variables were used to predict inclusion in wave 3. Inverse predicted probability scores developed through this logistic regression equation were multiplied by the NSHAP's wave 2 standard sampling weights before being incorporated into the analyses. Nonetheless, selective attrition might have caused underestimation of how neighborhood declines affect cognitive functioning if those more disadvantaged and vulnerable were more prone to attrition.

Table 1
Mediating pathways.

Larger Variable	Component Variables
Community involvement	Volunteer work in the past year Attendance at meetings of organized groups in the past year Attendance at religious services
Size of close social network	–
Social support	Social support from family Social support from friends
Community social capital	–
Total household assets	–
Physical activity	–
Substance consumption	Alcoholic drinks per week Cigarettes per day
Depressive symptoms	–

Missing data were dealt with through multiple imputation using chained equations (ten imputed datasets). Census tract-level socioeconomic disadvantage had no missing data. Change in cognitive functioning was missing for 15.81% of cases, and missing data in the mediators and confounders ranged from none, to 0.05% (workforce status, education, physical health, change in depressive symptoms), to 20.58% for change in frequency of volunteer work. The remaining variables with at least 10% missing data included change in frequency of attendance at meetings of organized groups, frequency of attendance at religious services, social support from family members, community social capital, and total household assets. While change in cognitive functioning was included in the multiple imputation process, the analyses excluded the 345 respondents originally missing data in this variable (see Von Hippel 2007), resulting in an analytical sample of 1837 respondents. Standard errors were adjusted for wave 2 census tract-level clustering. Analyses employed the Stata 16 statistical software package.

3. Results

Table 2 display descriptive statistics for the time-changing variables. At both waves, the average respondent showed relatively high cognitive functioning (wave 2: 15.26, wave 3: 14.58). Within each wave, neighborhood-level socioeconomic disadvantage had a standard deviation (SD) of just over three quarters (wave 2: 0.78, wave 3: 0.77) of that of each of its three standardized items. Furthermore, change in socioeconomic disadvantage had an SD of 0.55, suggesting a considerable amount of variability in neighborhood change.

At both waves, depressive symptoms were relatively few (wave 2: 1.40, wave 3: 1.47). Both average size of close network (wave 2: 4.60, wave 3: 4.19) and average extent of physical activity (wave 2: 2.90, wave 3: 2.66) showed moderate decreases over time.

At both waves, respondents were on average moderate drinkers and smokers. While social support from family tended to be quite high, that from friends was more moderate. The average respondent was sparsely involved in volunteer activities and organized groups (between 'once or twice a year' and 'several times per year'), and moderately attended religious services (between 'several times per year' and 'about once a month').

Table 3 presents descriptive statistics for the time-fixed variables. Women were slightly overrepresented (56.89%). The average respondent was initially slightly over 70 years of age, with an SD of 7.18 years implying a considerable amount of variability. Slightly over three quarters of the sample were white. While the majority of respondents' highest level of education was a high school diploma (55.07%), 30.23% had university degrees.

Table 4 displays the results of the two OLS regression models (model 1 controlling for gender and race/ethnicity, model 2 adjusting for all control variables) that reveal how changes in census tract-level socioeconomic disadvantage were associated with changes in cognitive functioning. Both models showed increased census tract-level socioeconomic disadvantage significantly associated with cognitive decline (model 1: coeff.: -0.414 (robust standard error: 0.172), $p < 0.05$; model 2: coeff.: -0.337 (0.159), $p < 0.05$). We used Stata's 'margins' post-estimation command to analyze the magnitude of this effect within model 2. We predicted change in cognitive functioning according to three extents of change in neighborhood socioeconomic disadvantage: one SD less than the mean (−0.56), the mean (−0.01), and one SD more than the mean (0.54). All covariates were kept at their means. The corresponding predictions were −0.54, −0.72, and −0.91, respectively. Moving from one SD less than to one SD more than the mean in change in socioeconomic disadvantage was associated with a further 0.37 point decrease in cognitive functioning (13.86% of the SD of change in cognitive functioning), which is a modest, yet notable, impact. Model 2 further revealed that compared with those with a university degree, those with only a high school diploma underwent worse cognitive declines (coeff.: -0.343 (0.172), $p < 0.05$). However, with and without adjustment for the control variables, having a university degree did not significantly moderate the focal relationship (results not shown).

