NEIGHBORHOOD INFLUENCES ON COGNITIVE LEVEL AND TRAINING GAINS IN THE ACTIVE STUDY

By

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To Mom and Dad, with love: Here is your lanyard.

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NEIGHBORHOOD INFLUENCES ON COGNITIVE LEVEL AND TRAINING GAINS IN THE ACTIVE STUDY

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A growing body of research supports the role of neighborhood in the lives of older adults. Low neighborhood-level socioeconomic status has been associated with poorer physical health, reduced rates of physical activity, increased incidence of depression and psychological stress, and less neighborhood-based social support networks and social engagement. Many of these outcomes have also been identified as correlates of late life cognition. Yet few studies to date have specifically investigated the role of the neighborhood as a unique source of explanatory variance in cognitive aging. The current study supplemented data from the ACTIVE (Advanced Cognitive Training with Independent and Vital Elders) study with neighborhood-level data from publicly-available data sets. In ACTIVE, 2,802 adults aged 65-96 from six US catchment areas completed baseline cognitive assessments and were randomized to one of three cognitive interventions or a no-contact control condition. An immediate posttest repeated the cognitive assessments to assess training-related change. The study investigated: 1) whether neighborhood-level socioeconomic position (SEP) is related to initial cognitive level and training response in ACTIVE and 2) whether neighborhood

facilities supporting physical and psychosocial health mediate the relationship between neighborhood SEP and the ACTIVE cognitive outcomes. Neighborhood SEP positively predicted vocabulary but after controlling for individual demographics, especially race, SEP did not have significant direct effects on other measures of cognitive level or on the response to the ACTIVE interventions. Subsets of facilities either positive or negative relationships to most cognitive outcomes, which were separate from the effect of SEP. Additional analyses examined whether SEP effects remained after controlling for covariate influences such as area type (urban, suburban, rural), interactions of neighborhood racial composition with race, and individual mobility. SEP effects were small across analyses, suggesting that current neighborhood SEP has some effects on cognition, but these effects are weak relative to individual-level demographic predictors. By bridging the social epidemiology and cognitive aging traditions, this dissertation sought to improve our understanding of the contextual factors influencing individual differences in late life cognition.

CHAPTER 1
STATEMENT OF THE PROBLEM

Overview

The “neighborhood” has emerged as one of the most popular levels of analysis in studies of contextual influences on health and well-being. This owes to both the social organization of life within neighborhoods, and to the availability of data at neighborhood-like levels of analysis (i.e., census tracts). A growing body of research supports the role of neighborhood characteristics in the lives of older adults. Low socioeconomic status at the neighborhood-level has been associated with poorer physical health, reduced rates of physical activity, increased incidence of depression and psychosocial stress, as well as less neighborhood-based social support networks and social engagement. Many of these health-related and well-being outcomes have also been identified as correlates of late life cognition. Yet few studies to date have specifically investigated the role of the neighborhood as a unique source of explanatory variance in cognitive aging.

The current study supplemented data collected in the ACTIVE (Advanced Cognitive Training with Independent and Vital Elders) study with neighborhood-level data derived from publicly available data sets. ACTIVE offers a unique opportunity to examine the association of neighborhood-level characteristics not only with baseline cognitive level, but also with response to cognitive training. In ACTIVE, 2,802 adults aged 65-96 from six US catchment areas completed a baseline assessment including multiple cognitive measures. Participants were then randomized to one of three ten-session cognitive intervention programs or a no-contact control condition. An immediate posttest repeated most of the cognitive assessments to assess training-related change.

The current study examined neighborhood variables as predictors of individual differences in baseline cognition, and in initial response to training.

Contemporary scholarship on neighborhood factors has highlighted the importance of understanding whether neighborhood variables add explanatory variance *above and beyond* individual differences. In addition, theoretically motivated research on neighborhood effects must also postulate mediating influences (i.e., potential process variables) that explain how contextual variables might exert their influence at the individual level. Thus, the current study not only to investigated whether neighborhood-level socioeconomic position (SEP) is related to initial cognitive level and training response in ACTIVE participants, but also investigated neighborhood-level mediators of neighborhood SEP on individual outcomes (Figure 1-1). Exploration of mediators was based on health-supporting facilities in the neighborhood (e.g., physicians' offices, exercise facilities, churches).

Innovations of the present study include: (a) examination of the association of neighborhood characteristics and resources with late life cognitive outcomes; (b) examination of potential neighborhood-level mediators of the late life neighborhood-cognition relationship, and (c) focus on the association of neighborhood-level characteristics with not only baseline cognitive level, but also response to cognitive training. The study also leverages the resource of the ACTIVE trial data, and augments it with new secondary data collection (i.e., neighborhood level data not collected by the ACTIVE investigators), thereby seeking to bridge the social epidemiology and cognitive aging traditions in understanding late life cognition. Thus, the present study sought to achieve the following aims.

Specific Aims and Hypotheses

Preliminary Aims

Prior to exploring the main research questions, preliminary analyses sought to (1) establish a latent factor construct representing neighborhood-level socioeconomic position based on a parsimonious set of socioeconomic indicators (e.g. area-level income, education and occupational attainment), (2) develop summary variables or latent constructs representing facilities supporting physical health (PHY) and psychosocial health (PSY), and (3) develop a hierarchical factor analytic model of baseline cognition in ACTIVE estimating both multiple specific cognitive domains (e.g., memory, reasoning, speed), and a higher-order factor capturing general cognition or '*g.*'

Aim 1

Confirm that neighborhood socioeconomic position (SEP) shows bivariate relationships with baseline cognitive level and response to training. Hypothesis: Neighborhood SEP is expected to have significant positive associations with baseline cognitive level and response to training.

Intermediate Aim

Estimate the Aim 1 structural equation model in 3 separate models specifying data at different levels of geographic aggregation (e.g., block group, census tract, 5-digit ZIP code tabulation area). Compare model fit and regression paths for each geographic level to identify the ideal (i.e., best model fit, strongest regression paths) level at which to estimate the models for Aim 1 and 2. Hypothesis: Model fit and regression paths are not expected to differ significantly among geographic aggregation levels, but fit and relationships are expected to be optimal when estimated at the census tract level.

Aim 2

Explore whether facilities supporting physical health (PHY) and/or facilities supporting psychosocial health (PSY) mediate the relationship between neighborhood SEP and 1) baseline cognitive level, and 2) response to cognitive training. Hypothesis: PHY and PSY are expected to at least partly mediate the anticipated relationships between neighborhood SEP and 1) baseline cognitive level, and 2) response to training.

Exploratory Follow-Up Aims

Other area- and individual-level factors not considered in the main model may explain additional portions of the expected relationship between SEP and cognition. Follow-up analyses will examine how residence in an urban versus suburban area, neighborhood-level segregation, and individual mobility mediate or moderate the relationship between SEP and cognition.

Figure 1-1. Conceptual mediation model of neighborhood influences on late life cognition.

CHAPTER 2
BACKGROUND AND SIGNIFICANCE

Overview

The section to follow will review 1) the characteristic trajectory of cognitive aging. In addition, it will consider the everyday consequences of age-related changes in cognition and will offer a conceptual framework through which to understand cognitive aging research, 2) the concepts of cognitive reserve, cognitive enrichment, and environmental enrichment, 3) the evidence for neighborhood as a context for environmental cognitive enrichment across the life span, 4) discussion of potential mediators in neighborhood influences on cognition, 5) current “best practices” in neighborhood research, 6) an overview of the parent study, and 7) limitations of the proposed study.

Cognitive Aging

Normative Pattern of Cognitive Aging

Normative cognitive aging is characterized by stability, decline, and improvement; at the aggregate, cognitive aging is most characterized by decline (Carstenson, Mikels, & Mather, 2006). Types of cognition that remain stable or improve are those related to acquired knowledge, such as verbal ability and semantic memory. Cognitive skills related to processing abilities (including attention, memory, reasoning, and perceptual speed) are more greatly affected by advancing age (Singer et al., 2003; Schaie, 1990). Age-related changes are also observed for several dimensions of brain structure, including cortical thinning, generalized and region-specific volumetric reductions (Park & Reuter-Lorenz, 2009), and changes in the white matter tracts, including an anterior-to-posterior gradient decline in white matter integrity (Head et al., 2004) and increases in white matter hyperintensities, especially in the frontal lobes (Wen & Sachdev, 2004). Much of the research regarding the explanatory factors underlying cognitive aging has focused on individual-level biological and behavioral correlates. As future sections will discuss, there is also evidence to suggest that the immediate life environment, including neighborhood, may help to shape the influence of these age-related biological changes.

Why Optimal Cognitive Aging is Important

Due to improvements in medical care and technology in recent history, people in developed nations are living longer and the proportion of older adults in these countries is steadily increasing (e.g., Martin & Preston, 1994). However, increasing age is accompanied by exponentially increasing rates of decline as described in the paragraph above, as well as increasing incidence of dementia (e.g., Herbert, Scherr, Bienias, Bennett, & Evans, 2003). As a consequence, longer life spans do not necessarily translate to longer periods of independent function, but instead signal the risk for an increasing proportion of cognitive dysfunction among industrialized nations. This risk carries important implications both for society (e.g., rising costs of providing long-term care for a greater proportion of disabled older adults), and for the individual, for whom living longer is not necessarily advantageous if those additional years also involve a reduced quality of life. It is therefore imperative, at both the societal and individual level, that researchers identify ways to maintain healthy cognitive functioning in later life, as well as ways to minimize the duration of time in which older adults are functionally impaired.

Conceptual Framework: Potential and Limits of Cognitive Aging

Paul Baltes and colleagues offered a helpful conceptual framework to guide our understanding of the potential for, and limitations of, optimal cognitive aging (e.g., Baltes, 1987; Baltes, Lindenberger, & Staudinger, 2006). They described late life cognition as having two important features. First, it is malleable: at any point in development, individuals possess a range of possible cognitive functioning, with potential for improved performance. Second, this potential becomes increasingly limited with age: the biological effects of aging not only reduce cognitive performance, but also narrow the range of possible functioning – and potential for improvement. Kliegl and Baltes (1987) demonstrated both of these features in a now-classic cognitive training study in which 1) with training, the memory performance older adults improved to the level of untrained younger adults, and 2) trained younger adults outperformed trained older adults at all points in the study, demonstrating that older adults' performance could improve with practice, but this improvement potential was limited.

Kliegl and Baltes used the term developmental reserve capacity to refer to the potential for improved cognitive functioning (or cognitive plasticity) following intervention. They also referred to baseline reserve capacity as the cognitive performance potential under optimal testing conditions (i.e., without intervention). However, it was developmental reserve capacity that was believed to be most reduced by the biological effects of aging.

After Baltes and colleagues introduced these concepts, other cognitive aging researchers helped popularize the term "cognitive reserve (e.g., Stern, 2002)," but from a different perspective**.** Developmental reserve capacity refers to the potential for improvement through intervention – and is reduced by age-related biological change – whereas cognitive reserve refers to the potential for attenuated functional decline resulting from age-related biological change. Both concepts are relevant to the current study investigating environmental effects on cognitive aging. Contextual factors, as will be explored in the sections to follow, may influence both the biologically-constrained potential for cognitive improvement through intervention, and also the potential for attenuated cognitive decline in aging.

Cognitive Reserve

Research on cognitive reserve focuses on the factors which promote maintained cognitive function, or attenuated cognitive decline, in the presence of age-related changes in the brain. It arose in response to the observation that some individuals appear to be better able than others to tolerate age-related brain pathology; that is, without expressing the same degree of clinical impairment (Bennett et al., 2005). This observation suggests manifest cognition is the product of not only the "bottom-up" influence of brain structure and pathology, but also of other "top-down" influences. These influences cumulatively serve as a "buffer," the level of which varies among individuals, against the biological changes associated with ARCD and dementia.

Many of the factors contributing to cognitive reserve are related to lifestyle, such as include physical activity and fitness (e.g. Kramer et al., 2004; Churchill et al., 2002), engagement in intellectually stimulating activities (e.g. education, occupational complexity, and cognitively stimulating leisure activities; Fillit et al., 2002; Schooler et al., 1999; Richards & Sacker, 2003), and social engagement (e.g., Barnes et al., 2004; Bassuk et al., 1999). Chronic disease and medical comorbidities, for which many of the risk factors are related to lifestyle (e.g. Fries, 2005), also influence cognitive reserve: hypertension, diabetes, hyperlipidemia and atherosclerosis are among the medical risk factors for cognitive decline (Fillit et al., 2002). Importantly, cognitive reserve is related to not only higher levels of maintained cognitive function in the presence of normal

ARCD (Stern, 2002), but also to reduced incidence of dementia (Fratiglioni et al., 2004) and to more rapid decline following dementia diagnosis (in other words, a reduced period of functional impairment or "morbidity compression;" Fries & Crapo, 1981). Fratiglioni and colleagues (2004) organized the lifestyle components of cognitive reserve into three classes: physical, mental/intellectual, and social factors.

Cognitive Enrichment

The influence of lifestyle factors on cognitive aging is at the forefront of current research initiatives. A recent review (Hertzog, Kramer, Wilson, & Lindenberger, 2009), comprehensively explored the same three lifestyle components of cognitive reserve - the physical, intellectual, and social - coining the term cognitive enrichment to describe their combined effects on cognition in aging. After a thorough review, the authors concluded available evidence supported the hypothesis that "maintaining an intellectually [and socially] engaged and physically active lifestyle promotes successful cognitive aging." They also reviewed epidemiological evidence demonstrating the negative effect of stress and chronic psychological distress on age-related cognitive change, and identified the importance of exploring the role of positive personal attributes in successful cognitive aging.

Environmental Enrichment

The concept of cognitive enrichment also served to link the cognitive reserve research with animal research on environmental enrichment (Jones et al., 1996; Kempermann et al., 1997; Sirevaag & Greenough, 1987). The research on environmental enrichment demonstrates that different living environments exert a combination of effects on cognitive function, purportedly through a combination of physical, cognitive, and social mechanisms. Specifically, this body of research reports that animals living in complex environments that provide opportunities for physical activity, cognitive stimulation, and social interaction demonstrate increased neurogenesis, dendritic branching, and gliogenesis, better learning and memory performance, and even protection against neurological insult (van Praag, Kempermann, & Gage, 2001)

Particularly relevant to the proposed study is the body of evidence supporting benefits of environmental enrichment, especially on memory, for aging animals (e.g., Cummins et al., 1973; Kempermann, Kuhn, & Gage, 1998; Winocur, 1998; Soffie et al., 1999; Nakamura et al., 1999). In fact, a recent study (Segovia, Yague, Garcia-Verdugo, & Mora, 2006) reported that 8-week immersion in an enriched environment produced increased concentrations of GABA and glutamate in the dentate gyrus of the hippocampus – neurotransmitters important for hippocampal function – but only for older mice, showing an age-specific effect of enrichment benefiting older animals. Enrichment – both prior to and after lesioning – has also been found to attenuate both cell death and functional impairment, and can facilitate recovery, in animals with brain lesions (Will et al., 1977; Darymple-Alford & Benton, 1984). Regarding enrichment in aging, this evidence suggests that even in compromised brains, it may not be " too late" for enrichment to provide benefit (although the degree of plasticity, bridging back to Paul Baltes' work, is likely reduced in the presence of biological degradation).

