Title
Neighborhood Predictors of Cognitive Training Outcomes and Trajectories in ACTIVE

Journal
Research on Aging, 39(3)

ISSN
0164-0275

Authors
Meyer, Oanh L
Sisco, Shannon M
Harvey, Danielle
et al.

Publication Date
2017-03-01

DOI
10.1177/0164027515618242

Peer reviewed

HHS Public Access
Author manuscript
Res Aging. Author manuscript; available in PMC 2018 March 01.

Published in final edited form as:
Res Aging. 2017 March ; 39(3): 443–467. doi:10.1177/0164027515618242.

Neighborhood Predictors of Cognitive Training Outcomes and Trajectories in ACTIVE

Oanh L. Meyer, PhD,
University of California, Davis School of Medicine

Shannon M. Sisco, PhD,
Department of Veterans Affairs

Danielle Harvey, PhD,
University of California, Davis School of Medicine

Laura B. Zahodne, PhD,
Columbia University

M. Maria Glymour, ScD,
University of California, San Francisco

Jennifer J. Manly, PhD, and
Columbia University

Michael Marsiske, PhD
University of Florida

Abstract

We examined the influence of neighborhood socioeconomic position (SEP), racial/ethnic composition, and living in a major city on cognitive trajectories and intervention outcomes. Data came from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study (N = 2,438). Mixed effects analyses examined associations between neighborhood variables and memory, reasoning, speed of processing, and everyday cognition, estimating differences in initial gains (potentially related to practice) and long-term rate of change over 10 years. The effect of reasoning training on initial gain was weaker for individuals in a major city. For everyday cognition, there was a stronger initial gain for memory-trained and control participants in areas with more racial/ethnic minorities, and for speed-trained and control individuals in higher SEP areas. The racial/ethnic minority effect was no longer significant after adjustment for multiple comparisons. Neighborhood factors may be more important in practice-related improvement than in long-term change.

Keywords

Neighborhood; Cognition; Cognitive Training; Plasticity; Social Determinants

---

Corresponding Author: Oanh Meyer, PhD, Alzheimer's Disease Center, Department of Neurology, University of California, Davis School of Medicine, 4860 Y Street, Sacramento, CA 95817, (916) 734-5218.

Cognitive impairment associated with diseases of aging is a major public health problem. A rich body of literature has described the various risk and protective factors that differentially affect cognitive impairment and decline. These factors include clinical diagnoses, baseline clinical characteristics, apolipoprotein E genotype, baseline volumetric measures of brain structure, and certain demographic characteristics (Evans et al., 1997; Glymour & Manly, 2008; Karlamangla et al., 2009; Mungas et al., 2010; DeCarli et al., 2008). Cognitive impairment and Alzheimer's disease (AD) appear to be more prevalent in certain racial/ethnic minority groups, including Black and Latino populations (e.g., Glymour, Weuve, & Chen, 2008; Sloan & Wang, 2005; Tang et al., 1998). Yet contextual social determinants of health (e.g., neighborhood environment) have rarely been studied as contributors of cognitive change in older adults. Additionally, it is unclear how these determinants impact response to cognitive training interventions meant to maintain or enhance cognitive abilities in older adults. These determinants of health are an important focus because they may contribute to racial/ethnic disparities in cognitive impairment and AD and can be modified through policy, prevention, and intervention (World Health Organization, 2006).

Social epidemiological theory suggests mechanisms for how neighborhoods might contribute to health outcomes (Bronfenbrenner, 1977; Diez Roux, 2012; Sampson, Morenoff, & Gannon-Rowley, 2002; Pickett & Pearl, 2001; Yen & Syme, 1999); one mechanism is via neighborhood socioeconomic position (SEP). Neighborhood SEP is related to a variety of outcomes, including health behaviors and health problems, greater morbidity and mortality (Antonovsky, 1967; Kitagawa & Hauser, 1973; Marmot, Kogevinas, & Elston, 1987; Robert & Li, 2001), and psychosocial outcomes such as psychological adjustment (Baum, Garofalo, & Yali, 1999; Everson-Rose, Skarupski, Barnes, Beck, Evans, & Mendes de Leon, 2011) and social support (Krause, 2006; Walker & Hiller, 2007). These latter outcomes are also related to late life cognitive function and plasticity (e.g. Barnes, Mendes de Leon, Wilson, Bienias, & Evans, 2004; Bassuk, Glass, & Berkman, 1999), suggesting that neighborhood characteristics might influence not only cognition, but response to cognitive interventions. Several recent studies (Al Hazzouri et al., 2011; Aneshensel, Ko, Chodosh, & Wight, 2011; Lang et al., 2008; Sheffield & Peek, 2009; Sisco & Marsiske, 2012; Wight et al. 2006) examined the relation between neighborhood effects and late life cognition, but to date, none have explored whether neighborhood factors predict response to cognitive interventions.

Neighborhood-Cognition Associations in Older Adults

Some research indicates that neighborhood effects on various dimensions of health may be especially important for older adults who may be more dependent on the resources in their immediate neighborhood due to financial and mobility constraints (Robert & Li, 2001). Researchers have suggested that low-SEP neighborhoods have fewer resources and services compared to high-SEP neighborhoods, and this might lead to cognitive impairments due to restricted opportunities for social and cognitive stimulation (Barnes et al., 2004; Ertel, Glymour, & Berkman, 2008). Using nationally representative data from the Study of Assets and Health Dynamics Among the Oldest Old (AHEAD), Wight and colleagues (2006) found that older adults living in neighborhoods with low level educational attainment had lower cognitive scores compared to those living in areas with high educational attainment, even after controlling for individual-level education (Wight et al., 2006). A United Kingdom study (Lang et al., 2008) compared the cognitive performances of older adults from the top and bottom quintiles (20%) of an index of multiple deprivation, and reported a downward trend in cognitive function for neighborhoods with greater deprivation after controlling for individual-level characteristics (Lang et al., 2008).

A handful of longitudinal studies have also shown that neighborhood factors influence cognitive change in older adults. Sheffield and Peek (2009) examined the influence of neighborhood socioeconomic status (SES) on 5-year change on the Mini Mental State Examination (MMSE), using data from the Hispanic Established Populations for Epidemiologic Studies of the Elderly (H-EPESE) study. Odds and rate of incident cognitive decline increased as a function of poorer neighborhood SES for Mexican Americans. More recent data from the Sacramento Area Latino Study on Aging (SALSA: Al Hazzouri et al., 2011) showed that lower neighborhood SEP was not associated with cognitive decline.

Racial/ethnic composition of neighborhoods also may play an important role in cognitive function. Data from H-EPESE showed that Mexican Americans living in more ethnically homogeneous neighborhoods experienced somewhat slower rates of decline, perhaps due to healthful behavioral norms, social organization, and support typical of such neighborhoods (Sheffield & Peek, 2009). Cross-sectional findings from the Health and Retirement Study (HRS: Aneshensel et al., 2011) indicated that the effect of neighborhood concentration of Black residents on cognitive function depended on individual education level. Among individuals with little formal education, cognitive performance declined slightly as the proportion of Black residents increased; however, among those with higher levels of education, cognitive function increased as the proportion of Black residents increased.