In a next step, the SEM approach revealed that changes in depressive symptoms, sizes of close networks, and physical activity substantially mediated between changes in census tract-level socioeconomic disadvantage and changes in cognitive functioning (see Table 7 for all eight putative mediators). Table 5 displays the SEM results pertaining to these three central mediators; all models adjusted for all control variables. Model 3's dependent variable was cognitive functioning. With the three central mediators adjusted for, census tract-level socioeconomic disadvantage was no longer statistically significantly associated with cognitive functioning (coeff.: -0.276 (0.157)). These three central mediators are relevant to engagement in activities that safeguard older persons' cognitive capacities, thus acting in a cumulative way. Looking at the unique contributions of the three central mediators, however, only depressive symptoms (coeff.: -0.606 (0.185), $p < 0.01$) and close network size (coeff.: 0.133 (0.053), $p < 0.05$) were significantly associated with cognitive functioning. The relationship between physical activity and cognitive functioning was insignificant (coeff.: 0.076 (0.041)).

Investigating the paths leading from census tract-level socioeconomic disadvantage to the three central mediators, census tract-level socioeconomic disadvantage was significantly associated with depressive symptoms (coeff.: 0.057 (0.026), $p < 0.05$), but not with sizes of close social networks (coeff.: -0.121 (0.098)) or physical activity (coeff.: -0.141 (0.098)).

Table 6 displays statistics produced through 'nlcom' for the three pathways of mediation in Table 5. While none of the three mediating pathways individually reached statistical significance, all three pathways in combination significantly mediated the central relationship (coeff.: -0.061 (0.023), $p < 0.01$). Dividing the coefficients of the mediating pathways by the total effect of census tract-level socioeconomic disadvantage (coeff.: -0.337 (0.158)) revealed the extents of mediation through depressive symptoms (10.39%), sizes of close networks (4.75%), and physical activity (3.26%). All three pathways together explained 18.10% of the total effect.

Fig. 1 displays a path diagram of mediation through these three mechanisms; all models adjusted for all control variables.

Table 7 displays the complete set of mediating pathways, based on SEM modelling including all putative mediators (results available upon request) and produced through 'nlcom.' None of the additional five pathways mediated the focal relationship.

Testing further pathways of mediation focused on community social capital, sizes of close social networks, social support, and community involvement did not yield significant mediation effects.

3.1. Robustness analyses

This study investigates the effects of changes in neighborhood socioeconomic circumstances through time, which encompass both improvements and declines. For a robustness check, we divided the census tracts (total = 598) into quartiles within each wave (based on the neighborhood socioeconomic disadvantage variable: most advantaged, more advantaged, less advantaged, and least advantaged). Among the 598 census tracts, 253 remained within the same quartile, 177 moved up in advantage, 46 moved from the most advantaged to the more advantaged quartile, 85 transitioned into the less and least advantaged quartiles, and 37 transitioned from the less advantaged to the least advantaged quartile. As such, there was a high degree of variability between sampled census tracts in how their socioeconomic circumstances changed between waves 2 and 3 of the NSHAP, supporting use of changes in census tract-level socioeconomic circumstances as a central

[2] Based on models adjusting for the full set of control variables. P values of smaller than 0.10 are displayed to illustrate the size of the effects.

Table 2
Descriptive statistics for time-changing variables (N = 1837).

Variables	Wave 2		Wave 3		Change over Waves 2 and 3	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean/ %	Standard Deviation
Dependent Variable						
Cognitive Functioning (0–20)	15.26	3.15	14.58	3.54	−0.68	2.67
Independent Variable						
Neighborhood-Level Socioeconomic Disadvantage	−0.07	0.78	−0.09	0.77	−0.01	0.55
Mediating Variables						
Depressive Symptoms (1–4)	1.40	0.42	1.47	0.44	0.07	0.43
Close Social Ties (0–7)	4.60	1.50	4.19	1.31	−0.42	1.66
Physical Activity (0–5)	2.90	1.78	2.66	1.86	−0.24	1.94
Number of Alcoholic Drinks per Week	2.78	5.98	2.33	5.09	−0.45	4.23
Number of Cigarettes per Day	1.39	4.84	0.97	4.04	−0.41	3.02
Social Support from Family (0–3)	2.42	0.68	2.40	0.68	−0.01	0.76
Social Support from Friends (0–3)	2.03	0.83	1.98	0.78	−0.07	0.80
Logged Total Household Assets[1]	12.02	3.03	11.85	3.22	−0.13	2.81
Neighborhood Social Capital	0.04	0.56	0.05	0.56	0.01	0.51
Frequency of Volunteer Work in Past Year (0–6)	2.36	2.12	2.25	2.17	−0.12	1.78
Frequency of Attendance at Meetings of Organized Groups in Past Year (0–6)	2.89	2.12	2.77	2.20	−0.16	2.01
Frequency of Attendance at Religious Services (0–5)	2.67	1.77	2.57	1.77	−0.09	1.16
Control Variable						
Change in Census Tract						
Did not Change Census Tracts between Waves 2 and 3	–	–	–	–	82.47%	–
Changed Census Tracts between Waves 2 and 3	–	–	–	–	17.53%	–