Critical Issues in Environmental Enrichment

Timing is a critical issue for environmental enrichment research. One issue relates to the duration of exposure to enrichment; that is, the length of exposure necessary to observe benefits. In a seminal paper on this topic, Will and colleagues (1977) reported that, in lesioned rats, the effects (both neuronal and functional) of 2 hours per day of enrichment were as beneficial as 24 hours per day. Regarding the effects of long-term exposure: van Praag, Kempermann and Gage (1999) found that rodents exposed to 68 or 180 days of enrichment demonstrated equivalent neurogenesis and memory performance (similarly, others reported the effects were the same for 30 or 60 days of exposure; Briones, Klintsova, & Greenough, 2004). However another study exposing rats to double that length of exposure, one year, did report greater neuronal and behavioral effects (Pham et al., 1999). It has also been reported that the brain changes induced by 30 days of enrichment are persistent (Briones et al., 2004), but the effects of an 80-day exposure are more persistent (Bennett et al., 1974).

Finally, the developmental stage at which enrichment is given may be critical for the size of benefit it provides. While benefits have been observed for newborn, young, and mature animals (e.g., Diamon, Krech, & Rosenzweig, 1964; Briones et al., 2004), it is believed that the capacity for enrichment-driven plasticity is reduced with age (e.g., Holtmaat et al., 2005). Some of the effects of enrichment with exercise (e.g., neurogenesis, synaptogenesis, angiogenesis, spatial learning) are reportedly stronger for younger than older animals (e.g., 3 months versus 19 months; van Praag et al., 2005). There is evidence that the age of onset for enrichment also matters for humans, at least early in the life span. Research on the impoverished stimulation of children in low-quality orphanages is well-known, showing developmental delays which, if moved to a foster care or adoptive home, can later be “caught up” (Kaler & Freeman, 1994; Windsor, Glaze, & Koga, 2007). However, the prognosis for cognitive and social development is poorer for children who leave the orphanage at 6 months of age or later (Rutter et al., 1999; Beckett et al., 2006). Less is known about the differential effects of enrichment for humans of different ages, although the Baltes perspective on developmental reserve capacity would suggest that, like animals, aging humans may experience a reduced benefit of enrichment compared to the young.

Another question is whether or not the benefits of enrichment are in fact only due to one or two individual factors. Animal research has addressed this by testing for the effects of single variables through controlled experimentation, especially for the effects of socialization and general activity. Van Praag, Kempermann, and Gage (2001) reported that generally, no single variable has been found that can account for the effects of enriched environment. Although the evidence from human research reviewed above suggests each component of enrichment (physical, cognitive, social) indeed affects cognition, these single components cannot be easily isolated in the human environment, let alone experimentally manipulated. Instead, van Praag and colleagues argue that an important feature of environmental enrichment is that "there is good reason to assume that it is the interaction of [these] factors that is an essential element of an enriched environment, not any single element that is hidden in the complexity."

Researchers have begun to point out analogues between the animal literature and environmental enrichment for humans (although thus far, the emphasis has been more on *enrichment* per se than on ways the *environment* provides opportunity for enrichment; Kramer et al., 2004, and Hertzog et al., 2009, offer comprehensive reviews). Physical, cognitive, and social activities influence the cognitive aging trajectory. The effects of neighborhood, to be reviewed in the following section, highlight the neighborhood as a potential arena providing the same interaction of physical, cognitive, and social sources of stimulation that are integral to environmental enrichment.

Neighborhood: a Context for Environmental Cognitive Enrichment?

Perspectives in ecological psychology also hint that the neighborhood may be a setting for human environmental enrichment. Bronfenbrenner (1979) offered a compelling conceptual model of “human ecological systems” to guide thinking about how the interaction of the person and environment influences lifespan development. He conceptualized human development as the product of a dynamic interaction between the individual and his or her environment, which consists of several nested settings. The nested setting most proximal to the individual is the microsystem, comprising the immediate life environments (e.g., neighborhood, home). The neighborhood, according to Bronfenbrenner, constitutes one of the immediate ecological environments in which human development occurs.

Bronfenbrenner’s model highlights several important issues relevant to conceptualizing neighborhood as a setting for environmental enrichment. First, his emphasis on development as the result of a dynamic interaction underscores the reciprocal nature of influence between the environment and individual. While fully exploring this relationship is beyond the scope of the current proposal, it is important to note that the individual is not only shaped by, but in turn shapes, his or her environment to some degree. Additionally, it is important to note that while the neighborhood represents one proximal sphere of influence on human development, it is a) not the only sphere, and b) is itself embedded within the other spheres. The individual is simultaneously being shaped by other environments, including his or her home, occupation, social settings, and culture. Thus, neighborhood effects only explain a portion of the variance in any developmental outcome, and may exert a less powerful influence than settings more proximal to the individual level, such as home and family.

The neighborhood is increasingly recognized as a key concept in sociological and epidemiological research for understanding the influences of the immediate environment on health and function (e.g., Nordstrom et al., 2004; Diez-Roux et al., 2003; Krieger et al., 2003; Sampson et al., 2002). There is evidence that neighborhood of residence is associated with health and behavioral outcomes, even when individual level income and education are controlled (e.g., Baum et al., 1999, Leventhal & Brooks-Gunn 2000). Controlling for such individual-level predictors is essential for helping to distinguish between contextual and compositional effects. Compositional effects have been described as “the difference people make to neighborhoods,” while contextual effects represent “the difference neighborhoods make to people” (Kubzansky et al., 2005). That is, compositional effects refer to the possibility that a neighborhood-level effect simply represents the aggregation of individual effects within that neighborhood. If this were the case, an observed “neighborhood effect” could be entirely explained by the individuals who make up that neighborhood. On the other hand, contextual effects imply that a neighborhood effect is present even after taking account of the potential effects contributed by the characteristics of individuals in that neighborhood. Concretely, if there is a contextual effect of neighborhood SES on late life cognition, then neighborhood SES should be positively associated with individual cognitive outcomes even after controlling for presumed individual-level effects on cognition (e.g., education). Contextual effects suggest that it is not simply the composition of individual characters that contributes to area-level differences in health or cognition, but that there is something *about the neighborhood environment* that differently influences health or cognition.

The issue of compositional versus contextual effects has substantial implications for policy. That is, if differences among neighborhoods can be fully explained by differences among the individuals who live in them, policymakers need only be concerned about intervening with individuals (Kawachi & Berkman, 2003). On the other hand, if the characteristics of the places people live in have an influence on their development, independent of the characteristics of the people themselves, there is value in health and cognitive intervention at the neighborhood level.

Area-level socioeconomic status (SES), followed by ethnic composition and residential stability, is the most consistently reported demographic predictor of cognitive outcomes – certainly in childhood, and potentially across the life span (Leventhal & Brooks-Gunn, 2000). SES is the strongest and most consistently reported area-level predictor of health outcomes among older adults, and studies suggest this relationship has a cumulative effect across the lifespan (Yen, Michael, & Perdue, 2009). The association of community-level SES with health is, in fact, stronger among adults aged 60-69 than among young and middle-aged adults or adults aged 70+, and during this time its association with health is comparable to or stronger than the relationship of individual SES to health (Robert & Li, 2001).

Krieger and colleagues (2003) identified three strengths of using area-based socioeconomic measures: 1) they can be appended to any database with addresses, 2) they provide data for determining contextual as well as compositional neighborhood effects, above and beyond effects due to individual SES, and 3) they can be applied equally to all persons regardless of age, gender, and employment status. Importantly, though it is heavily referenced in the neighborhood literature, SES is not presumed by most researchers to actually have a direct effect on developmental outcomes (e.g., Sampson, Morenoff, & Gannon-Rowley, 2002). In fact the widespread use of this measure is likely at least partly due to the ease by which it can be obtained; this may be a mixed blessing given the increasing call to identify process mechanisms explaining this relationship using models and hypotheses specified *a priori*, ideally investigated prospectively (e.g., Lang et al., 2007; Yen et al., 2009). In an influential, now-classic review of the neighborhood literature, Jencks and Mayer (1990) criticized neighborhood researchers' traditional reliance on census-derived sociodemographic indices of statistical areas in lieu of investigating the dynamic processes hypothesized to shape development. They postulated 5 theoretical frameworks for linking individual behavior with neighborhood effects (note: their focus was specifically on childhood development), briefly described below.

> *NEIGHBORHOOD INSTITUTIONAL RESOURCE MODEL*: the neighborhood influences development by the extent to which it provides access to resources providing stimulating learning and social environments (i.e., parks, libraries, community centers), as well as community services promoting healthy development, and protection through police presence in the community.
>
> *COLLECTIVE SOCIALIZATION MODEL*: neighborhoods influence individual development through the social organization of the community (i.e., adult role models, supervision, structure and routines).
>
> *CONTAGION/EPIDEMIC MODEL*: negative behavior of neighbors strongly influences development of their peers, causing negative behavior to spread to the behavior of others in the same community.
>
> *COMPETITION MODEL*: individuals are influenced by their neighborhood by the extent to which they must compete for scarce community resources.

Relative Deprivation Model: individuals are affected by their neighborhood by way of the evaluations they make of their own situation relative to their peers.

While several of the neighborhood studies reviewed below report outcome relationships to sociodemographic predictors, potential explanatory mechanisms, where possible, are also discussed.

Neighborhood Influences on Early Cognitive Development

Considerable attention has been dedicated to neighborhood influences on the early stages of cognitive development. Neighborhood SES is positively correlated with cognitive development and academic achievement across the entire spectrum of child development, beyond the effect of individual-level predictors. Two studies (Wasserman et al., 1998; Vrijheid et al., 2000) reported children born in low-SES areas were at increased risk for congenital anomalies and neural tube defects (presumably in part because some poor neighborhoods place residents at greater risk of exposure to toxins, e.g. toxic waste dumps), impacting the potential for cognitive development at a biological level from birth.

Beyond birth, neighborhood SES and IQ are associated as early as age 3 (Brooks-Gunn, 1997; Greenberg et al., 1999). Neighborhood characteristics are also associated with school-age mathematics reasoning skills (Entwisle et al., 1994) and reading attainment (Jackson, 2003). Conversely, living in a high SES neighborhood also has positive benefits for school readiness and school achievement (Leventhal & Brooks-Gunn 2000; Sampson et al., 1997). Neighborhood effects are detected well beyond the school-age years: area-level SES, number of female heads of household, and male joblessness are related to adolescent academic achievement, including high school graduation and drop-out rates, enrollment in college preparatory classes, and college attendance (Sampson et al., 1997).

Subsequent to the review by Jencks & Mayer, others have also attempted to explain the relationship between neighborhood-level characteristics and early cognitive development. Sampson and colleagues (2002), in an effort to move the previous decade's theoretical postulates forward, proposed the following four classes of social process-based neighborhood mechanisms:

> *SOCIAL TIES/INTERACTION:* this mechanism is based on the concept of social capitol, which characterizes neighborhood resources through social relationships (e.g., level/density of social ties between neighbors, frequency of social interactions among neighbors, and patterns of neighboring).
>
> *NORMS AND COLLECTIVE EFFICACY:* refers to residents' mutual trust and shared expectations, which can be influenced by clarity of neighborhood "rules," or by neighbors' fear of one another. Collective efficacy is the link between mutual trust and shared willingness to intervene for the public good. This has been measured, for example, in terms of levels of informal surveillance/guardianship, and in monitoring of teenage peer groups.
>
> *INSTITUTIONAL RESOURCES:* refer to the quality, quantity, and diversity of institutions in the community addressing its residents' needs (e.g. libraries, schools, organized social/recreational activities, medical facilities, support centers). These, and the participation of residents in these resources, have typically been measured using community surveys.
>
> *ROUTINE ACTIVITIES:* represents the concept of land use patterns and the ecological distribution of daily activities (e.g., location of schools, mix of residential and commercial areas, public transportation, flow of visitors). Direct measures of social activity are mostly absent; this topic is mostly investigated via types of land use in a neighborhood.

Bradley & Corwyn (2002) followed the theme of institutional resources, observing that living in a deteriorated neighborhood can mean less access to resources and recreational facilities, which may have implications for the maintenance of cognitive functioning later in life. They also noted that in the long term, local crime rate may pose a barrier to intra-community mobility for individuals across the life span; in the short term, living in a deteriorated neighborhood exposes children to greater violence and an increased likelihood of affiliation with deviant peers. Osofsky (1999) also argued that children in poor urban environments are more frequently exposed to guns, knives, drugs, and acts of random violence; it is known that exposure to such violence interferes with a child's ability to think clearly and solve problems (Garbarino 1999).

Neighborhood Effects on Cognition: Late Life

The research on neighborhood and late life development is scarcer than the research on neighborhood and early development. However, four recent studies have reported relationships between late life cognition and the neighborhood context on a broad scale. Wight and colleagues (2006; to our knowledge the first U.S. study to use nationally-representative data [Study of Assets and Health Dynamics Among the Oldest Old; AHEAD] to establish a neighborhood - late life cognition relationship) found that elders living in areas with low neighborhood-level educational attainment (defined by census tract area) achieved lower cognitive status scores compared to elders living in areas with high neighborhood-level educational attainment (as assessed using the Mini-Mental State Examination [MMSE]). These differences held up after controlling for individual-level education and area-level median household income (Wight et al., 2006). Additionally, the authors found that the cognitive impact of individual education was contingent on neighborhood education, such that low education was somewhat more harmful for cognition in low-education areas than in high-education areas.

Wight and colleagues did not examine etiological bases for neighborhood education effects. However, drawing on a taxonomy developed by Catalano & Pickett (2000), they offered three potential explanations: 1) Persons in low-education areas are exposed to more chronic life stress, creating hazards that lead to reduced employment opportunities, marginal occupations, and lower incomes, leading to fewer physical and social resources for stimulation. This lack of resources hinders engagement in physical and social activities, which are linked to cognitive function. 2) Low-education neighborhoods have fewer cognitively-stimulating coping resources, either due to lack of educated consumer demand to insufficient monetary tax resources. 3) Low-education neighborhoods may have a higher tolerance for poor health, stemming from untreated chronic conditions, exposure to hazards, and limited coping strategies, all of which may contribute to reduced cognitive functioning. These theoretical suggestions remain in need of substantial empirical investigation, but echo the frameworks put forth by other neighborhood researchers (e.g. Jencks & Mayer, 1990; Sampson et al., 2002).

Another recent United Kingdom study (Lang et al., 2007) compared the cognitive performances of older adults from the top and bottom quintiles (20%) on an Index of Multiple Deprivation (IMD; a composite index of neighborhood-level income, education, employment, housing, health/disability, living environment, and crime; neighborhoods were identified using census-defined areas). Participants completed measures of cognitive status (Mini-Mental Status Examination; MMSE), word list learning and memory, verbal fluency, and prospective memory, which were combined into a mean cognitive function score. (The use of the MMSE in this and the study by Wight and colleagues was not an ideal measure of cognition, as both studies assessed relatively healthy, independent elders. The MMSE is not sensitive to differences among healthy older adults, having been designed to screen for dementia [Folstein, Folstein, and

McHugh, 1975]. List learning, verbal fluency, and prospective memory, in comparison, would be more sensitive to differences among healthy older adults).