Finally, a small body of literature suggests that the prevalence of cognitive impairment and dementia is higher in rural compared to urban areas (Nunes, Silva, Cruz, Roriz, Pais, & Silva, 2010; Russ, Batty, Hearnshaw, Fenton, & Starr, 2012).

The Present Study

In this study, we build on the sparse literature investigating the influence of neighborhood characteristics on cognitive trajectories. An innovation of the present study is the capacity to also address whether neighborhood effects influence the magnitude and maintenance of response to cognitive interventions. As the population ages, cognitive interventions to reduce disability and increase cognition and independent functioning have become increasingly important. There is a theoretical basis for the notion that neighborhood factors may influence the degree of cognitive plasticity that is possible in late life. If biological factors are responsible for reductions in potential plasticity, and neighborhood characteristics influence those factors (e.g., by supporting physical fitness or health, as it has been shown to do), neighborhoods may indirectly influence not only one’s cognitive level, but also one’s potential for cognitive gain. Recent cross-sectional findings using data from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE: Sisco & Marsiske, 2012) trial indicated a significant relation between SEP and vocabulary, but no effect on immediate response to cognitive training (i.e., at post-test).

The current study builds on prior literature by examining how neighborhood characteristics might influence cognitive outcomes over the ensuing 10 years in the areas of reasoning, memory, speed of processing, and everyday cognition. Previous studies have shown a positive effect of the ACTIVE training on cognitive trajectories (e.g., Rebok et al., 2014). Thus, our first goal was to examine the influence of neighborhood characteristics (SEP, racial composition, and living in a major city) on cognitive trajectories independent of individual-level characteristics and baseline cognitive level, and whether neighborhood characteristics moderate the effect of training on cognitive trajectories. We hypothesized that individuals living in high-SEP neighborhoods and in major cities would benefit more from the intervention than individuals living in low-SEP neighborhoods or non-major cities (i.e., a three-way interaction of time by intervention by SEP and time by intervention by major city). Also, given that neighborhoods characterized by a high percentage of racial/ethnic minorities may also confer greater social support (Stewart, 2007), we hypothesized individuals living in areas with a higher percentage of racial/ethnic minorities would benefit more from the intervention. Second, previous studies also have shown that all ACTIVE participants, regardless of intervention group (i.e., both trained and controls) show an increase in cognitive scores after the first assessment (i.e., initial gain). Thus, our second goal was to examine the influence of neighborhood characteristics on the magnitude of that initial gain. We hypothesized that high-SEP neighborhoods, living in a major city or high percentage minority area would be associated with larger initial gains and better cognitive trajectories across memory, reasoning, speed of processing groups, and everyday cognition, independent of the intervention.

Method

Study Design

ACTIVE tested the effectiveness and durability of three cognitive interventions, and study design and major outcomes have been described in detail elsewhere (Jobe et al., 2001; Rebok et al., 2014). Briefly, the trial randomized individuals to one of three 10-session cognitive interventions designed to improve memory, reasoning, or processing speed performance or to a no-contact control condition. Following training, there was an immediate post-test for all trained and untrained participants, and follow-up assessments for everyone at 1, 2, 3, 5, and 10 years post-intervention.

The study enrolled participants and collected baseline data between 1997–2000 from six sites across the nation: University of Alabama (UAB) at Birmingham, Indiana University in Indianapolis, Hebrew Rehabilitation Center for Aged in Boston, Johns Hopkins University in Baltimore, Wayne State University in Detroit, and Pennsylvania State University. Testers at all six sites were trained in standardized assessment protocols and quality control by study investigators, and the coordinating center ensured fidelity to testing, scoring, and data management procedures.

Participants

The initial ACTIVE sample of 2,802 participants was cognitively healthy, independent, community-dwelling older adults aged 65 to 94 years. Efforts were aimed at recruiting a diverse sample, especially older Blacks, who were previously under-represented in most cognitive training research. Exclusion criteria included: a) being under age 65 at the start of the study, b) significant functional and/or cognitive decline at enrollment (e.g. impaired activities of daily living, MMSE < 23, Alzheimer's disease diagnosis), c) having a medical condition disposing the participant to imminent cognitive decline or to mortality within the next 2 years, d) severe sensory or communicative difficulties, e) having had cognitive training, or f) planning to be unavailable during the testing and training periods of the study. Recruitment strategies and sources varied by site, including on-site presentations, letters to interested persons and telephone calls, and newspaper advertisements. UAB recruited participants through the Alabama Department of Public Safety and through UAB eye clinics. The Hebrew Rehabilitation Center for Aged recruited from congregate and senior housing sites, senior centers, and a research volunteer registry. Indiana University and Johns Hopkins University recruited through a network of facilities providing activities and social services to seniors, local churches, and senior citizens' organizations, senior housing, and senior wellness or service programs. Pennsylvania State University recruited through a state-funded pharmaceutical assistance program for low-income elders. Wayne State University recruited from churches, hospital-based senior assessment centers, senior housing sites, and driver registration lists.

This study's sample consisted of a subset of 2,438 participants whose addresses could be geocoded to the level of the census tract and who had complete information on all variables of interest. We included only individuals who self-reported as non-Hispanic White (n = 1,758) or non-Hispanic Black (n = 680) because of small sample sizes in other ethnic groups.

Measures

The cognitive domains measured in ACTIVE included memory, reasoning, processing speed, and everyday cognition. Factor scores for each dependent variable were generated from confirmatory factor analysis using maximum likelihood estimation with robust standard errors using the regression method. Memory was measured using the Hopkins Verbal Learning Test (HVLT; Brandt, 1991), the Rey Auditory Verbal Learning Test (AVLT; Rey, 1941), and the Rivermead Behavioral Memory Test (Wilson, Cockburn, & Baddeley, 1985). Reasoning was measured using Letter Series (Thurstone & Thurstone, 1949), Letter Sets (Ekstrom, French, Harman, & Derman, 1976), and Word Series (Gonda & Schaie, 1985). Processing Speed was measured using the Useful Field of View test (UFOV; Ball, Owsley, Sloane, Roenker, & Bruni, 1993) and the Complex Reaction Time test (Ball & Owsley, 2000). Everyday Cognition was measured using the Everyday Problems Test (Willis & Marsiske, 1993), the Observed Tasks of Daily Living (Diehl, Willis, & Schaie, 1995), a timed task of problem solving in medication use, telephone use, and financial management, and the Timed Instrumental Activities of Daily Living (Owsley, Sloane, McGwin, & Ball, 2002), a timed test of ability to complete daily living tasks (e.g., find telephone number, make change, find and read ingredients on a can, find food items on a shelf, read instructions on medicine bottle). Higher scores on reasoning, memory, and everyday cognition indicated better cognitive outcomes, whereas higher scores on speed of processing indicated poorer (slower) cognitive performance.