[1] To adjust for inflation, amounts from wave 2 were multiplied by 1.086449 before being log transformed.

predictor.

Robustness checks repeated this study's analyses separately among respondents whose census tracts either improved, stayed the same, or transitioned from the most advantaged quartile into the more advantaged quartile (476 census tracts including 1495 respondents), and the rest of the respondents (the "worsening" group: 122 census tracts including 342 respondents). The results within both groups were similar to the overall results, except that the small sample size within the "worsening" group resulted in coefficients that did not reach statistical significance. These similar results support this study's focus on changes between the two waves in census tract-level socioeconomic disadvantage; the full spectrum of potential changes can either help prevent or accelerate older residents' cognitive declines.

Further robustness analyses differentiated respondents based on whether their wave 2 census tracts' boundaries changed between 2000 and 2010. While 192 census tracts (578 respondents) underwent boundary changes, 406 census tracts (1259 respondents) had stable boundaries. Robustness analyses based only on respondents within stable census tracts revealed coefficients in the same directions and of similar magnitudes, with somewhat lower levels of significance due to the smaller sample size.

4. Discussion

In a population-representative sample of older adults, worsening neighborhood socioeconomic circumstances were associated with decreases in cognitive functioning, confirming what was hypothesized. Changes in depressive symptoms, sizes of close networks, and physical activity mediated substantial portions (in total, 18.10%) of this overall effect, which was reduced to non-significance after adjustment for these three mediators. As such, our hypothesis that the focal relationship is mediated to some degree by each of the eight putative mediators was only partially confirmed. The modest magnitude of the overall effect is expected since contextual influences tend to be of smaller magnitude than personal characteristics (see Oberwittler 2004; Pickett and Pearl 2001; Stjärne et al., 2004). Furthermore, this study investigates contextual changes over only five to six years.

In contradiction to what was hypothesized, having a university degree did not significantly moderate the focal relationship, suggesting some uniformity in how worsening neighborhood socioeconomic circumstances affect cognitive declines. Nonetheless, education increases cognitive reserve and is significantly associated with an older adults' cognitive functioning at any particular point in time (see Singh-Manoux et al., 2011). Our findings confirm that having a university degree provides protection against cognitive declines through time.

This study's finding of mediation through depressive symptoms concurs with evidence linking neighborhood socioeconomic disadvantage with psychological distress (Kim 2010; Santiago et al., 2011) and depression with older persons' cognitive declines (Sachs-Ericsson et al., 2005; Sawyer et al., 2012). Neighborhoods undergoing worsening socioeconomic circumstances face higher rates of home foreclosures, more general housing instability (Burgard and Kalousova 2015; Cagney et al., 2014), and increased extents of delinquent and criminal activity (Aneshensel 2010; Leonard and Murdoch 2009), all of which raise distress and depression. Depression might be associated with cognitive declines through numerous means. Rather than causing cognitive declines, depression might be a prodrome, or early symptom of reduced cognitive abilities (Chen et al., 1999). Others have argued that depression is causally related to cognitive decline (Sawyer et al., 2012). Both midlife and later life depressive symptoms increase risk of later life declines in cognitive capacities (Livingston et al., 2020). Particular depressive episodes also heighten risk of later life cognitive declines (Livingston et al., 2020). Depressive symptoms lead to neurological alterations that precipitate elevated levels of glucocorticoids in the bloodstream and cause prolonged stimulation of the hypothalamic-pituitary-adrenal axis, culminating in hippocampal and neuronal damage, as well as furthering the build-up of amyloid-beta plaques, which increases Alzheimer's Disease symptomatology (Sachs-Ericsson et al., 2005; Sawyer et al., 2012). Additionally, depression causes lethargy (Dutton and Karakanta 2013; Nutt et al., 2006) that prevents the regular engagements in a variety of activities that protect older adults' cognitive capacities (Baer et al., 2013; Lindwall et al., 2012).