Lang and colleagues reported there was a clear and statistically significant downward trend in cognitive function for neighborhoods with greater deprivation, after controlling for individual-level wealth, income and education, across all age and gender groups. These effects were also robust after adjusting for the effects of individual systolic blood pressure and history of stroke, suggesting some other mechanism was responsible for the association between neighborhood and cognition. The authors also conducted a sensitivity analysis that included duration of residence (relevant to the current proposal's question of the importance of *duration* of exposure to enriched environment), which suggested length of stay in a particular area was not important for that particular analysis. This issue nonetheless warrants appropriate assessment with a longitudinal analysis.

Sheffield and Peek (2009) moved beyond cross-sectional analyses and examined the influence of neighborhood SES and ethnicity (proportion Mexican-American) on 5-year change in MMSE score, using a U.S. national sample of older Mexican Americans from the Hispanic Established Populations for Epidemiologic Studies of the Elderly study. They reported that, independent of individual-level risk factors, odds and rate of incident cognitive decline increased as a function of poorer neighborhood SES, and decreased with the proportion of Mexican-American neighborhood residents. Referring to the findings of Wight and colleagues, Sheffield and Peek likewise postulated that residents of socioeconomically disadvantaged neighborhoods may cognitively fare more poorly because such neighborhoods have more stressors and fewer physical, social, and cognitively stimulating resources. They also suggested that older Mexican Americans in ethnically-homogeneous Mexican American neighborhoods may benefit from healthful behavioral norms, social organization and support typical of such neighborhoods.

Finally, recent findings from the Baltimore Memory Study suggest that the relationship between neighborhood and late life cognition may depend on genotype (Lee, Glass, James, Bandeen-Roche, & Schwartz, 2011). Specifically, in this cross-sectional study, neighborhood psychosocial hazards were not found to be related worse cognitive performance. However, apolipoprotein E4 genotype was found to interact with high neighborhood psychosocial hazards resulting in poorer cognitive performance on measures of processing speed and executive functioning after controlling for individual-level covariates, suggesting evidence of a gene-environment interaction in neighborhood's relation to late life cognition.

Criticisms and Next Steps in Neighborhood Research on Late Life Cognition

The aforementioned studies establish preliminary evidence for the contribution of neighborhood factors to late life cognition, above and beyond individual-level factors. However they represent only the very beginning of investigation on this topic, leaving substantial room for further exploration. A review of these studies' limitations, together with a recent review of neighborhood research on general health outcomes in late life (Yen et al., 2009) guides suggestions for next steps in neighborhood research on late life cognition.

First, none of the studies differentiated between historic and recent effects of the neighborhood environment. That is, researchers have emphasized the importance of accounting for the influence of both current environment (e.g., Wilson et al., 2005) and prior environments to which the individual was exposed earlier in the lifespan (e.g., Vrijheid et al., 2000; Berkman & Glymour, 2006). Three of the four studies discussed here (and 25 of the 33 covered in Yen and colleagues' review) were cross-sectional, preventing exploration of not only historic environmental influences but of prospective neighborhood influences on cognitive change. Cross-sectional research at best provides a snapshot of current associations but cannot speak to the direction of causality, or to the developmental trajectory of associations over years. As the role of timing is critical for environmental enrichment effects (e.g., duration and age of onset of exposure), it is also important for neighborhood effects. A longitudinal analysis of the relationship between neighborhood and late life cognition should document change in both the neighborhood and individual with repeated measurements over time (ideally across the lifespan), but at the time of this dissertation no longitudinal study of neighborhood and health in late life had accomplished this. One out of eight published longitudinal studies measured both neighborhood and individual health characteristics at two time points, but did not examine whether change in these two sets of variables were related (Yen et al., 2009). A cross-sectional approach is also a weakness of the present study, although it extends beyond existing literature by examining the influence of current neighborhood on response to cognitive training. Furthermore, ACTIVE completed its 10th annual follow-up assessments in 2010, meaning a longitudinal evaluation of the relationship between neighborhood cognitive outcomes in ACTIVE will be possible in the near future.

Second, Yen and colleagues advocated that neighborhood research should take into account the amount of time an individual has resided in the neighborhood, which at the time only 10 out of 33 studies had done (Yen et al., 2009). Unfortunately, this data was not available for consideration in the present study. However, we did seek to meet another suggestion from this review, which was to specify an *a priori*, theoretically-driven model of the mechanism by which neighborhood influences cognition; according to Yen and colleagues, roughly one-third of the reviewed studies incorporated an existing theory in the formulation of their hypotheses.

Finally, the existing studies focused on broad differences in late life cognitive *status* (i.e., MMSE score), but did not investigate the effect of neighborhood on different cognitive domains (see recommendations by Cullum et al., 2000). This is a strength of the present study, which measures memory, reasoning ability, processing speed, and vocabulary, among other abilities. Elucidating the specificity of neighborhood effects on cognition may provide additional hints to ward potential mechanisms for neighborhood's influence. For example, effects on processing speed would hint toward a more biologically-mediated influence, whereas effects on vocabulary might hint toward a more socioculturally-mediated, and possibly lifespan-accumulative, influence.

An innovation of the present study is the capacity to address whether neighborhood effects might also influence the magnitude of potential profit from cognitive intervention. No study, in part because of a lack of data availability, has examined this question. However, looking back again at the cognitive aging framework put forth by Baltes, there is a theoretical basis for the notion that neighborhood factors may influence the degree of cognitive plasticity that is possible in late life. That is, if biological factors are responsible for reductions in potential plasticity, but neighborhood characteristics influence those factors (for example, by supporting physical fitness or physical health, as it has been shown to do), neighborhood may indirectly influence not only one's cognitive level but also one's potential for cognitive gain.

Most importantly, as Lang and colleagues clearly highlighted in their discussion, the mechanisms underlying the neighborhood-cognition association remain unclear, and are an important topic for further investigation. Similar to the problems with neighborhood research methodology that Jencks and Mayer (1990) raised, discovering a relationship between cognition and SES likely does not suggest that socio-demographic factors *act* upon cognition, but represent some related neighborhood factor that does influence cognition. Addressing whether the relationship exists does not answer the questions of how or why it exists, though the reasons for this relationship may well be important. To understand how neighborhood might influence cognitive aging, we must return to what we know about the factors affecting cognitive aging and explore, in turn, how these factors may be affected by the neighborhood.

Potential Neighborhood Mechanisms Affecting Cognitive Aging

Bridging back to cognitive aging work, researchers of cognitive reserve, cognitive enrichment, and environmental enrichment have all highlighted the same three factors influencing late life cognition: physical, cognitive/intellectual, and social activities. Given the logical (but as-yet unarticulated) implications of environmental enrichment for neighborhood effects, a sensible bridge between the existing cognitive aging literature and the research on neighborhood effects is this: just as individual cognitive differences are influenced by the level of individual engagement in physical, intellectual, and social activity, perhaps neighborhoods influence cognitive aging in the extent to which they afford opportunities for physical, intellectual, and social activity. This hypothesis constituted the foundation for the proposed mediators in this study.

It is challenging to elucidate the mechanisms governing relationships observed in cross-sectional data. As mentioned before, observed cross-sectional relationships can identify correlation but not causation. Significant findings should be replicated and followed up, where possible, with experimental studies. However, mediational models provide a way to begin to investigate process hypotheses in a cross-sectional study. A meditational model is supported if, beyond the observed relationship between a predictor and outcome (in this case, neighborhood and cognition), two additional relationships can be verified. Specifically, significant associations must be identified between 1) the predictor and the proposed mediator (i.e., neighborhood and physical/ intellectual/ social factors), and 2) the mediator and the outcome (i.e. physical/ intellectual/ social factors and late life cognition). If these are identified, these relationships lend support that the mediator may “carry” the predictor variable’s influence on the outcome. Evidence from the available literature supports the existence of both of these relationships, lending strength to the proposed mediation.

Neighborhood effects on physical, intellectual, and social factors

In late life, a key focus has been on the role of the neighborhoods in the physical health and function of older adults. Chronic medical conditions, which are present in 82% of adults over 65, have been extensively linked with neighborhood deprivation (e.g., Nordstrom, Diez-Roux, Jackson, & Gardin, 2004; Brown, Ang, & Pebley, 2007). Continued management of these conditions may be hindered by certain characteristics of deprived neighborhoods, such as limited availability or access to health care, access to exercise facilities and nutritious foods, infrastructure deprivation, and environmental stressors (Brown et al., 2007). Such hindrances are especially relevant for seniors, for whom independence and mobility are especially vulnerable to being compromised

(Shipp & Branch, 1999). Continued physical activity for seniors is also affected by the neighborhood, including differences in neighborhood safety, convenience to facilities, and microscale design (Cunningham & Michael, 2004).

Psychological distress, in the forms of depression (Yen & Kaplan, 1999), environmental stress (Van Der Meer et al., 2008), and reduced psychological well-being for older adults (Reschovsky, 1990), are also related to neighborhood deprivation. Social support and social engagement are also impacted by neighborhood factors: older adults living in a dilapidated neighborhood experienced more negative social interactions (Krause, 2006), and more perceived social disconnection in their environment (Walker & Hiller, 2007). As for intellectual stimulation, facilities in the neighborhood have previously been incorporated as sources of engagement in studies measuring cognitive activity among older adults (e.g. Wilson et al., 2005).

Effects of physical, intellectual, and social factors on cognition

Turning to the influence of these potential mediators on cognition, the same factors affected by neighborhood (medical health, physical health and fitness, intellectual/cognitive activity, and social engagement) also show evidence of being supporters of better cognition in the existing literature. There is evidence to support the hypothesis that affecting health, fitness, intellectual and social activity may be one way by which neighborhood factors affect individual level cognition. Lifestyle and behavioral factors identified as predictors of late life cognition include medical health (e.g., Van Harten et al., 2007; Yaffe, 2007; Gaulthier et al., 2006), physical activity (e.g., McAuley, Kramer & Colcombe, 2004; Etnier et al., 1997), cognitive activity (e.g., Wilson et al., 2005), stress and affective status (e.g., Vondras et al., 2005; Wilson et al., 2005; Sapolsky, 1996; McEwen & Sapolsky, 1995) and psychosocial engagement (e.g., Bassuk, Glass, & Berkman, 1999; Gow et al., 2007; Fratiglioni et al., 2004; Seeman et al., 2001; Helmer et al., 1999; Wang et al., 2002).

In human cognitive research, engagement in a stimulating environment is believed to facilitate maintenance or enhancement of cognitive function (*environmental complexity hypothesis;* Schooler, 1984, 1987). There is evidence that the engaging or stimulating nature of the immediate life environment can contribute positively to late life cognitive development. For example educational attainment, occupational complexity, and engagement in stimulating leisure activities are all positively correlated with measures of cognition (see Kramer et al., 2004 for a review). Regarding the issues of timing mentioned earlier for environmental engagement and neighborhood effects, there is clear evidence from the human cognitive literature that both engagement throughout the lifespan (e.g., Chodosh et al., 2002) and recent engagement (e.g., Wilson et al., 1999; Glass et al., 1999; Hultsch et al., 1993) are associated with higher levels of cognitive function in late life. Wilson, Bennett, and colleagues reported past and current engagement in cognitively-stimulating activities both contributed to reduced risk of incident Alzheimer's disease (Bennett et al., 2003; Wilson et al., 2005). Current cognitive activity was associated with better cognitive outcomes after controlling for past activity; the authors postulated that past engagement in cognitive activity acts on cognition primarily through promoting ongoing engagement in cognitive activities in late life (Wilson et al., 2005). As for response to cognitive interventions, there is currently no evidence on whether environmental factors can moderate the magnitude of gain due to cognitive training.

Proposed Mediators of the Late Life Neighborhood-Cognition Relationship

Based on the 1) the influence of neighborhood on the physical, intellectual and social factors discussed above and their association with cognition, and 2) support for the roles of those factors in cognitive reserve and environmental enrichment, we proposed that the neighborhood influences cognition through the physical, intellectual, and social mechanisms described above.

Following the suggestions of several seminal theoretical models from neighborhood research (Jencks & Mayer, 1990; Leventhal & Brooks-Gunn, 2000; Sampson et al., 2002), we proposed that the reason neighborhood-level socioeconomic indices relate to cognition is because those indicators represent the extent to which the neighborhood's resources translate into environmental opportunities for engagement in physical, intellectual, and social activities. As Jencks and Mayer (1990), Wilson and colleagues (2005), and Wight and colleagues (2006), among others, have pointed out, these resources can be measured in the form of local facilities which help promote these activities.

We proposed that two classes of neighborhood facilities - those promoting physical and psychosocial health - operate as mediators of the neighborhood-cognition relationship (Figure 1-1). These mediators were selected because they were believed to be physical representations of neighborhood resources offering physical, intellectual and social stimulation. Examples of facilities promoting physical health include hospitals, clinics, parks, recreational and fitness centers, and grocery stores providing fresh meat and produce. Examples of facilities promoting psychosocial health include museums, centers for learning, religious or civic organizations, fine arts centers, and centers for mental health. Complete lists of the facilities classified into each category can be found in the Methods chapter.

Some facilities may provide combinations of physical, intellectual and social stimulation, or may simultaneously support all three, reinforcing the notion of environmental enrichment as a product of all three factors in interaction. It has been especially noted (Hertzog et al., 2009) that for some activities, intellectual and social activities co-occur in a way that can be difficult to disentangle (i.e., attending fine arts performances, participating in continuing education, playing games at senior centers). For this reason, we elected to merge intellectual and social activities under the classification of *psychosocial health* facilities, and remained open to the possibility that a hybrid category of facilities supporting physical and psychosocial health may exist.

The ACTIVE Study

The Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study was a randomized, controlled clinical trial which examined the effects of three different cognitive interventions for community-dwelling older adults. In ACTIVE, 2,802 adults aged 65-96 from six US catchment areas (Baltimore/coastal Maryland; the metropolitan areas of Birmingham, Boston, Detroit and Indianapolis; and central Pennsylvania) completed a baseline assessment including multiple cognitive measures. Participants were then randomized to one of three ten-session cognitive intervention programs or a no-contact control condition. An immediate posttest repeated most of the cognitive assessments to assess training-related change. The current study examined neighborhood variables as predictors of individual differences in baseline cognition, and in initial response to training. Subsequent longitudinal occasions in ACTIVE were not included in this study.