Person-level variables included race/ethnicity: Black vs. White, age: centered at 70 years, education: centered at 12 years, and participation in cognitive training: controls vs. intervention group. Models also included covariate adjustment for gender, baseline depression (centered at the mean: 5.27) using the Center for Epidemiological Studies-Depression (CES-D) scale (Radloff, 1977) and baseline self-reported health (centered at the mean: 3.33) using a single-item from the SF-36. Consistent with previous ACTIVE studies, time was coded as years from baseline (0, .23, 1.23, 2.23, 3.23, 5.23, and 10.23) and captures rate of change. Initial gain was assessed by including an indicator variable coded "0" for baseline and "1" for all subsequent assessments; this indicator thus captures retest effects, which are likely to be stronger for all individuals in the beginning, regardless of intervention condition.

Similar to prior research (e.g., Sheffield & Peek, 2009; Al Hazzouri et al., 2011), neighborhoods were categorized by census tracts (Krieger, 2003), an administrative boundary designated by the U.S. Census Bureau. Census tracts are relatively permanent statistical geographical subdivisions typically containing about 4,000 residents (generally between 1,500 to 8,000). GeoLytics, a commercial provider of geocoding services and census demographic data, (1) geocoded the ACTIVE participant addresses, and (2) appended to these addresses data from the 2000 U.S. Census and 2002 Economic Census, creating a dataset that could be used to characterize the neighborhood environment. Geocoding was checked for quality assurance. Addresses associated with post office boxes, invalid house numbers, street names, and ZIP codes were flagged for follow-up; invalid addresses or poorly matched addresses were dropped (approximately 13%: our sample = 2,438, full ACTIVE sample = 2,802).

Neighborhood variables included neighborhood SEP (description below), percentage of racial/ethnic minorities in a census tract (defined as one minus percentage of Whites), and living in a major city – whether the census tract fell within a major metropolitan statistical area or not. To decrease collinearity with individual race/ethnicity, percentage of racial/ethnic minorities was standardized within each race/ethnicity's own distribution (i.e., for Blacks, percentage minority = (original variable − mean for Black race)/standard deviation for Black race). Because neighborhood SEP variables such as income, education, and occupation are often strongly correlated and load onto a common factor (Diez-Roux, 2004; Krieger, 2001), census-level data on these variables were combined into a weighted factor score to create a neighborhood SEP index that parsimoniously represented multiple socioeconomic variables. This factor score comprised median household income, percent of people with income ≥ $150,000, percent of people with ≥ Bachelor's degree, and percent of the work force in management positions or higher. This variable was mean-centered in regression analyses.

Data Analysis

Descriptive statistics were estimated using SPSS (IBM Corp., 2013). Sample characteristics are presented in Table 1. Mixed-effects regression models were estimated using R (R Development Core Team, 2010) to describe longitudinal trajectories of cognitive outcome measures and test the effects of neighborhood variables on cognitive trajectories independent of person-level covariates. Because ACTIVE was not designed to be a population-based study, each census tract only had one participant. Therefore, we treated each neighborhood factor as a person-level factor in a contextual analysis rather than perform multilevel modeling. Random intercepts for site and person within site were included to account for between-site and between-individual within site variability in level of cognitive outcomes. A random slope for person within site was also included to account for variation in rate of change between individuals from the same site.[1] Assumptions of linearity and normality were examined using graphical and statistical diagnostics. Residuals and random effects were examined to assure that they were normally distributed, and plots of residuals against predicted values and effects were examined to verify that nonlinear trends in the data or nonconstant variances were not present. Diagnostic results indicated that a model with autocorrelated residuals was better than one assuming independent residuals, so all models assumed this additional correlation structure.

Separate models were used to estimate trajectories for memory, reasoning, and speed factor scores within the corresponding intervention group and controls. That is, controls were compared to memory-trained participants with regards to memory scores, to reasoning-trained participants with regards to reasoning scores, and to speed-trained participants with regards to speed of processing scores. We hypothesized that everyday cognition could be influenced by training in all three cognitive abilities (Marsiske & Margrett, 2006), so similar to prior research using ACTIVE (e.g., Rebok et al., 2014), this outcome was assessed separately in each of the three intervention groups (i.e., everyday cognition scores comparing controls to – reasoning trained participants, to memory trained participants, and to speed of processing trained participants). Model 1 included time interactions with individual predictors of intervention group, age, race/ethnicity, and education, as well as demographic covariates (e.g., time by age, time by race/ethnicity);[2] Model 2 extended Model 1 by including neighborhood predictors and interactions of neighborhood characteristics with the initial gain indicator variable (e.g., initial gain by SEP) and the rate of change variable (e.g., time by SEP). If neighborhood characteristics predicted initial gain and/or rate of change, we then explored if this relationship was constant across intervention conditions (e.g., three-way interaction of time by intervention by SEP); thus, an optional Model 3 included relevant neighborhood by person-level interactions. To control for multiple comparisons, we used the Benjamini-Hochberg false discovery rate across the results of the final models (either Model 2 or Model 3) for all outcomes (Benjamini & Hochberg, 1995).

Results

Sample Characteristics

Table 1 shows characteristics of the sample by training group. Consistent with randomization in ACTIVE, participants' baseline characteristics were comparable across intervention groups. The sample consisted of 72.1% non-Hispanic Whites and 75.8%

[1]Although we account for clustering by site, site differences are not discussed because they were not the focus of the current study.
[2]All models adjust for gender, baseline health, and baseline depression, but we focus on race/ethnicity, age, and education for the purposes of this paper.

female. For the Black sample, the average percentage of racial/ethnic minorities in a neighborhood was 68.0%; for the White sample, the average was 12%. Neighborhood SEP was mean centered at 0 (SD = 3.30, range = −7.18 to 10.20), and percentage of those living in a major city was 36.6%.

Sixty-seven percent of the sample was retained five years after training and 44% at 10 years. Forty percent of the sample died post-baseline (as indicated by a single indicator variable of death = yes or no). Factors associated with loss to follow up (i.e., missing data at 10 years that were not due to death) as well as post-baseline death included older age, lower education, poorer physical and mental health, and worse performance on cognitive outcomes (e.g., MMSE). Loss to follow up and death did not vary by intervention group.

Mixed-Effects Models

Results from the final model (either Model 2 or Model 3) of mixed-effects analyses can be seen in Table 2 and are described below for each cognitive outcome.

Memory

In Model 1 (AIC = 9277.35), Black participants had lower memory scores ($\beta = -.39$, $SE = .049$, $p < .001$) and individuals with higher education ($\beta = .08$, $SE = .008$, $p < .001$) had better memory scores at baseline compared to their counterparts, whereas age ($\beta = -.04$, $SE = .004$, $p < .001$) and time ($\beta = -.12$, $SE = .009$, $p < .001$) were negatively associated with memory scores. There was a significant interaction of time and age, as well as significant interactions between the initial gain indicator variable and intervention, race, and age. Older individuals had weaker initial gains ($\beta = -.01$, $SE = .002$, $p < .05$) and declined more over time compared to younger individuals ($\beta = -.004$, $SE = .001$, $p < .001$). Initial gain was greater for trained participants ($\beta = .16$, $SE = .028$, $p < .001$), and weaker for Blacks ($\beta = -.07$, $SE = .033$, $p < .05$). In Model 2 (AIC = 9286.22), results were similar, and no neighborhood interactions (with initial gain or time) were significant, so we did not move on to Model 3. Adjustment for multiple comparisons in Model 2 confirmed all of the above effects, but the initial gain by age interaction was no longer significant, indicating that older individuals did not have weaker initial gains compared to younger participants.