Concurrent with this study, neighborhood-level socioeconomic disadvantage has been shown to be associated with restricted social networks composed of weaker ties (e.g., Haines et al., 2011; van Eijk 2010; York Cornwell and Behler 2015). Strong social networks improve general health through social support, beneficial social influences, social

Table 3
Descriptive statistics for time-fixed variables (N = 1837).

Variables	Wave 2	
	Mean/ %	Standard Deviation
Control Variables		
Census Tract Logged Population Density (persons per square mile) – Wave 2	6.97	1.87
Census Tract Location – Wave 2[1]		
In an MSA	81.06%	–
Not in an MSA	18.94%	–
Gender		
Female	56.89%	–
Male	43.11%	–
Age – Wave 2	70.29	7.18
Race/Ethnicity		
White	75.36%	–
Black	13.01%	–
Hispanic, Non-Black	9.23%	–
Other	2.40%	–
Marital/Relationship Status – Wave 2		
Married or Living with a Partner	75.50%	–
Separated or Divorced	7.95%	–
Widowed	14.70%	–
Never Married	1.85%	–
Parental Status – Wave 2		
No Children	6.37%	–
One or Two Children	43.06%	–
Three or More Children	50.57%	–
Education		
Less than High School Diploma	14.71%	–
High School Diploma	55.07%	–
University Degree	30.23%	–
Physical Health – Wave 2		
Excellent	14.92%	–
Very Good	34.69%	–
Good	33.22%	–
Fair	14.98%	–
Poor	2.18%	–
Functional Health Problems (0–3) – Wave 2	0.09	0.23
Paid Work Status – Wave 2		
Working for Pay	30.56%	–
Retired	61.06%	–
Not Working for Reasons other than Retirement	8.39%	–
Length of Residence in Local Area – Wave 2		
Up to Five Years	13.41%	–
Six Years to Twenty Years	31.68%	–
Over Twenty Years	54.91%	–
Participation in Wave 1		
Did not Participate in Wave 1	34.84%	–
Participated in Wave 1	65.16%	–

[1] Location within a metropolitan statistical area (MSA) denotes an urban area.

Table 4
OLS regressions of change in cognitive functioning.

VARIABLES	Wave(s) of Assessment	Model 1	Model 2
Change in Census Tact-Level Socioeconomic Disadvantage	Change W2 to W3	−0.414* (0.172)	−0.337* (0.159)
Female (ref. male)	W2	−0.283 (0.150)	−0.191 (0.149)
Black (ref. White)	W2	0.236 (0.270)	0.336 (0.274)
Hispanic, Non-Black		0.953* (0.407)	0.812* (0.395)
Other		0.387 (0.341)	0.397 (0.336)
Census Tract Logged Population Density (Persons per Square Mile)	W2		−0.031 (0.050)
Census Tract Located in MSA (ref. Not Located in MSA)	W2		−0.021 (0.229)
Age	W2		−0.065*** (0.013)
Separated or Divorced (ref. Married or Living with a Partner)	W2		−0.329 (0.299)
Widowed			−0.123 (0.237)
Never Married			0.011 (0.476)
No Children (ref. Three or More Children)	W2		0.168 (0.297)
One or Two Children			−0.137 (0.166)
High School Diploma (ref. University Degree)	W2		−0.343* (0.172)
Less than High School Diploma			−0.120 (0.267)
Poor Physical Health (ref. Excellent)	W2		0.422 (0.614)
Fair			−0.138 (0.313)
Good			−0.168 (0.216)
Very Good			−0.089 (0.202)
Functional Health Problems	W2		−0.399 (0.449)
Working for Pay (ref. Retired)	W2		0.035 (0.182)
Not Working for Reasons other than Retirement			−0.166 (0.335)
Length of Residence in Local Area: Six Years to Twenty Years (ref. More than Twenty Years)	W2		−0.070 (0.173)
Up to Five Years			0.252 (0.280)
Changed Census Tract (ref. Did not Change Census Tract)	Change W2 to W3		−0.594** (0.222)
Participated in Wave 1 (ref. Did not Participate in Wave 1)	W2 and W3		0.131 (0.199)
Constant		−0.653*** (0.123)	5.340*** (1.111)
Observations		1837	1837

Robust standard errors in parentheses.
Two-tailed tests ***p < 0.001, **p < 0.01, *p < 0.05.

activity and embeddedness, and receipt of material, monetary, and informational resources (Berkman et al., 2000). More specifically, restricted social networks are detrimental to older adults' cognitive health (Ali et al., 2018). Larger social networks provide abundant cognitive stimulation, which enriches neural plasticity (Giles et al., 2012), helping to prevent cognitive decline. Additionally, extensive social networks reduce the effects of stress upon hypothalamic-pituitary-adrenal axis stimulation, preserving the functioning of older persons' neurons (Giles et al., 2012). Furthermore, social networks further healthy living habits and receipt of healthcare, averting brain morbidity and other diseases that compromise older persons' cognitive health (Crooks et al., 2008).