Key training findings from ACTIVE

To date, ACTIVE findings are published or in press in over twenty manuscripts. As an intervention trial, much of the research in ACTIVE has been focused on documenting the presence of intervention effects and their pattern of transfer to other measures of everyday function. With regards to these findings, the evidence is as follows: (a) With regard to the proximal study outcomes (memory, reasoning, speed), participants in all three training groups (which got the basic 10-session program) experienced significantly greater gain than no-contact control participants on their targeted ability. Each intervention also served as a "contact control" for the other, and there was no evidence that training on one ability (e.g., reasoning) produced transfer to another (e.g., speed; Ball et al., 2002; Willis et al., 2006); (b) Effect sizes were consistent with previous research; above and beyond any practice-related gains experienced by control participants, net training effect sizes ranged from 0.2 (memory) to over 1.0 (speed; Ball et al., 2002; Willis et al., 2006); (c) training group differences were further increased for the subset of participants who received booster training (these participants received up to eight additional sessions one-year and three-years post-training; Willis et al., 2006); (d) all three training groups still significantly outperformed untrained controls at 5-years post-training; even where the mean longitudinal trend had become one of decline, trained participants experienced less decline than untrained controls; (e) the residual booster training effects were also still significant at the 5-year follow-up for Speed and Reasoning groups (but not the Memory) group; (f) transfer to everyday functional outcomes was small-to-modest.

Participants in all three training groups reported significantly less increase in perceived IADL (instrumental activities of daily living; e.g., food preparation, medication use) at 5-years posttest than untrained controls; this difference reached significance (after Bonferroni correction) only for the Reasoning-trained group, but the effect was of similar magnitude for all three training groups. No effect of the basic 10-session training program was detected on observed, performance-based tasks of daily living, but for the subset of participants who received additional booster training, some performance-based effects were observed. Specifically, at the five-year follow-up, in the Speed training group, booster-trained participants significantly outperformed those who received only the basic 10-session program on a performance-based construct of Everyday Speed (e.g., reacting to road signs; finding items in a pantry, locating a number in a phone book). In addition, in the Reasoning training group, booster-trained participants significantly outperformed those with basic training on a performance-based construct of Everyday Problem Solving (e.g., document literacy tasks involving directions, charts and forms in familiar everyday stimuli), although this difference was no longer significant after Bonferroni correction.

Socio-demographic – Cognition Associations in ACTIVE

Germane to the current work, more recent studies have begun to investigate individual differences in baseline cognitive function and training gains. McArdle and Prindle (2008) examined patterns of training gains in the Reasoning-trained group using a longitudinal structural equation model. While not the main goal of the paper, the authors found adding demographic covariates to their model suggested that individual-level MMSE score, age, and education interacted with the ACTIVE training effects. They also reported that Reasoning-trained participants in lower demographic profiles potentially did not gain as much, but had larger transfers of training.

Impairment Associations with ACTIVE Training Effects

Turning to cognitive individual differences, Unverzagt and colleagues (2007) examined the effects of low baseline memory performance (a performance region roughly equivalent to "cognitive impairment") on ability to profit from training gain. Interestingly, low memory participants were not different from normal-memory comparison participants in training gains from the Reasoning and Speed interventions; on the other hand, unlike normal memory participants, these low-memory elders did not appear to profit from the memory training, suggesting a focal and specific memory deficit that constrained both memory performance and memory plasticity.

Physical Health – Cognition Associations in ACTIVE

Investigating physical health and fitness predictors of cognition in ACTIVE, Kuo and colleagues in two studies examined cardiovascular risk factors as a predictor of baseline cognition. In one study (2006), participants who were overweight at study start actually performed better than normal weight peers on reasoning and speed, although the relationship between BMI and cognition was non-linear. In a second study (2005), the authors reported that hypertension was associated with faster one-year decline in reasoning, and diabetes mellitus (DM) was associated with faster decline on the Digit Symbol Substitution Test (a processing speed measure). Beyond the cognitive domain, hypertension and DM were associated with faster decline on self-reported physical function as well.

Psychosocial Health – Cognition Associations in ACTIVE

Regarding psychosocial health predictors of cognition, in two studies Wolinsky and colleagues have examined secondary quality of life outcomes of ACTIVE training. A first study (2006a) looked at the period twenty-four months after training. Here, participants in the Speed intervention arm were less likely to have clinically significant health-related quality of life decline (HRQoL) as indexed by the SF-36 scales) compared with controls, and Memory/Reasoning groups did not differ from controls. A follow-up investigation (2006b) examined the five-year HRQoL effects of training, reporting that while the Speed intervention appeared to protect against perceived HRQoL declines throughout the study, participants in the Memory and Reasoning intervention arms were significantly less likely to have extensive HRQoL decline only at 5 years post-training, and at a lower threshold than for Speed. However, at the five-year follow-up, all three interventions were successful in protecting against a lower threshold of age-related extensive declines in HRQoL.

Conclusions

For the current study, we took the following broad conclusions as supportive of pursuing further predictors of individual differences in cognition and cognitive training outcomes: First, training effects were substantial, and durable (if specific). Second, initial studies have been successful in identifying predictors of individual differences in baseline cognitive level and cognitive gains. Third, at the individual level, both physical health-cognitive and psychosocial-cognitive (HRQoL) associations have been found.

Limitations of the Present Study's Scope

Of course, the simplified model for the present study is under-specified, in the sense that it omits potential known individual-level predictors of cognition and other contextual factors. However, in order to ensure an appropriately feasible scope for a dissertation study, the current work was viewed as a preliminary study on which future research to examine individual level mediators of neighborhood influences on cognition (e.g., resource utilization, individual health and function, affective status) can be based.

Future research can then also examine other neighborhood-level moderators of the proposed predictors (e.g., factors that influence the ability to utilize contextual resources, like available transportation, safety, and weather), as well as predictors of longitudinal changes in cognition in the longer-term follows of ACTIVE sample.

The current study is intended to provide a preliminary lens on the association of concurrent contextual factors on individual cognition in ACTIVE. As discussed earlier in the chapter, it may be important to understand the influence of early socioeconomic position variables as well. This is acknowledged, and will remain an under-specified component of the current study. Future research may be able to investigate some indicators of early advantage. Glymour and Berkman (2006), for example, reported that county-level variation in length of the school year predicted individual differences in cognition in the HRS/AHEAD study. (It should be noted that in a currently fielded tenth annual follow-up of the ACTIVE trial, investigators are collecting participants' schooling history, so that similar analyses may be possible in future ACTIVE studies. These variables were not available to the candidate during the proposed period of study).

Areas for Exploratory Follow-Up

Acknowledging that the current study's conceptual model was simplified to maintain a feasible dissertation project scope, additional factors affecting the neighborhood-cognition relationship were explored as time and resources allowed. Exploratory follow-up work considered the important contributions of individual-level mobility, community-level racial/ethnic composition, and residence in an urban, suburban, or rural location.

Mobility

Several studies of neighborhoods and aging have suggested that older adults' vulnerability to declines in physical mobility (Manton, 1988) and driving skills, which are associated with concurrent changes in the number and location of activities (Marottoli, de Leon, Glass, Williams, Cooney, & Berkman, 2000) and with frequency of contact with social networks (van Tilburg, 1998), may lead older adults to greater dependence on the immediate residential neighborhood and the facilities it provides (e.g., Yen, Scherzer, Cubbin, Gonzalez, & Winkleby, 2007). However, many of the current studies on neighborhoods and health in aging have not accounted for physical mobility or driving status or habits (Yen et al., 2009). The present study sought to include geographic mobility and driving mobility (specifically, movement beyond the boundary of the immediate neighborhood) in follow-up models as a moderator of the neighborhood-cognition relationship.

Community-Level Racial/Ethnic Composition

While not a primary focus of the present study, many neighborhood studies have demonstrated that the racial/ethnic composition of a community is associated with individual health outcomes in different ways, especially depending on the race or ethnicity of the individual being studied (e.g., Eschbach, Ostir, Patel, Markides, & Goodwin, 2004; Acevedo-Garcia, 2001). Cognitive aging literature has also recently shown that community racial/ethnic composition interacts with individual-level race in predicting cognitive status and decline, although the reasons for this interaction are still the subject of speculation (Sheffield & Peek, 2009). Accordingly, follow-up work for the present study considered the influence of both community-level racial/ethnic distribution and its interaction with individual-level race.

Urban, Suburban, or Rural Residency

Recent literature has articulated the importance of considering differences between urban, suburban and rural contexts in examining person-environment interactions in late life (e.g., Wahl, 2005). That is the social and physical nature of the older person's interaction with the immediate environment can differ greatly, in terms of the needs felt and behaviors required for adaptive functioning, depending on whether the interaction takes place in an urban, suburban, or rural setting. Moreover, the prevalence and interaction of certain individual-level factors with area-level factors differs by this classification. For example, low-SES individuals living in high-SES neighborhoods tends to occur more often in rural areas, and is associated with poorer cognitive outcomes, whereas the opposite (high SES individuals living in low SES neighborhoods) tends to be found in urban areas (Deeg & Thomese, 2005).

The present study considered approximations of urban, suburban, and rural classifications in follow-up models (described in detail in the Methods). Importantly, this classification represents a relatively broad approximation of a complex and hotly-debated issue. Extant literature recognizes obstacles to research design and methodology related to poor consensus on urban/suburban/rural definitions and the difficulty of controlling for confounding variables (Golant, 2004), heterogeneity of settings within each of these categories, and the fact that the meaning of these categories are constantly changing over time (Wahl, 2005). While attention to these categories in contextual gerontological research is important, it is best to consider them as a frame by which to differentiate contexts for interactions, rather than as broad categories for comparison (e.g., Wahl, 2005).

CHAPTER 3
METHOD

Overview

The following chapter first outlines the relevant information about the parent study's design, sample, procedure and measures. Second, it describes how the additional dataset for the present study, which consists of U.S. Census-derived data merged with the ACTIVE dataset, was acquired. Third, it describes the analyses that were conducted to evaluate the aims outlined for this study.

The ACTIVE Study

The parent study, "Advanced Cognitive Training for the Independent and Vital Elderly (ACTIVE)," was a cooperative agreement between the National Institute on Aging/National Institute of Nursing Research and investigators at six field sites across the United States (catchment areas in parentheses): Johns Hopkins University (metropolitan Baltimore, MD and Maryland Eastern Shore); the Hebrew Senior Life Center for the Aged (metropolitan Boston and surrounding New England region); Pennsylvania State University (central Pennsylvania, primarily the region between Harrisburg PA and Pittsburgh PA); Wayne State University (Detroit Metropolitan area), Indiana University School of Medicine (Indianapolis Metropolitan area), and the University of Alabama-Birmingham (Birmingham and surrounding region). The study was coordinated centrally by the New England Research Institutes. Key references describing the design of the style and primary analyses include: Jobe et al., 2001; Ball et al., 2002; Willis et al., 2006.

Study Design

The primary objective of ACTIVE was to test the effectiveness and durability of three distinct cognitive interventions. In addition to examining proximal training effects on the intervention targets (memory, reasoning, and speed), the study also investigated whether performance of cognitively demanding tasks of daily living (e.g., food preparation, medication use, financial management) might also be improved by training. The initial trial randomized individuals to one of three 10-session cognitive interventions designed to improve memory, reasoning, or processing speed performance (Jobe et al., 2001) or to a no-contact control condition. Following conclusion of training, there was an immediate posttest, and follow-up assessments 1-, 2-, 3- and 5-years post-intervention. The current study sought to examine only the immediate pretest-posttest data (an approximately three-month period in which, following pretest, about two months of cognitive training were followed by an immediate posttest), focusing on the proximal outcomes. The initial clinical trial enrolled participants between 1997-2000, and concluded data collection in 2002. Information on potential covariates was collected (e.g. demographics, medical history, health-related quality of life and mood status). Testers at all six sites were trained in standardized assessment protocols, and quality control by both study investigators and the coordinating center ensured fidelity to testing procedures.

Participants

The initial sample of participants, which comprises the participants proposed for inclusion in this secondary data analysis, consisted of 2,802 randomized persons. Recruitment ran from March 1998 through October 1999. Recruitment strategies and sources varied by site; strategies included on-site presentations, letters to interested persons, newspaper advertisements, introductory letters and follow-up telephone calls. The University of Alabama 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 recruited through a network of facilities providing activities and social services to seniors, as well as local churches and senior citizens' organizations. Johns Hopkins University recruited from senior community organizations and centers, churches, senior housing, and through programs offering or coordinating wellness or service programs for seniors. Pennsylvania State University recruited through a state-funded pharmaceutical assistance program for low-income elders. Wayne State University recruited from a large range of community organizations, churches, hospital-based senior assessment centers, senior housing sites, and driver registration lists. Participants were cognitively healthy, community-dwelling older adults aged 65 to 94 years (mean age=73.6 years, mean years of education=13.5, mean MMSE = 27, 75.8% female, 72% Caucasian, 26% African American, 2% belonging to other minority groups). The majority of participants (64%) were not married, and most reported good to excellent health (84.3%). However, chronic medical conditions were present within the sample (e.g., hypertension 51%, high cholesterol 44%, ischemic heart disease 19.2%, chronic lung disease 14.9%). Efforts were aimed at recruiting older adults who were independent of care at the time of enrollment, and at recruiting a diverse sample especially inclusive of African Americans, 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, diagnosis of Alzheimer's disease), c) having a medical condition disposing the participant to imminent cognitive decline or to mortality within the next 2 years (e.g. recent stroke, certain cancers), d) severe sensory or communicative difficulties precluding participation in assessments and training, e) having had cognitive training, or f) planning to be unavailable during the testing and training periods of the study.

Of interest within the study sample, specific to the present study, are 1) the diversity among samples from different study sites, and 2) the diversity of contexts from which the overall sample was drawn. Table 3-1 illustrates the variation in individual demographic indicators across the ACTIVE study sites. Similarly, Table 3-2 illustrates patterns of site variation on several census measures, aggregated at the census tract level. The values in both tables represent significant site-level variation ($p < 0.001$) on all measures, as verified using multivariate analysis of variance

Interventions

The three interventions shared these design features: a) equivalent intensity and duration across ten, 60-75 minute sessions; b) small group settings; c) focus on strategies for solving problems, remembering, or responding quickly to information; d) modeling and demonstration of strategy usage; e) practice on exemplar problems; f) individual and group exercises; g) feedback on performance; h) fostering of self-efficacy regarding performance; i) applying strategies to real-world tasks; j) individualized training experiences, and k) social interaction activities. In all three conditions, Sessions 1-5 focused on strategy instruction and exercises to practice the strategy. Sessions 6-10 provided additional practice exercises, but no new strategies were introduced. The content for each of the 10 sessions was scripted in a trainer's manual.

Standardization of the training was ensured through certification of trainers and on-going quality control observations. Synopses of the topics of individual sessions for each of the training groups are presented in Appendix A; a summary of the interventions' contents are detailed here.

Memory training

Participants received instruction on multiple mnemonic strategies in the context of 4 basic memory principles (meaningfulness, organization, visualization, and association). Strategies were practiced extensively in both individual and group exercises, and on both laboratory-like tasks and tasks relevant to daily life. Participants also received individual and group feedback on performance, a practice test, and self-efficacy enhancement.

Reasoning training

Participants were taught strategies for identifying patterns or sequences in order to solve abstract reasoning problems and problems of everyday living. Participants practiced using individual and group exercises. Training was intended to improve the ability to solve problems requiring linear thinking by following a pattern or sequence.

Speed of Processing training

Training aimed to improve visual search speed and performance speed for one or more attentional tasks. Participants completed increasingly complex visual information processing tasks administered by computer, with stimuli presented for progressively shorter durations. The visual information processing tasks required use of selective and divided attention, at increasingly-difficult levels of demand.