Reasoning

In Model 1 (AIC = 6881.08), at baseline, Black participants had worse reasoning scores ($\beta = -.60$, $SE = .053$, $p < .001$) and those with higher education had better reasoning scores ($\beta = .11$, $SE = .009$, $p < .001$) compared to their counterparts, whereas age ($\beta = -.05$, $SE = .004$, $p < .001$) and time ($\beta = -.03$, $SE = .006$, $p < .001$) were negatively associated with reasoning scores. There were significant interactions of time and initial gain with race, age, and intervention, and a significant time by education interaction. Although initial gain was smaller for Blacks ($\beta = -.07$, $SE = .026$, $p < .01$), Blacks declined at a slower rate compared to Whites ($\beta = .01$, $SE = .005$, $p < .01$). Initial gain was greater for trained participants ($\beta = .43$, $SE = .022$, $p < .001$) but trained participants declined more quickly over time ($\beta = -.03$, $SE = .004$, $p < .001$). Initial gain was weaker for older participants ($\beta = -.004$, $SE = .002$, $p < .05$) and older participants declined more quickly over time ($\beta = -.001$, $SE = .0004$, $p < .001$). Participants who were more educated declined more over time ($\beta = -.002$, SE = .

001, $p < .01$). Model 2 (AIC = 6885.84) included neighborhood predictors. After accounting for neighborhood interactions with time, race differences in slope ($\beta = .01$, $SE = .007$, $p = .09$) and initial gain ($\beta = -.03$, $SE = .034$, $p = .42$) were no longer significant. Additionally, initial gain was weaker for individuals who lived in a major city ($\beta = -.07$, $SE = .032$, $p < .05$), and stronger for those who lived in an area with a higher percentage of minorities ($\beta = .03$, $SE = .013$, $p < .05$). In model 3 (AIC = 6880.53), relevant three-way interactions were tested (initial gain by percent minority by race, initial gain by city by race, initial gain by percent minority by intervention group) and a significant initial gain by city by intervention group interaction emerged ($B = -.12$, $SE = .047$, $p < .01$). The initial gain due to reasoning training was lower for those who lived in a major city versus those who did not (see Figure 1, Part A). Adjustments for multiple comparisons confirmed the above mentioned effects, except for the time by education interaction, and the initial gain by age, and initial gain by percent minority interactions. That is, education was unrelated to decline, and there were no differences in initial gains by age or neighborhood percent minority.

Speed of Processing

In Model 1 (AIC = 11594.94), individuals who were more educated ($\beta = -.04$, $SE = .009$, $p < .001$) scored better on processing speed at baseline. Those who were Black ($\beta = .26$, $SE = .055$, $p < .001$), and older participants scored worse ($\beta = .06$, $SE = .004$, $p < .001$). There were significant interactions of time with age and intervention, as well as initial gain with intervention, education, and age. Initial gain was stronger for those in the intervention ($\beta = -.82$, $SE = .036$, $p < .001$), but those trained declined more over time ($\beta = .04$, $SE = .007$, $p < .001$). Initial gain was weaker for those with more education ($\beta = .02$, $SE = .007$, $p < .05$). Initial gain was weaker for older individuals ($\beta = .01$, $SE = .003$, $p < .05$) and older individuals declined more over time ($\beta = .002$, $SE = .001$, $p < .01$). In Model 2 (AIC = 11603.12), no neighborhood interactions were significant, so we did not move on to Model 3. Adjustments for multiple comparisons confirmed Model 2 effects except that initial gain was not weaker for older individuals.

Everyday Cognition

A total of nine models were estimated (similar to the sequence above: three models in each trained group- memory, reasoning, speed of processing) to examine the influence of neighborhood predictors on everyday cognition. No significant neighborhood findings emerged for reasoning, so results are not discussed. Only the final model is discussed for memory and speed of processing groups (contact author for supplementary table with everyday cognition results for all three groups). For memory-trained and control participants, a significant initial gain by percentage minority interaction emerged ($B = .03$, $SE = .015$, $p < .05$); however this effect was no longer significant after adjustment for multiple comparisons. No significant three-way interactions emerged. For speed-trained and control participants, there was a significant initial gain by neighborhood SEP interaction: initial gain was stronger for trained and untrained individuals living in a higher SEP area ($B = .02$, $SE = .005$, $p < .05$; see Figure 1, Part B). This was still significant after adjustment for multiple comparisons. No significant three-way interactions emerged.[3]

[3]We also ran everyday cognition analyses for the full sample (with all intervention groups included) and found similar results.

Discussion

The purpose of this study was to examine the effects of neighborhood characteristics on cognitive test performance differences associated with repeated testing, changes over a 10-year follow-up period, and response to cognitive training. Our findings suggest that neighborhood variables are more strongly associated with initial gains (related to practice) than they are to long-term rate of change or response to cognitive interventions. Additionally, the pattern of effects varies across cognitive tasks and neighborhood characteristics.

Neighborhood Socioeconomic Position

Although theory suggests that high SEP neighborhoods may promote better cognitive outcomes and benefits from cognitive training, our hypothesis regarding neighborhood SEP was only partially supported in this study. We found that for the sample that included controls and speed-trained individuals, those who lived in neighborhoods with higher SEP demonstrated greater initial gains in everyday cognition, but not long-term gains. Although no studies have examined how neighborhood SEP is related to response to cognitive interventions, previous studies have shown low neighborhood SEP is associated with cognitive decline (e.g. Sheffield and Peek, 2009). However, Sheffield and Peek (2009) examined only Mexican American older adults. Our findings corroborate those of Al Hazzouri et al. (2011) who also sampled older Mexican Americans (primarily) and did not find a significant relationship between neighborhood SEP and cognitive decline. These heterogeneous results may be due to differences in measures across studies; for example, Sheffield and Peek operationalized their SEP variable as distinct quartiles, while we and Al Hazzouri et al. operationalized SEP as a single continuous variable. Additionally, it did not appear that Sheffield and Peek (2009) specified an initial gain (practice/retest) effect in their study, which may have conflated rate of change with the initial boost that comes as a result of repeated testing.

Living in a Major City

For the reasoning-trained group, those who did not live in a major city demonstrated greater initial gains, or practice-related improvement, in reasoning. Furthermore, our three-way interaction showed that the initial gain due to reasoning training was lower for those who lived in a major city versus those who did not. In other words, contrary to our hypothesis, people who lived in a major city benefited less from reasoning training. A potential explanation is that individuals who do not live in a major city have the most to gain from practice on cognitive tests and cognitive interventions because they potentially live in more resource-deprived areas and have fewer opportunities to be exposed to, or are less familiar with, the stimuli or procedures used in cognitive testing (Barnes et al., 2004). Indeed, research has shown that the prevalence of cognitive impairment and dementia is higher in rural compared to urban areas (Nunes et al., 2010; Russ et al., 2012). Although this is speculative, these less urban areas may have residents who are more vulnerable to cognitive impairment, thus, have the most to gain from cognitive practice and training.