This study further suggests mediation through reduced physical activity. Increased crime within neighborhoods undergoing worsening socioeconomic circumstances can prevent older persons from exiting their homes and getting physical exercise (Foster and Giles-Corti 2008; Fried and Barron 2005; Piro et al., 2006), which protects cognitive functioning through facilitating the release of neurotrophins, improving cerebrovascular health, and reducing stress and cortisol levels (Sofi et al., 2011). However, community social capital did not mediate the focal relationship. The primary causes of reduced physical activity among older residents of neighborhoods undergoing worsening socioeconomic circumstances might be declines in neighborhoods' aesthetic appeal (Kamphuis et al., 2009), maintenance, and effective structural design (van Lenthe et al., 2005).

All three pathways thus play a role in the effects of worsening neighborhood socioeconomic circumstances upon older persons' cognitive functioning. Depression implicates neurodegenerative and cardiovascular processes that can directly affect cognitive functioning. Physical activity may improve brain health through cardiovascular

Table 5
SEM mediation (depressive symptoms, close social ties, and physical activity) analysis of change in cognitive functioning, OLS regressions.

VARIABLES	Wave(s) of Assessment	Model 3 Δ Cognitive Functioning	Model 4 Δ Depressive Symptoms	Model 5 Δ Close Social Ties	Model 6 Δ Physical Activity	Residual Variances
Change in Depressive Symptoms	Change W2 to W3	−0.606** (0.185)				
Change in Close Social Ties	Change W2 to W3	0.133* (0.053)				
Change in Physical Activity	Change W2 to W3	0.076 (0.041)				
Change in Census Tact-Level Socioeconomic Disadvantage	Change W2 to W3	−0.276 (0.157)	0.057* (0.026)	−0.121 (0.098)	−0.141 (0.098)	
Female (ref. male)	W2	−0.098 (0.149)	0.066* (0.026)	−0.372*** (0.102)	−0.051 (0.113)	
Black (ref. White)	W2	0.275 (0.265)	−0.060 (0.045)	−0.029 (0.205)	0.373* (0.184)	
Hispanic, Non-Black		0.783* (0.387)	−0.004 (0.051)	−0.111 (0.216)	0.541* (0.238)	
Other		0.315 (0.343)	−0.083 (0.074)	0.270 (0.270)	−0.051 (0.267)	
Census Tract Logged Population Density (Persons per Square Mile)	W2	−0.037 (0.050)	0.000 (0.008)	0.040 (0.035)	0.009 (0.036)	
Census Tract Located in MSA (ref. Not Located in MSA)	W2	−0.022 (0.222)	0.032 (0.034)	0.185 (0.163)	−0.054 (0.174)	
Age	W2	−0.058*** (0.013)	0.006** (0.002)	−0.007 (0.008)	−0.032** (0.010)	
Separated or Divorced (ref. Married or Living with a Partner)	W2	−0.356 (0.294)	−0.072 (0.043)	−0.322 (0.209)	0.337 (0.201)	
Widowed		−0.213 (0.232)	−0.140*** (0.041)	0.106 (0.134)	−0.124 (0.179)	
Never Married		−0.066 (0.475)	−0.070 (0.093)	0.047 (0.383)	0.351 (0.387)	
No Children (ref. Three or More Children)	W2	0.099 (0.296)	0.023 (0.045)	0.496 (0.266)	0.216 (0.216)	
One or Two Children		−0.131 (0.164)	0.008 (0.027)	0.059 (0.105)	−0.118 (0.125)	
High School Diploma (ref. University Degree)	W2	−0.314 (0.165)	0.018 (0.029)	−0.093 (0.118)	−0.070 (0.122)	
Less than High School Diploma		−0.154 (0.255)	−0.066 (0.051)	0.189 (0.177)	−0.405* (0.202)	
Poor Physical Health (ref. Excellent)	W2	0.343 (0.562)	−0.138 (0.146)	0.299 (0.291)	−0.593 (0.377)	
Fair		−0.156 (0.306)	0.000 (0.047)	0.240 (0.213)	−0.178 (0.201)	
Good		−0.143 (0.213)	0.050 (0.032)	0.130 (0.155)	−0.159 (0.167)	
Very Good		−0.107 (0.196)	−0.005 (0.031)	0.141 (0.148)	−0.050 (0.150)	
Functional Health Problems	W2	−0.361 (0.417)	0.096 (0.066)	−0.235 (0.279)	0.688* (0.303)	
Working for Pay (ref. Retired)	W2	0.039 (0.177)	0.001 (0.027)	0.145 (0.121)	−0.303* (0.140)	
Not Working for Reasons other than Retirement		−0.159 (0.330)	−0.104* (0.046)	−0.301 (0.196)	−0.395 (0.239)	
Length of Residence in Local Area: Six Years to Twenty Years (ref. More than Twenty Years)	W2	−0.085 (0.172)	0.016 (0.030)	0.041 (0.121)	0.251 (0.134)	
Up to Five Years		0.293 (0.281)	0.043 (0.043)	−0.074 (0.172)	−0.065 (0.162)	
Changed Census Tract (ref. Did not Change Census Tract)	Change W2 to W3	−0.620** (0.214)	−0.045 (0.035)	0.013 (0.126)	−0.045 (0.149)	
Participated in Wave 1 (ref. Did not Participate in Wave 1)	W2 and W3	0.137 (0.193)	0.009 (0.028)	−0.041 (0.111)	0.058 (0.124)	
Variance (*e.*Δ Cognitive Functioning)	Change W2 to W3					6.681*** (0.276)
Variance (*e.*Δ Depressive Symptoms)	Change W2 to W3					0.176*** (0.010)
Variance (*e.*Δ Close Social Ties)	Change W2 to W3					2.685*** (0.116)
Variance (*e.*Δ Physical Activity)	Change W2 to W3					3.556*** (0.171)
Constant		4.807*** (1.091)	−0.581** (0.204)	0.817 (0.715)	0.975 (0.742)	
Observations		1837	1837	1837	1837	1837