Control group

This was a no-contact group that only completed the cognitive testing at each occasion, in order to help researchers account for practice effects from repeated testing.

Outcome measures

Baseline cognitive level was characterized using the measures in Table 3-3 below. Immediate gains following the cognitive intervention were assessed by comparing performance improvements on tests in the domain of training (memory, reasoning, or speed) to performance on the other untrained measures.

Additional Individual-Level Covariates

ACTIVE also collected individual-level information which was used to help account for individual differences influencing cognition in the present study. These covariates included demographic variables (gender, age, education, race (white, non-white)), MMSE score, recent depressive symptoms (Center for Epidemiological Studies Depression scale, CES-D; Radloff, 1977), and general health, including physical functioning (36-Item Short-Form Health Survey, SF-36; Ware & Sherbourne, 1992). A measure of individual mobility called the Life Space Questionnaire (LSQ; Stalvey, Owsley, Sloane, & Ball, 1999) was also collected. The LSQ queried whether in the past week the participant had left the bedroom, house, block, neighborhood, town, and so forth. The LSQ also accounted for whether the participant personally drove himself or herself to more distal places, or was driven by another person.

Relationship of the proposed study to the parent study

ACTIVE included multiple assessments of participants. The present paper, however, restricted itself to (a) baseline cognitive performance (i.e., performance at intake, prior to intervention), and (b) immediate pre-post change (i.e., direct improvement on training targets, immediately following training). As noted earlier, ACTIVE included a broad list of covariates, some of which were construed as potential secondary outcomes of the larger trial.

In this the proposal, additional individual-level covariates will be drawn from the ACTIVE database, including presence of chronic diseases, medications taken, and/or health behaviors known to be associated cognitive functioning (smoking, alcohol consumption), and affective indicators known to be associated with cognitive functioning (e.g. depression). Neighborhood level correlates were obtained from external data sets and merged with ACTIVE data at the individual participant address level. The project linked publicly-available geographic datasets with individual address information collected from the baseline ACTIVE study. The geographical data collected was used to characterize a) the neighborhood-level socioeconomic position (SEP), and b) the richness of the neighborhood environment as defined by facilities supporting physical health (PHY) and psychosocial health (PSY).

It should be noted that ACTIVE did not aim to include measures of *individual-level* socioeconomic position. Education (highest level achieved) was assessed for all participants. Other person-level socioeconomic indices (e.g., income, occupational prestige) were not collected at baseline. (Occupational history, operationalized as the last job held, was collected at a two-year follow-up in ACTIVE, but was only available for the subset of participants who returned at this occasion. Moreover, this paper did not seek to investigate time points beyond the immediate posttest period).

Data for the Proposed Study

Geocoding of the ACTIVE data

Geographic information systems (GIS) are “automated systems for the capture, storage, retrieval, analysis and display of spatial data” (Clarke, 1995). These systems contain 1) a database or databases, 2) a geographic or spatial map, and 3) a mechanism to link these two together (Clarke, McLafferty, & Tempalski, 1996). GIS can spatially represent and manipulate information in virtually any type of dataset related to a geographic location. *Geocoding* (Rezaeian, Dunn, St. Leger, & Appleby, 2007) assigns Cartesian mathematical coordinates (e.g., longitude and latitude) to a geographical point (e.g., street address). Multiple types of spatially related of data can be represented on a single map and integrated in a combined database.

Acquisition of neighborhood level data and merging with geocoded ACTIVE data

GeoLytics, a provider of geocoding services and census demographic data, was paid to 1) geocode the ACTIVE participant addresses, and 2) append 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. Each ACTIVE participant’s address at the time of enrollment was geocoded to a matching street, city, ZIP code and state address in existing public domain maps provided by the U.S. Geologic Survey (USGS). These addresses were also linked to their census-defined block group, census tract, and ZIP-code areas. Geocode misclassification can detract from accurate analyses (Krieger, 2003), so the geocodes were checked for quality assurance. Addresses with invalid house numbers, street names, and ZIP codes were flagged for follow-up; invalid addresses or poorly-matched addresses were dropped from the analysis (93% of the ACTIVE addresses accurately matched to a

USGS geocode). Participants receiving mail by post office boxes were excluded from further analyses; such addresses cannot be verified to represent the participant's actual place of residence. The final data provided by GeoLytics, containing the geocoded addresses and census variables, was e-mailed to the investigators in 6 comma-delineated files: one containing the full data resulting from the geocoding (latitude/longitude coordinates, census tract number, block group number, etc.), one containing the 2002 Economic Census variables, two containing the 2000 Census Long Form variables at the census tract level, and two more containing the same Long Form variables at the block group level (in case the investigators desired to follow up with more geographically-specific analyses at a later point.)

Following recommendations by prior U.S. neighborhood-level research (Krieger et al., 2003), the neighborhood area for SEP was defined by the boundaries of the participant's census tract area. Census tracts are subdivisions of a county, with an average size of approximately 4,000 residents. These geographic boundaries were originally designed to be homogenous with respect to population characteristics, economic status, and living conditions. The geographical areas for neighborhood facilities were, by necessity, defined by participant ZIP-code area (for confidentiality, Economic Census data is not provided for geographic units smaller than the ZIP code area).

The geocoded ACTIVE dataset contained approximately 400 variables drawn from the 2000 U.S. Census (Long Form) and the 2002 U.S. Economic Census (selected to match the approximate years in which ACTIVE baseline data was collected, from 1997-2002). The neighborhood-level constructs of *neighborhood socioeconomic* *position (SEP)* and *neighborhood facilities and resources* were created from these data, as described in greater detail in the analytic plan.

Census Variables Used to Create Neighborhood-Level Constructs

The census indicators used to characterize the three neighborhood-level constructs are found in Table 3-4 through Table 3-6. The sections to follow describe the constructs created using factor analytic approaches.

Socioeconomic position

Neighborhood socioeconomic position was measured by creating a socioeconomic position (SEP) index (Krieger, 2001). SEP, an American adaptation of area-level socioeconomic indicators extensively researched in the United Kingdom (e.g., *Townsend Index*, Townsend, Philimore, & Beattie, 1998; *Carstairs Index*, Carstairs & Morris, 1991), combines multiple neighborhood-level measures of SES (e.g., occupational class, income, poverty, wealth, education, overcrowding). Because measures of income, education, and occupation are often strongly correlated and have been found to load onto a common factor among census-level variables (Diez-Roux et al., 2001), data on these factors were combined to create an SEP variable parsimoniously representing these socioeconomic domains. An area-level summary measure was derived by combining the census variables (Table 3-4) into a weighted composite following exploratory and confirmatory factor analyses, as outlined in the Statistical Analyses section to follow**.**

Facilities supporting physical and psychosocial health

Neighborhood-level facilities were to be defined by two, potentially three, composite indices: Physical Health Facilities (PHY) and Psychosocial Health Facilities (PSY), and possibly a third group, Hybrid (HYB), categorizing facilities supportive of both physical and psychosocial health. These indices were developed through exploratory factor and canonical variate analyses (as described in the analysis section below) of the variables collected from the 2002 Economic census (Tables 3-5 and 3-6). The census variables were selected based on their theoretical promotion of either physical health (i.e., grocery stores, hospitals, clinics, fitness centers) or psychosocial health (i.e. senior centers, religious organizations, libraries, museums). The variables represent the number of each type of facility available within the participant's ZIP code area. Facilities were defined using codes provided by the internationally-standardized 2002 North American Industry Classification System (NAICS), and data on the number of these facilities was publicly available from the 2002 Economic Census at www.census.gov.

Follow-Up Analyses

Exploratory follow-up analyses also sought to examine the contributing influences of individual mobility, community-level racial composition, and urban/suburban/rural classification in the neighborhood SEP – facilities – cognition relationships. Individual mobility was quantified dichotomously as whether or not the individual had traveled outside the neighborhood in the past week, using the ACTIVE Life Space Questionnaire data (Stalvey et al., 1999). Community-level racial composition was obtained by calculating the percentage of white residents within each census tract, using data from the 2000 U.S. Census.

Urban, suburban, and rural classifications were not directly available using the 2000 U.S. Census, but the census provided variables that could be used to approximate these classifications. The census provides maps categorizing areas of land as urbanized areas (UAs; core census block groups or blocks that have a population density of at least 1,000 people per square mile), urban clusters (UCs; surrounding census blocks that have an overall density of at least 500 people per square mile), and rural areas (all territory not classified as an urbanized area or urban cluster). Census tracts are often split between UAs, UCs, and rural territories, and may be quantified as the percentage UA, UC, or rural. The large majority of census tracts used in the present study were 100% UA, UC, or rural.

For the sake of exploring the nature of urban, suburban, and rural settings in shaping the neighborhood-cognition relationship, these categories were approximated by classifying participants as 1) living in a census tract that was 50% or more UA and located within a city with population > 250,000 (i.e, Baltimore, Boston, Detroit, and Indianapolis), 2) living in a census tract with majority (>50%) UA located in a city with population <250,000, or 3) living in a census tract with <50% UA or rural (all census tracts containing any percent UC over zero fell into this category). These classifications were intended to roughly correspond to urban, suburban, and rural, for the sake of exploratory analysis of this issue.

Statistical Analysis Plan

The analytical framework for the study involved exploratory and confirmatory factor analysis, structural equation modeling, repeated measures mixed effects modeling, and ordinary least squares regression. Statistical Package for the Social Sciences (SPSS) 18.0 and Analysis of Moment Structures (AMOS) 16.0 were used to conduct all statistical analyses. While no data were missing for any neighborhood-level variables, in a few instances data were missing from the ACTIVE dataset’s cognitive variables (e.g., due to failure to complete a task or attrition between the baseline and post-training testing occasions). Models were estimated using Full Information Maximum Likelihood

(FIML), which uses all available data (thereby not eliminating participants with incomplete data). Strictly speaking, FIML requires data to be Missing Completely At Random or Missing At Random (i.e., no systematic differences between missing and non-missing participants after covariate adjustment). In the current dissertation, we relied on a broader argument advanced by Schafer & Graham (2002); specifically, Missing-Completely-At-Random, Missing-At-Random, and Missing-Not-At-Random are seldom “pure types” (i.e., most missing situations are a combination of one of these). Moreover, use of modern missing data approaches (e.g., FIML or multiple imputation) are more likely to yield robust, unbiased parameter estimates then older, obsolete methods (e.g., introducing bias due to listwise deletion) artificially reducing variance via mean- or regression-based imputation (Schafer & Graham, 2002). Prior to detailing the plan of analysis, guiding principles for neighborhood research are briefly reviewed.

“Best practice” principles in neighborhood research

In the design of the present study, the investigators were influenced by recent scholarship regarding the evaluation of neighborhood level factors on individual function (Galobardes, Lynch, & Smith, 2007). As such, it strives to follow “best practice” for the conduct of neighborhood-level studies of cognition (Diez-Roux, 2004). For example, it is essential to include mediators of neighborhood level variables on individual function (Diez-Roux, 2001; Pearl, Bravemen & Abrams, 2001; Raugh, Andrews, & Garfinkel, 2001). This helps to explicate the processes by which contexts may influence individual development (Galobardes, Lynch, & Smith, 2007). In keeping with recent scholarship, the current study can be classified as ecologic (where neighborhood variables are assessed for each person), as opposed to multi-level (which would require systematic sampling of multiple individuals within each neighborhood (Diez-Roux, 2001). This has disadvantages (ideally, random variation within neighborhoods should be formally assessed), but the secondary analysis approach in this study precluded a true multi-level design.

Preliminary Aims – Neighborhood Constructs

Our preliminary aims were to empirically establish constructs, defined using publically available neighborhood-level data, representing neighborhood-level socioeconomic position, physical health facilities and psychosocial health facilities, and baseline cognition as measured in ACTIVE. Given the lack of substantial prior measurement work on the specific set of neighborhood-level indicators to be included in this study, exploratory factor analyses were conducted on all of the neighborhood variables prior to testing the relationship between neighborhood and cognitive outcomes. For example, Morenoff and colleagues (2007) examined social disparities as predictors of hypertension in the Chicago Community Adult Health Study. In their work, socioeconomic position (SEP) was dimensionalized into a set of four factors via orthogonal varimax rotation. Because, in our work, SEP, PHY and PSY were expected to represent correlated dimensions, we initially followed the method of Morenoff and colleagues, but used Promax rotation to allow optimal fit to the data. Criteria for acceptable model fit indices included RMSEA < 0.06, CFI > 0.95 , NFI > 0.95, and TLI > 0.95 (Hu & Bentler, 1999; Tabachnick & Fidell, 2007). The variables in Tables 3-4 through 3-6 for neighborhood SEP, PHY, and PSY were examined to identify latent constructs among the variable sets. A weighted composite measure of SEP was estimated and optimized in AMOS based on common factors identified in the exploratory factor analysis. For ordinary least squares analyses, factor scores (weighted composites using information from the factor analysis) were generated.

Because a theoretically acceptable weighted composite could not be generated using EFA, canonical variates, or CFA in AMOS for PHY and PSY (see details in the Results section and Appendix B), summed composites of facilities positively and negatively associated with cognition were calculated for use in the regression models.

Preliminary Aims – Cognitive Constructs

The measurement model specified for the present study sought to examine the relationship of neighborhood characteristics with five dimensions of cognition. The ACTIVE dataset was well-designed for this kind of inquiry, having captured at least three measures each of specific cognitive domains including memory, reasoning, processing speed, and everyday cognition, or measures of cognition related to everyday abilities. These measures tend to be more related to the 'mechanics' of cognition; ACTIVE also collected a measure of vocabulary, related to the cognitive 'pragmatics' or 'fund of knowledge.

Aim 1

The first predictive analytic aim of the present paper was to confirm that neighborhood socioeconomic position (SEP) shows bivariate relationships with the five cognitive domains at ACTIVE's baseline (and if so, which domains), and with the immediate responses to memory, reasoning and speed training in ACTIVE.

Prior to structural equation modeling, all variables were inspected for consistency with the assumption of multivariate normality (to permit maximum likelihood estimation). Where that assumption was not met, Blom transformations were applied to those variables. Blom transformations are rank-based inverse normal transformations of a continuous variable's sample distribution, applied in order to improve the normality of that distribution. The variable is first converted to ranks, and those ranks are then back-transformed using sample quantile or a fractional rank to approximate expected normal scores in a *z*-distribution (Blom, 1958). The SEP and cognitive measurement models were then combined in a structural equation model estimating regression paths from neighborhood-level SEP to the cognitive constructs of '*g'*, Reasoning, Speed, Everyday Cognition, and Vocabulary (a path could not be estimated for SEP or any covariates to Memory). Age, years of education, gender, and physical functioning were included in the model as covariates. Figure 4-3 illustrates this structural equation model.