Neighborhood Racial/Ethnic Minority Concentration

Initially, we found that those who lived in neighborhoods with a higher concentration of racial/ethnic minorities, relative to their race/ethnicity, demonstrated greater initial gains in reasoning. Also, models examining secondary outcomes of training (i.e., everyday cognition) also found an effect of racial/ethnic concentration. Specifically, for the sample that included controls and memory-trained individuals, individuals who lived in neighborhoods with higher concentrations of racial/ethnic minorities demonstrated greater initial gains in everyday cognition, similar to the reasoning finding. However, these findings regarding the role of percent minority in a neighborhood must be interpreted with caution since they were no longer significant after adjustment for multiple comparisons, which may explain why the literature on racial/ethnic composition of neighborhoods as it relates to cognition is mixed. Moreover, most studies have focused only on health benefits for Latinos living in neighborhoods with a high concentration of other Latino residents (e.g. Patel, Eschbach, Rudkin, Peek, & Markides, 2003; Eschbach, Ostir, Patel, Markides, & Goodwin, 2004; Al Hazzouri et al., 2011). It should be noted that due to the high collinearity between person-level race/ethnicity and neighborhood percentage of racial/ethnic minority variable, we standardized the neighborhood percentage of racial/ethnic minority variable according to racial/ethnic group means, and this may have limited our ability to detect differences. Future work should explore alternative strategies for addressing collinearity issues that would elucidate the role of neighborhood racial/ethnic composition on cognitive outcomes.

ACTIVE Intervention Study Effects

Interestingly, although neighborhood factors were not significant in predicting initial gains in memory or speed of processing outcomes, they were significant in predicting everyday cognition. That is, neighborhood factors affected memory and speed practice skills as they relate to everyday cognition, but not as they related to their targeted outcomes – memory and speed. A possible explanation is that neighborhood or social contextual factors matter more in higher-order processes or outcomes that have real-world significance – such as reasoning and everyday cognition, and less so in cognitive tests specific to memory and speed. Our bivariate correlations (not shown) indicate the strongest relation between reasoning and everyday cognition; thus neighborhood effects may not have emerged because their effects were overpowered by the effects of reasoning training. Because memory and speed were less strongly related to everyday cognition, it is possible there was more room for neighborhood effects to emerge in these cases. These explanations are speculative however, and future research should attempt to replicate these findings.

Within the reasoning group, we also found that racial differences in initial gain and change over time were no longer significant after accounting for neighborhood interactions. This may be because 80% of Black participants lived in a major city, and thus race may be confounded with living in a major city. Nonetheless, future research should further examine how neighborhood characteristics may explain or contribute to racial disparities in cognitive health.

Although not the focus of the current paper, it should be noted that for reasoning and speed outcomes, results indicated that trained participants declined more quickly over time.

However, this result is unlikely because participation in the ACTIVE intervention accelerated decline. A more likely explanation is that change over time is coupled with loss of training gains (see Jones et al., 2013 for discussion on this topic).

Limitations

It is important to note several limitations of the current study. As with any neighborhood study, it is unclear whether the neighborhood factors impact the participants who move into certain areas (causation), or whether certain characteristics of residents dictate where they live (selection). Our focus on longitudinal outcomes helps ameliorate this concern but cannot conclusively rule out the “selection” hypothesis. Also, we only had baseline addresses, and it was unclear how long people lived at these addresses or whether they had moved. It may be that neighborhoods affect individuals differently depending on length of time in the community. Because this dataset did not include data on relocation or reasons for attrition, we were unable to address these issues. Research has shown that for older adults who do move, the correlates of health and well-being can be complicated, because older adults’ types of moves and reasons for moving vary considerably (Litwak & Longino, 1987; Speare & Meyer, 1988; Wiseman, 1980). Relocation to an institution has often been associated with negative health and well-being outcomes, although this is not universally true (e.g., Curtiss, Hayslip, & Dolan, 2007; Danermark & Ekstrom, 1990). Negative effects on health and daily functioning have been found even for those moving voluntarily within the community (Choi, 1996; Ferraro, 1983; Lawton & Yaffe, 1970), although findings for these effects are mixed (Wilmoth & Chen, 2003; Dimond, McCance, & King et al., 1987; Eckert & Haug, 1984). In other words, the meaning and nature of relocation for older adults is likely varied, and the effects of relocation on health and cognition are not clearly predictable. This is an important issue and future research on neighborhood effects should ensure that data collection on relocation is captured and examine how it affects cognitive decline (or response to cognitive training). Another limitation was that we did not perform multi-level modeling to distinguish compositional from contextual effects because each census tract only had one person, making individual and neighborhood-level effects indistinguishable. Also, estimating neighborhoods based on census tract is not ideal: census tracts are administrative boundaries based on population density, and may not always capture true neighborhoods, especially in rural areas where neighborhoods may not exist. In this study, rural participants’ census tracts may be better considered as the general area in which they lived, versus a neighborhood per se. Of note, the majority of participants dropped from the original ACTIVE sample after geocoding were those who lived in rural areas, for example those who used “Rural Route” addresses rather than physical addresses. Also, it is important to note the somewhat small effects which should be replicated in future studies. Finally, the sample included only non-Hispanic Black and White participants and individuals who were healthier and more educated. Thus, caution must be used in generalizing study findings to the general older adult population, particularly non-Black minorities, and individuals who live in rural areas or who are less educated and in poorer health.

Conclusion

Despite these limitations, the current study adds new knowledge to the field of cognitive function and neighborhood effects. ACTIVE was the first multisite clinical trial to test the effects of cognitive training on cognitive abilities and function. A strength of the current study is the inclusion of neighborhood factors as they potentially relate to cognitive trajectories and intervention gain. In line with previous research, our findings indicate that neighborhood factors do impact cognitive outcomes albeit in a subtle way (i.e., mostly through practice-related effects). A novel finding was that older adults not located in a major city benefitted more from a cognitive intervention to enhance reasoning abilities. An implication is that older adults from areas that are less urbanized may derive the most benefit from practice-related improvement and cognitive training. If this were true, policy and intervention efforts focused on cognitive improvement in these areas might be the most efficacious for improving overall cognitive health. However, more research is needed to support this supposition and we suggest cognitive intervention studies attend to neighborhood effects, their interaction with race/ethnicity, and the potential differential effects of neighborhood characteristics across cognitive domains.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This work was supported by the Advanced Psychometrics Methods in Cognitive Aging Research (R13AG030995) and by National Institutes of Health grants to the University of California, Davis Alzheimer's Disease Center (P30AG010129), the Latino Aging Research Resource Center (P30AG043097) and the Clinical and Translational Science Center (UL1 TR 000002). The ACTIVE intervention trials were supported by grants from the National Institute on Aging and the National Institute of Nursing Research to Hebrew Senior Life (U01NR04507), Indiana University School of Medicine (U01NR04508), Johns Hopkins University (U01AG14260), New England Research Institutes (U01AG14282), Pennsylvania State University (U01AG14263), the University of Alabama at Birmingham (U01AG14289), and the University of Florida (U01AG14276).