Robust standard errors in parentheses.
Two-tailed tests ***p < 0.001, **p < 0.01, *p < 0.05.

Table 6
Mediation pathways for Table 5 SEM results (N = 1837).

Variables	Coefficients	Robust Standard Errors	T-Score	P-Value
Change in Depressive Symptoms	−0.035	0.018	−1.89	0.059
Change in Close Social Ties	−0.016	0.014	−1.13	0.259
Change in Physical Activity	−0.011	0.010	−1.11	0.268
Joint Mediation of All Three Change Variables	−0.061	0.023	−2.62	0.009
Total Effect of Change in Socioeconomic Disadvantage	−0.337	0.158	−2.14	0.033

Table 7
Complete set of mediation pathways between change in socioeconomic disadvantage and change in cognitive functioning (N = 1837).

Variables	Coefficients	Robust Standard Errors	T-Score	P-Value
Change in Depressive Symptoms	−0.031	0.017	−1.80	0.072
Change in Close Social Ties	−0.014	0.013	−1.08	0.281
Change in Physical Activity	−0.010	0.009	−1.10	0.273
Change in Alcohol and Cigarette Use	0.005	0.006	0.82	0.412
Change in Social Support from Family and Friends	0.017	0.014	1.25	0.213
Change in Household Assets	0.010	0.021	0.49	0.627
Change in Neighborhood Social Capital	0.005	0.011	0.42	0.672
Change in Community Involvement	0.009	0.015	0.62	0.538
Total Effect of Change in Socioeconomic Disadvantage	−0.336	0.158	−2.13	0.033

improvements. Cognitively stimulating and social activities, the nature of which often cannot be fully discriminated such as in leisure activities that often have social and cognitively stimulating components (Scarmeas and Stern 2003), may both build up cognitive reserve that helps prevent cognitive declines.