Cognitive aging research has in recent years has also focused increasingly on the use of CFA and SEM to explore whether differences in late life cognitive performance are related to general or specific processes. Contemporary research also notes that conceptualizing late life cognition using a single general factor ('g') is a simplistic approach to a complex and dynamic cognitive system (McArdle, Hamagami, Meredith, & Bradway, 2000), suggesting neighborhood influences should be investigated at both the general and domain-specific level. Neighborhood environmental influences may support some dimensions of cognition more strongly than others, in addition to influencing general cognitive status, as extant research has reported. As such, a follow-up analyses embedded with Aim 1 estimated the extent to which SEP separately predicts (beyond specific cognitive domains) differences on a higher-order factor representing general cognition or *'g',* which will capture the shared variance among the five cognitive domains in the cognition measurement model.

Neighborhood SEP as a predictor of training gains was estimated as repeated-measures mixed effects models (Cnaan, Laird, & Slasor, 1997) rather than as structural equation models because this provided a more flexible interface for the analysis of training gains, which was operationalized as a two-occasion difference score (and thus would not significantly benefit from a latent variable approach) while still permitting FIML estimation for maximum power in the presence of missing data (i.e., using all available cases). Separate models were estimated for each domain trained (memory, reasoning, or speed) to examine the gains of each training group relative to other participants who did not receive that training (i.e., the other two training groups and the no-contact controls). Each model tested SEP as a continuous predictor and occasion (baseline, post-test) and training group (received training on the ability being examined or not) each as class variables. Each model also tested all possible two-way interactions and the three-way interaction of SEP, occasion, and group. Interactions were estimated as residualized interaction terms to correct for collinearity with the model's main effects.

Intermediate Aim: Comparison of Geographic Levels for Aim 1 Model

To evaluate whether the chosen geographic level of analysis, the census tract, is the most appropriate unit at which to investigate neighborhood effects, the model fit and regression paths the baseline model in Aim 1 were run at two other levels of geographic aggregation: the block group level, which is the next-smallest level of aggregation, and the 5-digit ZIP Code Tabulation Area (ZCTA), which is the next-largest level of aggregation. Because these three models identified the same variables and were structurally-equivalent, their model fit indices (i.e, NFI, CFI, RMSEA, AIC, BIC) and regression loadings could be compared. The geographic unit yielding the smallest model fit indices and strongest regression loadings was selected for use in the final models for Aims 1 and 2.

Aim 2

The analytic approach for Aim 2 shifted to testing neighborhood facilities as mediators of SEP's effect on individual cognitive outcomes (e.g., Memory composite, Vocabulary) using Preacher and Hayes' (2008) approach for multiple mediation in ordinary least squares (OLS) analysis. This permitted simultaneous assessment of facilities positively and negatively related to cognition as potential mediators of the SEP-cognition relationship. From a hierarchical regression framework, the attenuation of the direct path between SEP and cognition, following the introduction of those proposed mediators (Baron & Kenny, 1986), was evaluated statistically (e.g., comparisons of model Akaike Information Criteria, model R^2, and regression weights). For all tests of mediation, Preacher and Hayes' test for indirect effects in SPSS (2008) was employed,. This approach calculated a bootstrapped estimate (1000 samples, with bias correction and acceleration) of the indirect effect of SEP on cognition through all proposed mediators combined, and through each mediator individually. This multiple mediation approach using OLS was maintained in all exploratory follow-up analyses of additional mediators and moderators, including urban/suburban status, neighborhood segregation, and individual mobility.

Power Considerations

Considering statistical power, with a sample size of 2,539 individuals, the study has been powered to significantly detect effects that might be characterized as "weak" (Cohen's d = 0.2) or better. Indeed, for the ACTIVE parent study, for the proposed ten-year follow-up, power curves have indicated (based on obtained within-person correlations and number of repeated measures) that, even after attrition, there will be adequate power to detect effect sizes of 0.2 over 10 years for measures of cognitive abilities, Everyday Problem Solving and Everyday Speed and an effect size of 0.4 for IADL Difficulty.

There are two other indications of adequate statistical power. First, using G*Power 3.0 (Faul, Erdfelder, Lang & Buchner, 2007), the smallest detectable effect size for a unique single predictor in a set of twenty predictors, given alpha=0.01, power of 0.8, and N=2,539 was determined. That sensitivity power analysis suggested unique predictor effects as low as f^2=0.008, which corresponds, roughly, to a unique predictor-specific (partial) R^2 of 0.008. Second, the study's sample size (2,521) falls well within Bollen's (1989) suggestion "to have at least several cases per free parameter". The sample size falls well above the *N*=100 to *N*=500 minimum suggested by other expert researchers (e.g. Anderson & Gerbing, 1984).

Table 3-1. Demographic variation across ACTIVE study sites.

ACTIVE site	Age at Baseline	Education	MMSE	% Female	% White
UAB(*N*=447)	72.2 (5.4)	14.0 (2.7)	27.6 (2.0)	61.4	91.1
IU(*N*=457)	73.6 (6.0)	13.6 (2.8)	27.3 (2.0)	77.1	58.3
HRCA (*N*=363)	77.1 (6.6)	14.6 (2.7)	27.0 (1.9)	73.1	94.3
JHU (*N*=422)	73.1 (5.4)	13.1 (2.6)	27.1 (2.0)	83.7	66.9
WSU (*N*=466)	73.9 (5.4)	12.1 (2.7)	27.2 (2.0)	75.4	35.4
PSU (*N*=416)	73.6 (5.9)	12.1 (1.9)	27.5 (2.0)	84.1	93.6

Note: UAB=University of Alabama-Birmingham; IU=Indiana University School of Medicine; HRCA=Hebrew Rehabilitation Center for Aged (now Hebrew Senior Life); JHU=Johns Hopkins University; WSU=Wayne State University; PSU=The Pennsylvania State University; Values represent means; values in parentheses represent standard deviations. All sites significantly different on all variables (univariate ANOVAs, uncorrected $p < .001$)

Table 3-2. Site-level variation on neighborhood-level census measures.

ACTIVE site	% income over $150,000	Median household income in 1999	% with Bachelor's or higher	% with HS diploma	% of labor force unemployed	% below poverty level
UAB	7.94	51800.33	37.79	22.46	4.25	8.70
(*N*=447)	(9.13)	(21132.58)	(21.84)	(10.61)	(5.16)	(8.84)
IU	5.05	45658.86	30.66	26.80	5.66	11.20
(*N*=457)	(6.33)	(18463.21)	(19.32)	(9.71)	(4.52)	(9.71)
HRCA	11.35	62061.21	48.57	20.62	3.75	8.31
(*N*=363)	(10.50)	(23236.42)	(21.98)	(10.06)	(2.76)	(5.87)
JHU	1.99	32673.41	17.34	35.18	8.71	16.77
(*N*=422)	(2.88)	(10676.54)	(12.40)	(9.00)	(6.37)	(10.04)
WSU	7.32	48115.91	26.53	24.70	9.65	15.64
(*N*=466)	(10.79)	(28076.28)	(21.37)	(9.11)	(7.07)	(13.16)
PSU	1.17	29345.72	12.72	49.15	7.59	17.51
(*N*=416)	(1.01)	(8620.85)	(6.29)	(5.64)	(6.13)	(11.26)

Note: UAB=University of Alabama-Birmingham; IU=Indiana University School of Medicine; HRCA=Hebrew Rehabilitation Center for Aged (now Hebrew Senior Life); JHU=Johns Hopkins University; WSU=Wayne State University; PSU=The Pennsylvania State University; Values represent means; values in parentheses represent standard deviations. All sites significantly different on all variables (univariate ANOVAs, uncorrected $p < .001$).

Table 3-3. Measures of cognition and response to training used in the ACTIVE study.

Domain	Measure	Description
Memory	Hopkins Verbal Learning Test (Brandt, 1995)	12-word list memory task assessing immediate and delayed recall over 4 trials (3 immediate, 1 delayed).
	Rey Auditory Verbal Learning Test (Rey, 1941)	15-word list memory task assessing immediate and delayed recall over 5 consecutive learning trials.
	Rivermead Behavioral Memory Test (Wilson, Cockburn, & Baddeley, 1985)	Paragraph recall task (3-4 sentences) assessing immediate verbal episodic memory.
Inductive Reasoning	Letter Series (Thurstone & Thurstone, 1949)	Task requiring accurate identification of the next logical letter group in a series of letters (e.g., a m b a n b a o b _).
	Letter Sets (Ekstrom, French, Harman, & Derman, 1976)	An inductive reasoning task requiring participants to identify which of 4 sets of letters is unrelated to the others (e.g., eef hhi llm ysy)
	Word Series (Gonda & Schaie, 1985)	Task requiring accurate identification of the next logical word in a series.
Processing Speed	Useful Field of View (Ball, Owsley, Sloane, Roenker, & Bruni, 1993)	Computer-administered task measuring visual sustained, selective, and divided attention through four subtasks.
	Complex Reaction Time (Ball & Owsley, 2000)	Computer-administered task measuring the time taken to perform various motor behaviors and to complete each task.
	Digit-Symbols Substitution Test & Symbol-Copy Test (Wechsler, 1981)	Digit-Symbol is a timed task requiring copy of numbers under a series of corresponding symbols; Symbol-Copy is a test in which individuals simply transcribe symbols, thereby providing an estimate of the psychomotor component of Digit-Symbol performance.
Vocabulary	Vocabulary Test (Ekstrom, French, Harman, & Derman. 1976)	Multiple-choice measure of vocabulary attainment; participant is presented with a word and must choose one of four possible synonyms; “recognition vocabulary”.

Table 3-4. Measures and sources of data for building socioeconomic position (SEP).

Measure	Indicators	Source
Neighborhood SEP: Weighted composite of the following socioeconomic measures obtained for the census tract	*Education* = % persons aged 25+ with less than 9th grade education; % persons aged 25+ years with a high school diploma; % persons aged 25+ years with 4 or more years of college *Income* = Median household income; % households with income > $150,000 *Poverty* = % households with income < $15,000 *Occupational class* = % persons aged 16+ years employed in executive, managerial, or professional occupations *Unemployment* = % persons aged 16+ years in the labor force unemployed	2000 U.S. census

Table 3-5. Measures and sources of data for building physical health facilities (PHY).

Measure	Indicators	Source
Physical health facilities (PHY). Numbered codes correspond to 2002 NAICS classifiers.	445110 Supermarkets & other grocery (except convenience) stores 445220 Fish & seafood markets 445230 Fruit & vegetable markets 446110 Pharmacies & drug stores 611620 Sports & recreation instruction 621111 Offices of physicians, except mental health specialists 621112 Office of physicians, mental health specialists 621210 Offices of dentists 621320 Offices of optometrists 621340 Offices of physical, occupational, & speech therapists and audiologists 621399 Offices of all other miscellaneous health practitioners 621491 HMO medical centers 621492 Kidney dialysis centers 621493 Freestanding ambulatory surgical and emergency centers 621498 All other outpatient care centers 622110 General medical & surgical hospitals 622310 Specialty hospitals (not psychiatric or substance abuse) 624210 Community food services	2002 U.S. Economic Census

Table 3-6. Measures & sources of data for building psychosocial health facilities (PSY).

Measure	Indicators	Source
Psychosocial health facilities (PSY). Numbered codes correspond to 2002 NAICS classifiers.	611610 Fine arts schools 611630 Language schools 621112 Offices of physicians, mental health specialists 621330 Offices of mental health practitioners (not physicians) 621420 Outpatient mental health & substance abuse centers 622210 Psychiatric & substance abuse hospitals 623311 Continuing care retirement communities 624120 Services for the elderly & persons with disabilities (includes senior citizens' activity centers) 485991 Senior Transportation Services 711110 Theater companies and dinner theaters 711120 Dance companies 711130 Musical groups and artists 711190 Other performing arts companies 711211 Sports teams and clubs 712110 Museums 712130 Zoos & botanical gardens 712190 Nature parks & other similar institutions 713910 Golf courses & country clubs 713920 Skiing facilities 713940 Fitness & recreational sports centers 813 Religious, grant-making, civic, professional, and similar organizations 813410 Civic/social organizations (excluding youth development organizations; includes senior citizens' social associations)	2002 U.S. Economic Census

CHAPTER 4
RESULTS

Overview

The results reported in the following chapter describe: 1) completion of the preliminary analyses proposed in the Aims (i.e., development of factor-analytic models representing neighborhood-level socioeconomic position (SEP), facilities supporting physical and psychosocial health (PHY and PSY), and general and specific dimensions of baseline cognition in ACTIVE), 2) estimation of the relationships between neighborhood SEP and baseline cognition and response to ACTIVE training, controlling for individual-level predictors (Aim 1), 3) evaluation of neighborhood facilities as a mediator of SEP's association with cognition (Aim 2), and 4) follow-up analyses of additional variables influencing the relationships among neighborhood SEP, facilities, and cognition.

Preliminary Aims

Development of Neighborhood-Level Socioeconomic Position (SEP)

Neighborhood SEP was initially developed using exploratory factor analysis to combine the 8 indicators of area-level SES listed in the Methods (median household income, % households with income > $150,000, % persons in poverty, % with 9th grade education or less, % with High School education or less, % with Bachelor's degree or higher, % unemployed, and % working in management positions or higher). All variables were normalized by applying a Blom transformation to accommodate the assumptions of normality required for factor analysis. The exploratory analysis indicated all 8 variables loaded strongly onto one factor (eigenvalue = 5.97), explaining 71% of the variance; factor loading values ranged from 0.71 to 0.94. All indicators were then included in a confirmatory factor analysis, in which modification indices (MI) suggested high intercorrelations of error variances among variables (e.g., ranging up to MI = 1325.42). To derive an optimally-fit, parsimonious set of variables capturing the shared variance of characteristics on which SEP is typically based (e.g., income, education, and occupational attainment), redundant variables were progressively removed from the model.

The final, simplified SEP factor model (Table 4-1; Figure 4-1) consisted of four variables measuring socioeconomic advantage in income, education, and occupation (median household income, percent with income >$150,000, percent with bachelor's degree or higher, and percent in management positions or higher). As two indices of area-level income might be expected to correlate, a correlation path was estimated between the error variances of median household income and percent income >$150,000, and was retained in all subsequent models. Model fit was good (CFI = 0.999, NFI = 0.999, TLI = 0.996, χ^2/df ratio = 8.23 (p = 0.004), RMSEA = 0.05 (p = 0.36)). Notably, the variables loading on the latent SEP factor are all indicators of neighborhood affluence or advantage rather than disadvantage; prior neighborhood research has suggested that measures of social advantage, compared to social disadvantage, may be especially important protective factors in neighborhood influences on development (e.g., Leventhal & Brooks-Gunn, 2000).