References

Antonovsky A. Social class, life expectancy and overall mortality. The Milbank Memorial Fund Quarterly. 1967:31–73. [PubMed: 6034566]

Al Hazzouri AZ, Haan MN, Osypuk T, Abdou C, Hinton L, Aiello AE. Neighborhood socioeconomic context and cognitive decline among older Mexican Americans: Results from the Sacramento Area Latino Study on Aging. American Journal of Epidemiology. 2011; 174(4):423–431. [PubMed: 21715645]

Aneshensel CS, Ko MC, Chodosh J, Wight RG. The urban neighborhood and cognitive functioning in late middle age. Journal of Health and Social Behavior. 2011; 52(2):163–179. DOI: 10.1177/0022146510393974 [PubMed: 21673145]

Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. Investigative Ophthalmology & Visual Science. 1993; 34:3110–3123. [PubMed: 8407219]

Ball, K., Owsley, C. Increasing mobility and reducing accidents in older drivers. In: Schaie, KW., editor. Societal Impact on Mobility in the Elderly. New York, NY: Springer; 2000.

Barnes LL, Mendes de Leon CF, Wilson RS, Bienias JL, Evans DA. Social resources and cognitive decline in a population of older African Americans and whites. Neurology. 2004; 63(12):2322–2326. [PubMed: 15623694]

Bassuk SS, Glass TA, Berkman LF. Social disengagement and incident cognitive decline in community-dwelling elderly persons. Annals of Internal Medicine. 1999; 131(3):165–173. [PubMed: 10428732]

Baum, A., Garofalo, JP., Yali, AM. SES and chronic stress: Does stress account for SES effects on health?. In: Adler, NE.Marmot, M.McEwen, BS., Stewart, J., editors. Socioeconomic Status and Health in Industrialized Nations. New York: New York Academy of Science; 1999. p. 131-144.

Benjamini Y, Hochberg Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. Journal of the Royal Statistical Society, Series B (Methodological). 1995; 57:289–300.

Bradley, DE., Longino, CF. International handbook of population aging. Springer; Netherlands: 2009. Geographic mobility and aging in place; p. 319-339.

Brandt J. The Hopkins Verbal Learning Test: development of a new memory test with six equivalent forms. The Clinical Neuropsychologist. 1991; 5:125–142.

Bronfenbrenner U. Toward an experimental ecology of human development. American Psychologist. 1977; 32:513.

Choi NG. Older persons who move: Reasons and health consequences. Journal of Applied Gerontology. 1996; 15:325–344.

Curtiss K, Hayslip B Jr, Dolan DC. Motivational style, length of residence, voluntariness, and gender as influences on adjustment to long term care: a pilot study. Journal of Human Behavior in the Social Environment. 2007; 15:13–34.

Danermark B, Ekstrom M. Relocation and health effects on the elderly: A commented research review. Journal of Sociology and Social Welfare. 1990; 17:25.

DeCarli C, Reed BR, Jagust WJ, Martinez O, Ortega M, Mungas D. Brain behavior relationships amongst African Americans, Caucasians and Hispanics. Alzheimer Disease and Associated Disorders. 2008; 22(4):382. [PubMed: 19068502]

Diehl M, Willis SL, Schaie KW. Everyday problem solving in older adults: observational assessment and cognitive correlates. Psychology and Aging. 1995; 10:478–490. [PubMed: 8527068]

Diez-Roux AV. Estimating neighborhood health effects: the challenges of causal inference in a complex world. Social Science and Medicine. 2004; 58:1953–1960. [PubMed: 15020010]

Diez-Roux AV. Conceptual approaches to the study of health disparities. Annual Review of Public Health. 2012; 33:41–58.

Dimond M, McCance K, King K, Benoliel JQ, Chang BL. Forced residential relocation its impact on the well-being of older adults. Western Journal of Nursing Research. 1987; 9:445–464. [PubMed: 3433738]

Eckert JK, Haug M. The impact of forced residential relocation on the health of the elderly hotel dweller. Journal of Gerontology. 1984; 39:753–755. [PubMed: 6491188]

Ekstrom, RB., French, JW., Harman, H., Derman, D. Kit of Factor-Referenced Cognitive Tests. Princeton, NJ: Educational Testing Service; 1976.

Ertel KA, Glymour MM, Berkman LF. Effects of social integration on preserving memory function in a nationally representative US elderly population. American Journal of Public Health. 2008; 98(7):1215. [PubMed: 18511736]

Eschbach K, Ostir GV, Patel KV, Markides KS, Goodwin JS. Neighborhood context and mortality among older Mexican Americans: Is there a barrio advantage? American Journal of Public Health. 2004; 94(10):1807–1812. [PubMed: 15451754]

Ferraro KF. The health consequences of relocation among the aged in the community. Journal of Gerontology. 1983; 38:90–96. [PubMed: 6848593]

Evans DA, Hebert LE, Beckett LA, Scherr PA, Albert MS, Chown MJ, Taylor JO. Education and other measures of socioeconomic status and risk of incident Alzheimer disease in a defined population of older persons. Archives of Neurology. 1997; 54(11):1399–1405. [PubMed: 9362989]

Everson-Rose SA, Skarupski KA, Barnes LL, Beck T, Evans DA, Mendes de Leon CF. Neighborhood socioeconomic conditions are associated with psychosocial functioning in older black and white adults. Health & Place. 2011; 17(3):793–800. [PubMed: 21421335]

Geolytics. Incorporated: Demographic data, US Census and GIS Products. 2012.

Glymour MM, Manly JJ. Lifecourse social conditions and racial and ethnic patterns of cognitive aging. Neuropsychology Review. 2008; 18(3):223–254. [PubMed: 18815889]

Glymour MM, Weuve J, Chen JT. Methodological challenges in causal research on racial and ethnic patterns of cognitive trajectories: measurement, selection, and bias. Neuropsychology review. 2008; 18(3):194–213. [PubMed: 18819008]

Gonda, J., Schaie, K. Schaie-Thurstone Mental Abilities Test: Word Series Test. Reading, England: Thames Valley Test Company; 1985.

IBM, Corp. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp; 2013.

Jobe JB, Smith DM, Ball K, Tennstedt SL, Marsiske M, Rebok GR, Kleinman K. ACTIVE: A cognitive intervention trial to promote independence in older adults. Controlled Clinical Trials. 2001; 22:453–479. [PubMed: 11514044]

Karlamangla AS, Miller-Martinez D, Aneshensel CS, Seeman TE, Wight RG, Chodosh J. Trajectories of cognitive function in late life in the United States: demographic and socioeconomic predictors. American Journal of Epidemiology. 2009; 170:331–342. [PubMed: 19605514]

Kitagawa, EM., Hauser, PM. Differential mortality in the United States: A study in socioeconomic epidemiology. Harvard University Press; 1973.

Kramer AF, Bherer L, Colcombe SJ, Dong W, Greenough WT. Environmental influences on cognitive and brain plasticity during aging. Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2004; 59A(9):940–955.