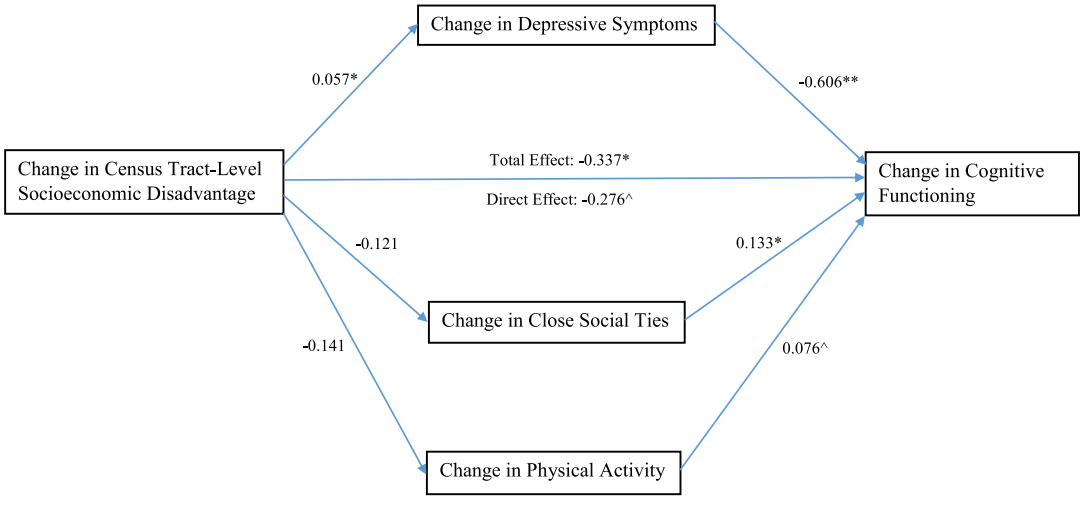
The three census tract-level socioeconomic measures here analyzed are central assessments of structural advantage/disadvantage. This study's mediation analyses show how changes in neighborhood structural advantages/disadvantages are proxies for concomitant changes in a complex set of associated variables such as residents' stress, depression, well-being, quality of life, social activity, opportunities for physical activity, etc.

As mentioned above, it is still unclear if increased depression shortly before onset of cognitive decline is a risk factor for or early symptom of reduced cognitive capacities (Chen et al., 1999; Livingston et al., 2017). This is also true for the other central mediators, reduced sizes of close social networks and physical activity. However, since worsening neighborhood socioeconomic circumstances predicted increases in depressive symptoms and decreases in sizes of close networks and physical activity, and neighborhood conditions are exogenous to individual social and health factors, concerns about reverse causation are alleviated.

This study's robustness analyses revealed that the impacts of changes in neighborhood-level socioeconomic circumstances upon older residents' cognitive functioning apply to neighborhoods declining into disadvantaged circumstances, as well as to neighborhoods either improving, changing only moderately, or declining but remaining on a more advantaged level. This suggests that these effects occur across the full range of neighborhood socioeconomic circumstances; while worse neighborhood socioeconomic circumstances are detrimental to cognitive capacities, more opulent neighborhood socioeconomic circumstances help prevent or slow cognitive declines.

4.1. Policy recommendations

The findings that neighborhood socioeconomic changes in either direction lead to parallel changes in older residents' cognitive functioning suggest that policies that improve neighborhood socioeconomic circumstances will yield benefits for older residents' cognitive health. This study further recommends that especially within neighborhoods undergoing worsening socioeconomic circumstances, policies and programs should facilitate older persons' participation in community groups and activities. Such involvements could help older adults develop strong and supportive social relationships, engage in salubrious amounts of physical activity, and avoid depressive symptoms. As well as protecting health more generally, such efforts can safeguard older persons' cognitive functioning.



Two-tailed tests *** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

Fig. 1. Path diagram of SEM mediation analysis from Table 5.[2]

4.2. Strengths and limitations

Strengths of this study include the possibility to assess neighborhood socioeconomic circumstances at the census tract level and link them to a population-representative sample, and testing multiple putative mediators. A further strength is that this is one of the few studies to investigate changes in both neighborhood socioeconomic circumstances and cognitive capacities, alleviating concerns of selection bias. Moreover, this study employs the CCFM, which is a highly effective measure of cognitive functioning, and advanced statistical techniques for the simultaneous analysis of multiple mediators (see VanderWeele and Vansteelandt 2014).

Numerous potential mediators based on ordinal categories (frequency of volunteer work, attendance at meetings of organized groups, attendance at religious services, and physical activity) were treated as continuous variables as continuous change scores were developed. The construction of these variables within the NSHAP makes this limitation inevitable, given our focus upon variables denoting change.

Only short-term effects are examined within this study based on a five to six year timespan. Future research examining longer trajectories of neighborhood socioeconomic changes might reveal effects of stronger magnitude than those here uncovered.