Development of the Baseline Cognition Measurement Model

As described in the Methods section, the present paper sought to characterize both general and specific aspects of late life cognition. Figure 4-2 illustrates the conceptual structure of the ACTIVE cognitive data: the measured variables related to memory (HVLT Total Recall, AVLT Total Recall, and RBMT Paragraph Immediate

Recall) were combined to represent a Memory factor; measures of Reasoning (Letter Sets, Letter Series, and Word Series scores) combined to form a Reasoning factor; guided by preliminary exploratory analyses, measures of processing speed (UFOV and CRT scores) optimally first combined into separate UFOV and CRT factors, which were then combined to form a Speed factor (recall that for Speed, lower scores mean better performance); and individual measures of everyday cognition (Timed Activities of Daily Living, Observed Tasks of Daily Living, and the Everyday Problems Test) combined on a factor representing Everyday Cognition. Because these cognitive 'mechanics' domains were represented by latent factors (making them 'purer' representations of their domains), the Vocabulary measure was also represented as a factor by using odd and even scores as indicators loading on a single Vocabulary factor; this effectively transforms that factor into a construct representing the odd-even split half reliable variance of the measure. All cognitive variables collected in ACTIVE were Blom-transformed by the original data collectors prior to the present analysis, and were normally distributed. The disturbance terms of all cognitive factors (Memory, Reasoning, Speed, Everyday Cognition, Vocabulary) were permitted to correlate with one another. . The error variances of the UFOV 2 and 4 subtests, and the Everyday Problems Tests and Vocabulary, were also allowed to correlate in the process of optimizing model fit; these correlations were retained in subsequent models. Model fit was acceptable (CFI = 0.98, NFI = 0.97, RFI = 0.96, TLI = 0.97, RMSEA = 0.046, (p = 1.00), χ^2/df ratio = 6.40, ($p < 0.001$)). The baseline cognition measurement model and factor loading coefficients are illustrated in Figure 4-2 and Table 4-2.

Statistical Representation of Facilities Supporting Cognition

Development of the construct representing neighborhood facilities related to cognition was intended to be theory- and consensus-driven. However a series of such approaches including consensus classification, exploratory and confirmatory factor analyses did not identify a theoretically interpretable factor structure. A detailed description of these approaches and their outcomes is documented in Appendix B.

Instead, *post hoc* analyses evaluated the individual correlations of the presence or absence of each type of facility with six individual measures of cognition (ACTIVE memory, reasoning, or speed composite, everyday cognition factor score, vocabulary, and MMSE; see Table B-2). This examination revealed that if a facility *was* significantly associated with multiple cognitive measures, it almost always predicted differences in the same direction on all of those measures. Specifically, 18 out of the 39 facilities correlated in the same direction with at least 3 of the 6 measures of cognition. However, while all facilities had been theoretically believed to support cognition, the presence of some was associated with better cognition, and others with poorer cognition. Of these 18 facilities related to cognition, half were positively associated with the cognitive measures, and the other half were negative associated with the cognitive measures (Table 4-3). These two sets of 9 facilities were summed into two variables representing facilities which, if present in a participant's ZIP code, were related to better or poorer cognition. These variables are limited in that they were created *post hoc* and, as Table 4-3 illustrates, combined atheoretically. However because facilities as a mediator of neighborhood SEP's relationship with cognition has been relatively unexamined, the aim of this exploratory approach was simply to gauge whether neighborhood facilities, when optimally combined to predict cognition, even posed the potential to mediate this relationship.

Aim 1: Neighborhood SEP Predicting ACTIVE Cognitive Measures

Baseline Cognitive Level

The SEP and cognitive measurement models were combined in a structural equation model estimating regression paths from neighborhood-level SEP to the cognitive constructs of Memory, Reasoning, Speed, Everyday Cognition, and Vocabulary. Age, years of education, gender, and race (1 = White, 0 = African American) were included in the model as covariates. Model fit was adequate (CFI = 0.97, NFI = 0.96, TLI = 0.96, χ^2/df ratio = 6.24, ($p < 0.001$), RMSEA = 0.05 ($p = 1.00$)). After controlling for individual-level demographics, SEP remained a significant predictor of reasoning and vocabulary ($p < 0.01$; Table 4-4). A schematic of the Aim 1 predictive structural equation model is depicted in Figure 4-3.

It was noted that the cognitive factors in the Aim 1 SEM were all significantly correlated ($p < 0.001$). Given these correlations, and as mentioned in the statistical analysis plan in the Methods chapter, a follow-up analysis within Aim 1 examined whether neighborhood SEP might additionally predict differences in general cognition (*'g'*) above and beyond differences within the specific cognitive domains. Figure 4-4 illustrates how *g* was estimated as a higher-order factor combining the shared variance among the five cognitive domains, and how SEP was allowed to predict this factor in addition to those included in the previous model. In this scheme, 'g' was effectively 'partialed out' of the five cognitive domains; this allowed the investigation of whether SEP affected cognition generally, and then whether it had additional significant unique associations with the individual cognitive domains after controlling for general cognition.

Model fit was adequate (CFI = 0.96, NFI = 0.96, TLI = 0.95, χ^2/df ratio = 6.52, ($p <$ 0.001), RMSEA = 0.05 (p = 0.99)). Standardized factor loadings of the cognitive domains on *g* are illustrated in Table 4-4, and regression paths from SEP to the cognitive factors are illustrated in Table 4-5. After controlling for individual-level demographics, SEP did not demonstrate a significant relationship with *g*. Additionally, with the addition of *g* to the structural equation model, 1) the effect of SEP on the reasoning factor was no longer significant, and 2) estimation of a regression path from any predictors to the memory factor resulted in failure of the model to converge.

Response to Cognitive Training

Repeated-measures mixed effects models were used to estimate whether neighborhood SEP predicted differences in training-related gains, beyond practice-related gains, on post-training measures of memory, reasoning, and speed. Three separate models examined the gains of each training group relative to other participants who did not receive that training. Each model tested SEP as a continuous predictor and occasion (baseline, post-test) and training group (received training on the ability being examined or not), all possible two-way interactions, and the three-way interaction of SEP, occasion, and group. Significant effects for occasion, training group, and their interaction were observed as previously reported in the parent study. A main effect was found for SEP, but for SEP to predict differences in response to ACTIVE training the three-way interaction would have to be significant; this was not found for any of the trained abilities (Memory: $F(1, 4594) = 0.66$, $p = 0.42$; Reasoning: $F(1, 4847) = 0.001$, $p = 0.98$; Speed: $F(1, 4793) = 0.001$, $p = 0.97$).

Intermediate Aim: Comparison of Geographic Levels for Aim 1 Model

Follow-up analyses compared the results when estimating the same factor structure for neighborhood SEP predicting the same cognitive factors at different geographic levels of analysis: block group, census tract, and 5-digit ZIP code tabulation area (ZCTA). Model fits at the block group (CFI = 0.97, NFI = 0.96, TLI = 0.95, χ^2/df ratio = 6.23 ($p < 0.001$), RMSEA = 0.05, ($p = 1.00$), AIC = 1684.59, BCC = 1686.98) and census tract levels (CFI = 0.98, NFI = 0.97, TLI = 0.97, χ^2/df ratio = 5.32, ($p < 0.001$), RMSEA = 0.04 ($p = 1.00$), AIC = 1753.73, BCC = 1756.17) were acceptable and highly comparable. Model fit at the 5-digit ZCTA level was less favorable compared to the two smaller geographic units (CFI = 0.95, NFI = 0.95, TLI = 0.94, χ^2/df ratio = 9.02, ($p < 0.001$), RMSEA = .00, ($p < 0.001$), AIC = 2336.42, BCC = 2338.84), and did not meet all model fit criteria. As can be observed by the comparison of regression paths from SEP to the cognitive outcomes in Table 4-6, the strength of associations between neighborhood SEP and cognition differed very little among different levels of geographic aggregation. As such, because the census tract has historically been the most frequently and most strongly recommended geographic level for approximating the neighborhood, especially in terms of SEP (e.g., Krieger et al., 2003, Yen et al., 2009) and because it differed very little in model fit or regression coefficients from the other geographic levels, the census tract level of aggregation was selected for all final analyses involving SEP.

Aim 2: Facilities as Mediator of SEP and Cognition

Facilities related to better or poorer cognition (“positive facilities,” “negative facilities”) were estimated in the model for Aim 1 in a second step as mediators of the relationship between SEP and cognition, this time examining each cognitive domain separately using Preacher and Hayes' (2008) procedure for estimating indirect effects in multiple-mediator models. This approach allowed for estimation of neighborhood effects on memory, which could not be estimated in the structural equation model from Aim 1 (because of convergence issues). To use the same latent factors from Aim 1 in this approach, factor scores for each of the cognitive measures, based on the Aim 1 structural equation model, were saved in AMOS to the SPSS dataset and used in OLS multiple-mediation models. Bootstrapping bias in all mediation models was very minimal (e.g. $\leq$ 0.001).

Indirect effects of SEP through both positive and negative facilities were obtained for *g*, (R^2 = 0.60, $F(7,2511)$ = 536.54, $p < 0.001$; Table 4-7), everyday cognition (R^2 = 0.54, $F(7,2511)$ = 421.20, $p < 0.001$; Table 4-7), and vocabulary (R^2 = 0.50, $F(7,2511)$ = 361.30, $p < 0.001$; Table 4-7). SEP had indirect effects through positive but not negative facilities on reasoning (R^2 = 0.44, $F(7,2511)$ = 286.74, $p < 0.001$; Table 4-7), and indirect effects through negative but not positive facilities on speed (R^2 = 0.56, $F(7,2511)$ = 448.76, $p < 0.001$; Table 4-7) and memory (R^2 = 0.44, $F(7,2511)$ = 292.92, $p < 0.001$; Table 4-7). In all cases, more "positive facilities" were associated with better cognition, and more "negative facilities" were associated with poorer cognition.

Additional follow-up models explored the effect of controlling for general cognition when estimating the effects of facilities on the specific cognitive domains. This addition to the models resulted in a distortion of effects such that the relationship of facilities with cognition had no consistent or sensible pattern. For example, sometimes positively-categorized facilities had negative associations with cognition, and sometimes negatively-categorized facilities had positive associations with cognition; in general, the direction of effects was highly varied across cognitive outcomes, and effects were quite small (e.g., unstandardized beta weights around 0.001). These results were deemed uninterpretable and, given that cognition is generally measured in everyday life without partialing out the effect of general cognition (e.g., when memory is measured, general cognitive ability is included in its measurement), final discussion focuses on the Aim 2 models that did not control for general cognition, as presented in Table 4-7.

Follow-Up Analyses

A primary gap in the literature, set out in the introduction, is a lack of understanding for the underlying mechanism by which neighborhood SEP is related to late life cognition. The goal of this study was to investigate whether neighborhood facilities might mediate this relationship, but several other potential mediators and moderators were also considered in this paper. The following sections explore the three additional areas of follow-up analysis: area type (urban, suburban, rural), the interaction of race and neighborhood sociodemographics, and individual mobility. These areas were investigated using hierarchical regression models (Tables 4-8 through 4-13), in which each subsequent model step added one of these factors as a predictor of cognitive outcomes. The hierarchical models began by estimating the simple effect of SEP on cognition (Model 1, Tables 4-8 to 4-13), then added education, age, and gender in a second step (Model 2, Tables 4-8 to 4-13). These covariates, and every predictor added at each new model step, were retained in all subsequent models. Neighborhood SEP significantly predicted all cognitive outcomes ($p < 0.001$) when estimated independently and when estimated simultaneously with education, age, and gender ($p < 0.001$).

Because there is a unique relationship between neighborhood and race; that is, racial segregation plays a role in the distribution of individuals within neighborhoods (Frey & Myers, 2002), race was examined as a separate covariate from education, age, and gender (Model 3, Tables 4-8 to 4-13). When race was added to the model, the effect of SEP was eliminated for *g,* memory, speed, and everyday cognition, and held only for reasoning ($p = 0.001$, Table 4-10) and for vocabulary ($p < 0.001$, Table 4-13).

Individual Race, Neighborhood SEP, and Community Racial/Ethnic Composition

Prior studies have suggested that neighborhood effects on health and cognition may also be affected by the interaction of individual race with neighborhood SEP or neighborhood racial composition (e.g. Clarke et al., 2009, Sheffield & Peek, 2009, Yen, Michael, & Purdue, 2009). Therefore neighborhood-level racial composition (residualized from the main effect of individual race due to high collinearity; tolerance = 0.33, $r = 0.70$) and two residualized interactions – individual race with neighborhood SEP and individual race with neighborhood racial composition (measured as proportion of Whites in the census tract) – were examined as predictors of cognition (Model 4, Tables 4-8 to 4-13). Results showed there was no main effect of neighborhood racial composition on cognitive outcomes, nor an interaction of individual race with neighborhood SEP in predicting cognition in this dataset. There was an interaction of individual race and neighborhood racial composition for speed ($p = 0.04$; Figure 4-4). The nature of this interaction suggested that there was a slight tendency for both races to perform better on processing speed when they came from neighborhoods more similar to their own racial status (i.e., Whites performed better the higher the proportion of other Whites in the neighborhood, and African Americans performed better the lower the proportion of Whites in the neighborhood). The strengths of these associations were very small (e.g., $R^2 = 0.01$).

Urban, Suburban, and Rural Classifications

The importance of neighborhood SEP and facilities may differ based on whether the neighborhood is in an urban, suburban, or rural area. As described in the Methods, a commonly-accepted classification for these categories was not readily available, but an approximation of them (Urbanized Area in a Major City, $N = 915$; Urbanized Area not in a Major City, $N = 1163$; and Urban Cluster/Rural, $N = 443$) was developed for the sake of exploratory analysis. Model step 5 entered this variable into the nested regression model as two dichotomous predictors (Urban or not, Rural or not), making Suburban classification the reference value. Because we were interested in how the effects of SEP and neighborhood facilities might be related to these area types, positive and negative facilities were also included as main effects in this model step, as were three interaction terms for each of the area type dummies (Urban, Rural) with neighborhood SEP, positive facilities, and negative facilities. All interactions were estimated as residualized product terms after accounting for the variance associated with the main effects.

There were no instances in which SEP interacted with area type to predict cognition, but there were several instances in which urban area type interacted with the presence of negative facilities (Model 5, Tables 4-8 to 4-13), specifically in predicting *g* (Table 4-8), reasoning (Table 4-10) and vocabulary (Table 4-13). There was also a trend-level effect for this interaction in predicting everyday cognition (ß = -0.03, $t = -1.73$, $p = 0.08$; Table 4-12). In each case the nature of the interaction was such that more negative facilities were associated with poorer cognition in all areas, but this relationship was strongest in urban-like areas.

Mobility

A sixth and final model step added the interaction of neighborhood SEP and its facilities with individual mobility as a follow-up analysis. Mobility was measured categorically as whether the individual had left the immediate community in the past week (*N* =1831) or not (*N* = 690), using the Life Space Questionnaire's natural cut-off distinguishing near- and far-life space. There were significant main effects of mobility for all cognitive outcomes (Model 6, Tables 4-8 to 4-13). Once again, SEP did not interact at any point with mobility, but in once instance mobility significantly interacted with neighborhood facilities. Specifically, mobility interacted with positive neighborhood facilities in predicting vocabulary, such that having positive facilities in the neighborhood more strongly predicted better vocabulary scores among those who had not left their neighborhood (Model 6, Figure 4-5, Table 4-3).

Table 4-1. Standardized loadings (ß) of census indicators on neighborhood SEP.

Observed Variable	ß
% Income > $150,000	0.83**
% Education ≥ Bachelor's	0.95**
% Occupation = Management	0.96**
Median Household Income	0.84**

** $p < 0.001$

Table 4-2. Standardized loadings (ß) of cognitive indicators on main cognitive factors.