Krause N. Neighborhood deterioration, social skills, and social relationships in late life. International Journal of Aging and Human Development. 2006; 62(3):185–207. [PubMed: 16625936]

Krieger N. A glossary for social epidemiology. Journal of Epidemiology and Community Health. 2001; 55:693–700. [PubMed: 11553651]

Lang IA, Llewellyn DJ, Langa KM, Wallace RB, Huppert FA, Melzer D. Neighborhood deprivation, individual socioeconomic status, and cognitive function in older people: analyses from the English Longitudinal Study of Ageing. Journal of the American Geriatric Society. 2008; 56:191–198.

Lawton MP, Yaffe S. Mortality, morbidity, and voluntary change of residence by older people. Journal of the American Geriatrics Society. 1970; 18:823–831. [PubMed: 5457319]

Litwak E, Longino CF. Migration patterns among the elderly: A developmental perspective. The Gerontologist. 1987; 27:266–272. [PubMed: 3609792]

Marmot MG, Kogevinas M, Elston MA. Social/economic status and disease. Annual Review of Public Health. 1987; 8(1):111–135.

Marsiske, M., Margrett, JA. Handbook of the Psychology of Aging. Vol. 6. Amsterdam: Elsevier; 2006. Everyday problem solving and decision making; p. 315-342.

Mungas D, Beckett L, Harvey D, Tomaszewski Farias S, Reed B, Carmichael O, DeCarli C. Heterogeneity of cognitive trajectories in diverse older persons. Psychology and Aging. 2010; 25(3):606. [PubMed: 20677882]

Nunes B, Silva RD, Cruz VT, Roriz JM, Pais J, Silva MC. Prevalence and pattern of cognitive impairment in rural and urban populations from Northern Portugal. BMC Neurology. 2010; 10(42):1–12. [PubMed: 20051133]

Owsley C, Sloane M, McGwin G, Ball K. Timed Activities of Daily Living (TIADL) tasks: relationship to cognitive function and everyday performance assessments in older adults. Gerontology. 2002; 48(4):254–265. [PubMed: 12053117]

Patel KV, Eschbach K, Rudkin LL, Peek MK, Markides KS. Neighborhood context and self-rated health in older Mexican Americans. Annals of Epidemiology. 2003; 13(9):620–628. [PubMed: 14732301]

Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: A critical review. Journal of Epidemiology and Community Health. 2001; 55(2):111–122. [PubMed: 11154250]

Radloff LS. The CES-D scale. A self-report depression scale for research in the general population. Applied Psychological Measurement. 1977; 1(3):385–401.

R Development Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing; Vienna, Austria: 2010. http:///www.R-project.org/

Rebok GW, Ball K, Guey LT, Jones RN, Kim H, King JW, Willis SL. Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults. Journal of the American Geriatrics Society. 2014; 62(1):16–24. [PubMed: 24417410]

Rey A. L'examen psychologique dans les cas d'encephalopathie tramatique. Archives de Psychologie. 1941; 28:21.

Robert SA, Li L. Age variation in the relationship between neighborhood socioeconomic context and adult health. Research on Aging. 2001; 23(2):233–258.

Russ TC, Batty GD, Hearnshaw GF, Fenton C, Starr JM. Geographical variation in dementia: Systematic review with meta-analysis. International Journal of Epidemiology. 2012; 41(4):1012–1032. [PubMed: 22798662]

Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing neighborhood effects: Social processes and new directions in research. Annual Review of Sociology. 2002:443–478.

Sheffield KM, Peek MK. Neighborhood context and cognitive decline in older Mexican Americans: results from the Hispanic Established Populations for Epidemiologic Studies of the Elderly. American Journal of Epidemiology. 2009; 169(9):1092–1101. [PubMed: 19270047]

Sisco S, Marsiske M. Neighborhood influences on late life cognition in the ACTIVE study. Journal of Aging Research. 2012; 2012:435826. [PubMed: 22966458]

Sloan FA, Wang J. Disparities among older adults in measures of cognitive function by race or ethnicity. The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences. 2005; 60B(5):P242–P250.

Speare A, Meyer JW. Types of elderly residential mobility and their determinants. Journal of Gerontology. 1988; 43:S74–S81. [PubMed: 3361098]

Stewart P. Who is kin? Family definition and African American families. Journal of Human Behavior in the Social Environment. 2007; 15:163–181.

Tang MX, Stern Y, Marder K, Bell K, Gurland B, Lantigua R, Mayeux R. The APOE-ε 4 allele and the risk of Alzheimer disease among African Americans, whites, and Hispanics. Journal of the American Medical Association. 1998; 279(10):751–755. [PubMed: 9508150]

Thurstone, LL., Thurstone, TG. Examiner Manual for the SRA Primary Mental Abilities Test (Form 10–14). Chicago: Science Research Associates; 1949.

United States Census Bureau. Geographical Areas Reference Manual. Washington, DC: Department of Commerce; 2000.

Walker RB, Hiller JE. Places and health: A qualitative study to explore how older women living alone perceive the social and physical dimensions of their neighborhoods. Social Science and Medicine. 2007; 65:1154–1165. [PubMed: 17553603]

Wight RG, Aneshensel CS, Miller-Martinez D, Botticello AL, Cummings JR, Karlamangla AS, Seeman TE. Urban neighborhood context, educational attainment, and cognitive function among older adults. American Journal of Epidemiology. 2006; 163(12):1071–1078. [PubMed: 16707655]

Willis, S., Marsiske, M. Manual for the Everyday Problems Test. University Park: Pennsylvania State University; 1993.

Wilmoth JM, Chen PC. Immigrant status, living arrangements, and depressive symptoms among middle-aged and older adults. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences. 2003; 58:S305–S313.

Wilson, BA., Cockburn, J., Baddeley, A. The Rivermead Behavioral Memory Test Reading. England: Thames Valley Test Company; 1985.

Wiseman RF. Why older people move theoretical issues. Research on Aging. 1980; 2:141–154.

Working Together for Health. World Health Organization; Geneva, Switzerland: 2006.

Yen IH, Syme SL. The social environment and health: a discussion of the epidemiologic literature. Annual Review of Public Health. 1999; 20(1):287–308.