Additionally, multilevel modelling could possibly have provided further insights. However, for sample size reasons (see above), we could not effectively employ multilevel modelling in this study.

A lingering question is how to explain the remaining 81.9% of the total effect not captured by the eight putative mediators. We speculate that, on the one hand, these are connected to neighborhood-level variables difficult to operationalize within a survey, such as the quantity and quality of medical and social service facilities. The use of effective medical facilities may have direct biological connections with cognitive functioning through treatment of cardiovascular conditions and management of cardiovascular risk factors that are strongly related to brain health (see Sofi et al., 2011). Additionally, availability of medical and social service facilities are potential sources of instrumental and emotional support beyond that provided by family and friends. Instrumental and emotional support are protective of older adults' cognitive functioning (Amieva et al., 2010; Ellwardt et al., 2013).

Another possible mechanism is through environmental toxins. Neighborhoods in worse socioeconomic circumstances have higher extents of pollution and environmental hazards (Ailshire et al., 2017; Chi et al., 2016; Hazlehurst et al., 2018). Air pollution, in particular, has biological links with older adults' declining cognitive capacities (Ailshire and Clarke 2015; Ailshire et al., 2017; Andersson et al., 2018; Cerin 2019; Livingston et al., 2020). There is also some evidence that lead in groundwater might cause hearing impairment and cognitive declines (Fuller-Thomson 2018).

Additionally, contextual effects might be related to more fine-grained levels (e.g. within streets) of neighborhood resources and risks (which are not available within the NSHAP's third wave, preventing the creation of measures of change). While we investigated participation in volunteer and community activities, these measures do not assess the quality of community amenities, such as libraries, exercise facilities, parks, and green spaces. Neighborhoods' socioeconomic circumstances also determine resources available to create disability- and age-friendly environments. For example, they can affect the presence of effective public transport systems with disability-friendly features (White 2015). Availability of supermarkets and food markets with nutritious food such as vegetables and fruit also play a role, as exposure to a western-style diet (high levels of saturated fat and much additional sugar) can decrease learning and memory abilities within one week (Stevenson et al., 2020). Future research should study potential pathways such as these between changes in neighborhood socioeconomic circumstances and cognitive declines.

On the other hand, further individual-level variables may be assumed to be affected by changing neighborhood socioeconomic circumstances. Among the many community institutions and programs that decline within neighborhoods undergoing worsening socioeconomic circumstances are senior centers that help older persons remain socially active and connected (Aneshensel et al., 2016). These declines might also include social programs that are beneficial for older adults, including volunteer programs through which younger persons serve as social companions for older clients.

While speculative, worsening neighborhood socioeconomic circumstances might impact features of older residents' personalities and behavioral patterns that affect their physical, mental, and social activity levels, thus impacting their cognitive capacities. Worsening neighborhood socioeconomic circumstances could increase social disorder, causing older residents to experience fear, apprehension, and lack of control over their neighborhoods' social and physical conditions (Kim 2010; Leonard and Murdoch 2009; Ross et al., 2001). Consequent reduced sentiments of personal mastery and self-efficacy could discourage involvements in diverse activities that protect cognitive health.

The magnitudes of the explanatory abilities of the three central mediators are expected given some of the limits in studying the more distant factor of neighborhood effects. This distance increases the difficulty in finding associations between neighborhood-level exposures and individual-level outcomes (Kwan 2018). One limitation is based on the idiosyncrasy of neighborhood effects; different people respond in diverse and individualized ways to their communities' characteristics, making it difficult to establish a general main effect. Another limitation exists because of the temporal dynamics of neighborhood influences (Kwan 2018). In the present study, for example, neighborhood effects upon respondents who relocated to new census tracts might have differed based on the timing of this transition. Additionally, the effects of neighborhood socioeconomic changes likely varied based on their specific timing. Furthermore, the contextual socioeconomic characteristics here studied likely differed to some extent within different locations within each census tract (see Kwan 2018). While our findings identify important effects of neighborhoods and relevant means through which these effects occur, these limitations should be kept in mind.

5. Conclusion

This study revealed that worsening neighborhood socioeconomic circumstances increase older residents' cognitive declines, partly through depressive symptoms, smaller sizes of close networks, and less physical activity. This study encourages discussion and analyses of further mediating pathways.

Ethical statement

No ethical approval was required as this is a secondary analysis of data gathered by third parties.

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Declaration of competing interest

None.

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