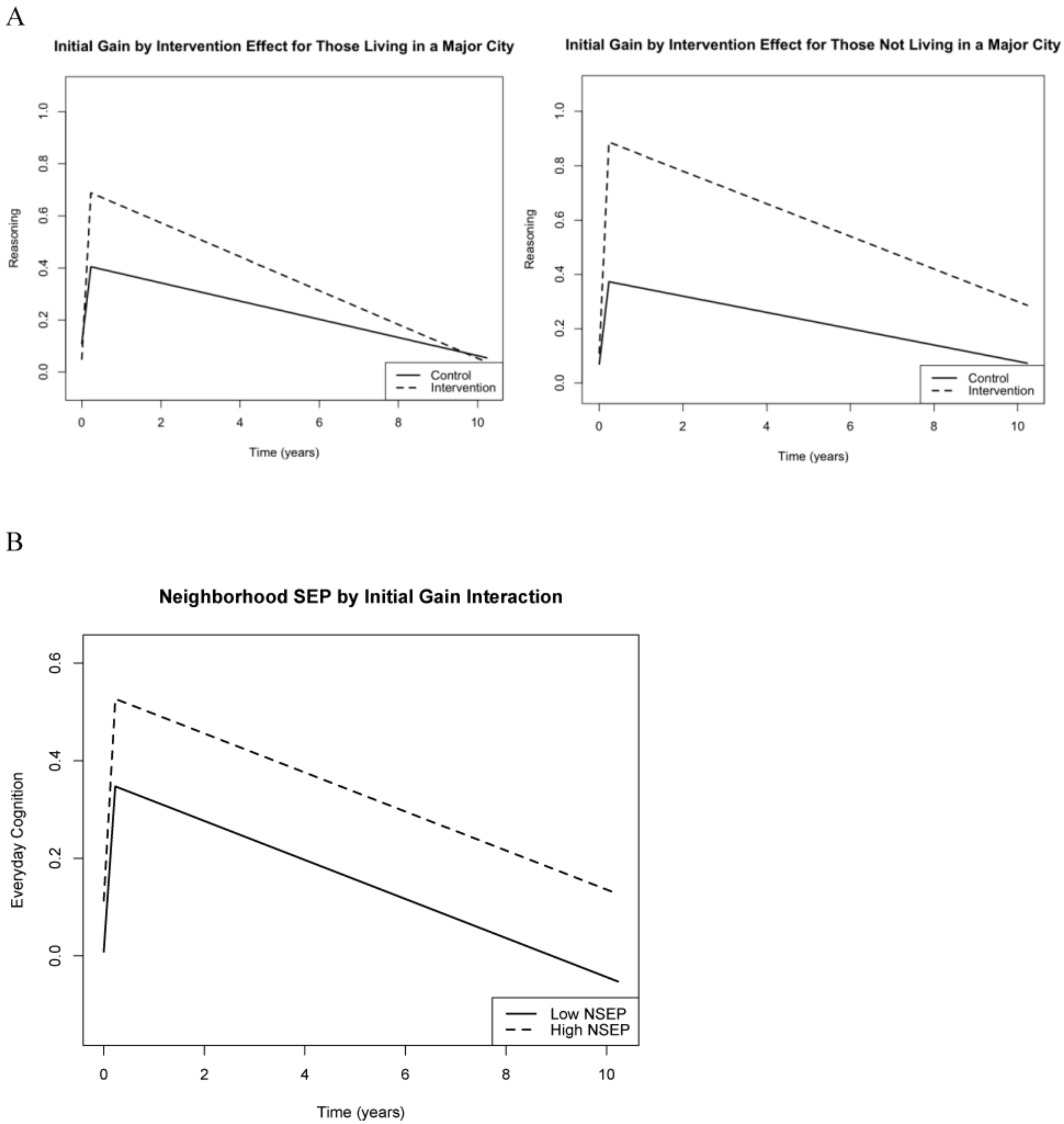

Figure 1.

Model Estimated Trajectories: (A) Initial gain×Intervention× Major City interaction on reasoning; (B) Initial gain×Neighborhood Socioeconomic Position interaction on everyday cognition for speed-trained and controls. All models adjust for covariates.

Table 1

Characteristics of ACTIVE Sample by Training Group (*N* = 2,438)

	Memory (*n* = 624) % or *M(SD)*	**Reasoning (*n* = 603) % or *M(SD)***	**Speed (*n* = 610) % or *M(SD)***	**Control (*n* = 601) % or *M(SD)***
Individual-level variables				
Black race	26.3	29.5	26.4	29.5
Female	76.1	76.3	77.4	73.2
Age (at baseline)	73.5 (6.0)	73.3 (5.66)	73.2 (5.64)	73.9 (5.86)
Years of education	13.53 (2.69)	13.48 (2.72)	13.70 (2.70)	13.42 (2.65)
Depressive symptoms score	5.18 (5.37)	5.50 (5.31)	5.15 (4.97)	5.02 (4.82)
Self-rated health	3.38 (.86)	3.29 (.89)	3.45 (.88)	3.36 (.88)
Neighborhood-level variables				
Socioeconomic position	.02 (3.27)	−.06 (3.31)	.05 (3.21)	−.18 (3.40)
Percent minority	28.6 (.34)	27.8 (.35)	24.9 (.33)	30.6 (.36)
Major city (Yes)	36.7	36.8	35.7	37.1

Note. Raw scores are used for each variable except for socioeconomic position, which is a factor score. Range of variables: age (65–91); years of education (5–20); depression (0–34); health (1–5); socioeconomic position (−7.18–10.20); percent minority (0–1.00).

Table 2

Regression Estimates of Final Models for Memory, Reasoning, and Speed from Mixed-Effects Models

	Memory Model 2		Reasoning Model 3		Speed Model 2	
Variable	***Estimate***	***SE***	***Estimate***	***SE***	***Estimate***	***SE***
Time	**−.12*****	.010	**−.03*****	.006	**.05*****	.011
Black race	**−.39*****	.066	**−.58*****	.070	**.26*****	.077
Age	**−.04*****	.003	**−.05*****	.004	**.06*****	.004
Education	**.08*****	.009	**.10*****	.009	**−.04*****	.010
Intervention (ref: controls)	−.004	.042	.04	.055	.03	.047
Initial gain (ref: baseline)	**.12****	.037	**.31*****	.031	**−.42*****	.048
Neighborhood socioeconomic position (NSEP)	.005	.007	.01	.008	−.003	.008
Major City (ref: not major city)	.02	.060	.03	.087	−.01	.073
Percentage minority	−.04	.022	−.02	.026	−.01	.027
Time × Age	**−.004*****	.001	**−.002*****	.0004	**.002***	.001
Time × Education	.00002	.001	−.002*	.001	−.002	.002
Time × Black race	.01	.010	.01	.007	−.01	.011
Time × Intervention	−.01	.006	**−.03*****	.005	**.04*****	.007
Initial gain × Age	−.01*	.002	−.004*	.002	.01*	.003
Initial gain × Education	.01	.006	−.001	.004	**.02***	.008
Initial gain × Black race	−.04	.045	−.03	.034	.01	.058
Initial gain × Intervention	**.16*****	.028	**.48*****	.028	**−.82*****	.037
Time × NSEP	.002	.001	−.0003	.001	−.001	.001
Time × Major City	.01	.011	−.005	.008	.01	.012
Time × Percentage Minority	.001	.003	−.0005	.002	.01	.004
Initial gain × NSEP	−.002	.005	−.001	.004	−.01	.006
Initial gain × Major City	−.05	.040	−.008	.040	.01	.053
Initial gain × Percentage Minority	.02	.015	.03*	.013	−.01	.020
Initial gain × Intervention × Major City			**−.12****	.048		
Time × Intervention × Major City			.02	.009		

Note. Models adjusted for gender, baseline depression, and baseline health. Higher scores on memory and reasoning are better, whereas lower scores on speed of processing are better. Bolded effects were significant after adjustment for multiple comparisons.

* $p < .05$,

** $p < .01$,

*** $p < .000$.