Indicator Variable	Interim Factor	Cognitive Factor*	ß
UFOV1	UFOV		0.53**
UFOV2	UFOV		0.78**
UFOV3	UFOV		0.80**
UFOV4	UFOV		0.65**
CRT1	CRT		0.93**
CRT2	CRT		0.91**
	UFOV	Speed	0.77**
	CRT	Speed	0.77**
AVLT Total Recall		Memory	0.78**
HVLT Total Recall		Memory	0.82**
Rivermead Total Recall		Memory	0.62**
Letter Series Score		Reasoning	0.92**
Letter Sets Score		Reasoning	0.70**
Word Series Score		Reasoning	0.90**
Everyday Problems Test		Everyday Cognition	0.83**
Timed Instrumental Activities of Daily Living (reverse-coded)		Everyday Cognition	0.68**
Observed Tasks of Daily Living		Everyday Cognition	0.69**
Vocabulary, Odd Items		Vocabulary	0.83**
Vocabulary, Even Items		Vocabulary	0.87**

Note: Speed is defined as a second order factor since better fit was yielded when local associations among UFOV and CRT measures were captured in a first order factor. These first order factors were then allowed to load on a second order Speed factor. ** $p < 0.001$.

Table 4-3. Facilities present in the neighborhood summed according to association with better or poorer cognition.

Facilities Associated with Better Cognition	Facilities Associated with Poorer Cognition
Fitness & recreational centers	Services for elderly and disabled persons
Golf courses	Specialty hospitals (other than psychiatric or substance abuse centers)
Fine arts schools	Civic and social organizations
Senior transportation services	Language schools
Mental health physician offices	Dentist offices
Mental health practitioner offices	Museums
Optometrist offices	Artists offices (other than dance or music artists)
HMO medical centers	Sports teams and clubs
Miscellaneous healthcare centers	Fish markets

Table 4-4. Standardized coefficients (ß) for SEP prediction of cognitive domains.

Cognitive Construct	ß
Reasoning	0.05**
Speed	-0.02
Memory	0.02
Everyday	0.01
Vocabulary	0.09**

** $p < 0.01$

Table 4-5. Standardized coefficients (ß) for loadings of domain-specific cognitive factors on '*g*'

Cognitive Construct	ß
Reasoning	0.91**
Speed	-0.85**
Memory	0.79**
Everyday	0.96**
Vocabulary	0.64**

** $p < 0.01$

Table 4-6. Standardized regression coefficients (ß) of SEP predicting cognitive factors at different levels of geographic aggregation.

	'g'	Speed	Reasoning	Everyday Cognition	Vocabulary
Block Group SEP	0.01	0.01	0.03	0.004	0.09**
Census Tract SEP	0.02	0.02	0.03	-0.02	0.07**
5-digit ZCTA SEP	-0.01	0.01	0.02	0.004	0.07

Note: All structural equation models also included the covariates (education, age, gender, and race [1=White, 0=African American) estimated in the Aim 1 SEM, but these effects are not shown here. * $p < 0.05$, ** $p < 0.01$

Table 4-7. Direct and indirect (through facilities) unstandardized effects (B) of SEP on cognition.

		Effects	B	SE	*t*	*z*
	a-paths	SEP → Positive Facilities	0.38**	0.05	7.83	
		SEP → Negative Facilities	0.13**	0.03	4.30	
g	*b-paths*	Positive Facilities → g	0.01**	0.005	2.96	
		Negative Facilities → g	-0.03**	0.008	-4.03	
	c-path	SEP Total Effect → g	0.02	0.01	1.47	
	c'-path	SEP Direct Effect → g	0.02	0.01	1.36	
	ab-paths	SEP-Positive Facilities-g	0.01*	0.002		2.55
		SEP-Negative Facilities-g	-0.004**	0.002		-2.93
Memory	*b-paths*	Positive Facilities → Memory	0.01	0.005	1.52	
		Negative Facilities → Memory	-0.03**	0.008	-3.52	
	c-path	SEP Total Effect → Memory	0.02	0.01	1.24	
	c'-path	SEP Direct Effect → Memory	0.02	0.01	1.29	
	ab-paths	SEP-Positive Facilities-Memory	0.003	0.002		1.50
		SEP-Negative Facilities-Memory	-0.004**	0.002		-2.60
Reasoning	*b-paths*	Positive Facilities → Reasoning	0.01*	0.01	2.31	
		Negative Facilities → Reasoning	-0.02*	0.01	-2.22	
	c-path	SEP Total Effect → Reasoning	0.05**	0.02	3.39	
	c'-path	SEP Direct Effect → Reasoning	0.05**	0.02	3.20	
	ab-paths	SEP-Positive Facilities-Reasoning	0.01*	0.003		2.20
		SEP-Negative Facilities-Reasoning	-0.003	0.002		-1.93
Speed	*b-paths*	Positive Facilities → Speed	-0.01	0.003	-1.82	
		Negative Facilities → Speed	0.01**	0.01	2.73	
	c-path	SEP Total Effect → Speed	-0.01	0.01	-1.28	
	c'-path	SEP Direct Effect → Speed	-0.01	0.01	-1.23	
	ab-paths	SEP-Positive Facilities- Speed	-0.003	0.001		-1.69
		SEP-Negative Facilities-Speed	0.002*	0.001		2.11

Table 4-7. Continued.

		Effects	B	SE	*t*	*z*
Everyday	*b-paths*	Positive Facilities → Everyday	0.01**	0.004	3.41	
		Negative Facilities → Everyday	-0.03**	0.01	-4.88	
	c-path	SEP Total Effect → Everyday	0.01	0.01	0.66	
	c'-path	SEP Direct Effect → Everyday	0.01	0.01	0.57	
	ab-paths	SEP-Positive Facilities-Everyday	0.01**	0.002		2.94
		SEP-Negative Facilities-Everyday	-0.004**	0.001		-3.14
Vocabulary	*b-paths*	Positive Facilities → Vocabulary	0.04**	0.01	3.49	
		Negative Facilities → Vocabulary	-0.05**	0.03	-3.19	
	c-path	SEP Total Effect → Vocabulary	0.16**	0.03	6.22	
	c'-path	SEP Direct Effect → Vocabulary	0.15**	0.03	5.92	
	ab-paths	SEP-Positive Facilities-Vocabulary	0.01**	0.005		3.11
		SEP-Negative Facilities-Vocabulary	-0.01*	0.003		2.47

Note: All models included the covariates (education, age, gender, and race [1=White, 0=African American) estimated in Aim 1, but these effects are not shown here. * $p < 0.05$, ** $p < 0.01$

Table 4-8. Standardized regression coefficients (ß) for nested models of neighborhood and individual-level socio-demographic variables on general cognition.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	0.17**	0.11**	0.02	0.02	0.01	0.01
Model 2						
Gender		0.33**	0.35**	0.35**	0.35**	0.36**
Age		-0.47**	-0.51**	-0.51**	-0.51**	-0.50**
Education		0.39**	0.38**	0.39**	0.38**	0.37**
Model 3						
Race			-0.36**	-0.36**	-0.35**	-0.35**
Model 4						
Race x SEP				0.02	0.02	0.01
% White				0.01	0.01	0.02
Race x % White				-0.02	-0.01	-0.02
Model 5						
Positive Facilities					0.04**	0.04*
Negative Facilities					-0.05**	-0.04**
Urban area vs. others					0.01	0.01
Rural area vs. others					0.00	-0.01
Urban x SEP					-0.001	0.01
Rural x SEP					0.003	0.01
Urban x Positive					0.00	0.001
Rural x Positive					0.01	0.01
Urban x Negative					-0.03*	-0.03*
Rural x Negative					-0.01	-0.01
Model 6						
Mobility						0.08**
Mobility x SEP						-0.004
Mobility x Positive						-0.02
Mobility x Negative						-0.01

* $p < 0.05$, ** $p < 0.01$

Table 4-9. Standardized regression coefficients (ß) for nested models of neighborhood and individual-level socio-demographic variables on memory.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	0.15**	0.10**	0.02	0.02	0.02	0.003
Model 2						
Gender		0.28**	0.31**	0.30**	0.31**	0.31**
Age		-0.41**	-0.45**	-0.44**	-0.44**	-0.43**
Education		0.34**	0.33**	0.33	0.33**	0.32**
Model 3						
Race			-0.31**	-0.31**	-0.29**	-0.29**
Model 4						
Race x SEP				-0.003	-0.01	-0.02
% White				0.02	0.02	0.03
Race x % White				-0.03	0.02	-0.03
Model 5						
Positive Facilities					0.02	0.02
Negative Facilities					-0.06**	-0.05**
Urban area vs. others					-0.01	-0.01
Rural area vs. others					-0.01	-0.02
Urban x SEP					0.02	0.03
Rural x SEP					0.01	0.01
Urban x Positive					0.01	0.01
Rural x Positive					0.01	0.01
Urban x Negative					-0.01	-0.01
Rural x Negative					0.01	0.01
Model 6						
Mobility						0.08**
Mobility x SEP						0.01
Mobility x Positive						-0.02
Mobility x Negative						-0.01

* $p < 0.05$, ** $p < 0.01$

Table 4-10. Standardized regression coefficients (ß) for nested models of neighborhood- and individual-level socio-demographic variables on reasoning.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	0.25**	0.14**	0.06**	0.06**	0.05*	0.03
Model 2						
Gender		0.03	0.06**	0.06**	0.05**	0.06**
Age		-0.33**	-0.37**	-0.37**	-0.37**	-0.36**
Education		0.41**	0.40**	0.40**	0.39**	0.38**
Model 3						
Race			-0.35**	-0.35**	-0.34**	-0.34**
Model 4						
Race x SEP				0.01	0.01	0.004
% White				0.01	0.01	0.02
Race x % White				-0.02	-0.01	-0.01
Model 5						
Positive Facilities					0.05*	0.04*
Negative Facilities					-0.04*	-0.03
Urban area vs. others					0.01	0.01
Rural area vs. others					-0.01	-0.02
Urban x SEP					0.01	0.01
Rural x SEP					-0.004	-0.002
Urban x Positive					-0.02	-0.02
Rural x Positive					-0.01	-0.004
Urban x Negative					-0.04*	-0.04*
Rural x Negative					-0.02	-0.02
Model 6						
Mobility						0.08**
Mobility x SEP						-0.01
Mobility x Positive						-0.03
Mobility x Negative						-0.01

* $p < 0.05$, ** $p < 0.01$

Table 4-11. Standardized regression coefficients (ß) for nested models of neighborhood- and individual-level socio-demographic variables on processing speed.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	-0.13**	-0.09**	-0.02	-0.14	-0.02	-0.003
Model 2						
Gender		0.13**	0.11**	0.11**	0.11**	0.12**
Age		0.60**	0.64**	0.63**	0.63**	0.62**
Education		-0.24**	-0.23**	-0.24**	-0.23**	-0.22**
Model 3						
Race			0.31**	0.31**	0.30**	0.30**
Model 4						
Race x SEP				-0.01	-0.01	-0.01
% White				-0.02	-0.03	-0.04*
Race x % White				0.03*	0.03	0.03
Model 5						
Positive Facilities					-0.02	-0.02
Negative Facilities					0.04*	0.03
Urban area vs. others					-0.01	-0.01
Rural area vs. others					-0.01	0.002
Urban x SEP					0.004	-0.002
Rural x SEP					-0.001	-0.002
Urban x Positive					-0.01	-0.01
Rural x Positive					-0.01	-0.01
Urban x Negative					0.02	0.03
Rural x Negative					0.004	0.004
Model 6						
Mobility						-0.08**
Mobility x SEP						0.01
Mobility x Positive						0.02
Mobility x Negative						0.004

* $p < 0.05$, ** $p < 0.01$

Table 4-12. Standardized regression coefficients (ß) for nested models of neighborhood- and individual-level socio-demographic variables on everyday cognition.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	0.24**	0.10**	0.01	0.01	0.01	-0.004
Model 2						
Gender		0.06**	0.09**	0.09**	0.09**	0.09**
Age		-0.34**	-0.38**	-0.38**	-0.38**	-0.37**
Education		0.50**	0.48**	0.49**	0.48**	0.47**
Model 3						
Race			-0.38**	-0.38**	-0.36**	-0.36**
Model 4						
Race x SEP				0.02	0.02	0.02
% White				0.001	0.00	0.01
Race x % White				-0.02	-0.01	-0.01
Model 5						
Positive Facilities					0.06**	0.05**
Negative Facilities					-0.07**	-0.06**
Urban area vs. others					0.02	0.01
Rural area vs. others					0.004	-0.01
Urban x SEP					-0.01	0.002
Rural x SEP					0.01	0.01
Urban x Positive					0.001	0.002
Rural x Positive					0.01	0.01
Urban x Negative					-0.03	-0.03
Rural x Negative					-0.01	-0.01
Model 6						
Mobility						0.09**
Mobility x SEP						-0.01
Mobility x Positive						-0.02
Mobility x Negative						-0.01

* $p < 0.05$, ** $p < 0.01$

Table 4-13. Standardized regression coefficients (ß) for nested models of neighborhood- and individual-level socio-demographic variables on vocabulary.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1						
SEP	0.39**	0.19**	0.10**	0.10**	0.09**	0.08**
Model 2						
Gender		0.04*	0.07**	0.07**	0.06**	0.07**
Age		0.10**	0.05**	0.05**	0.05**	0.06**
Education		0.50**	0.49**	0.49**	0.50**	0.47**
Model 3						
Race			-0.39**	-0.39**	-0.38**	-0.38**
Model 4						
Race x SEP				0.03	0.03	0.03
% White				-0.01	-0.01	0.001
Race x % White				0.004	0.01	0.01
Model 5						
Positive Facilities					0.06**	0.06**
Negative Facilities					-0.05**	-0.04**
Urban area vs. others					0.02	0.02
Rural area vs. others					-0.01	-0.01
Urban x SEP					-0.02	-0.01
Rural x SEP					0.00	0.002
Urban x Positive					0.02	0.01
Rural x Positive					0.02	0.03
Urban x Negative					-0.06**	-0.06**
Rural x Negative					0.003	0.002
Model 6						
Mobility						0.06**
Mobility x SEP						0.01
Mobility x Positive						-0.04**
Mobility x Negative						-0.01

* $p < 0.05$, ** $p < 0.01$

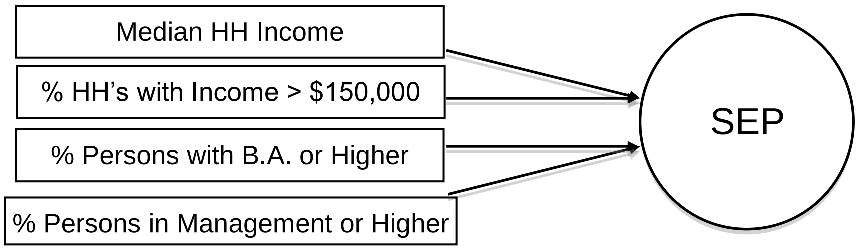

Figure 4-1. SEP factor structure model. Standardized loadings (ß) on SEP are to the left of each indicator; ** p < 0.001.

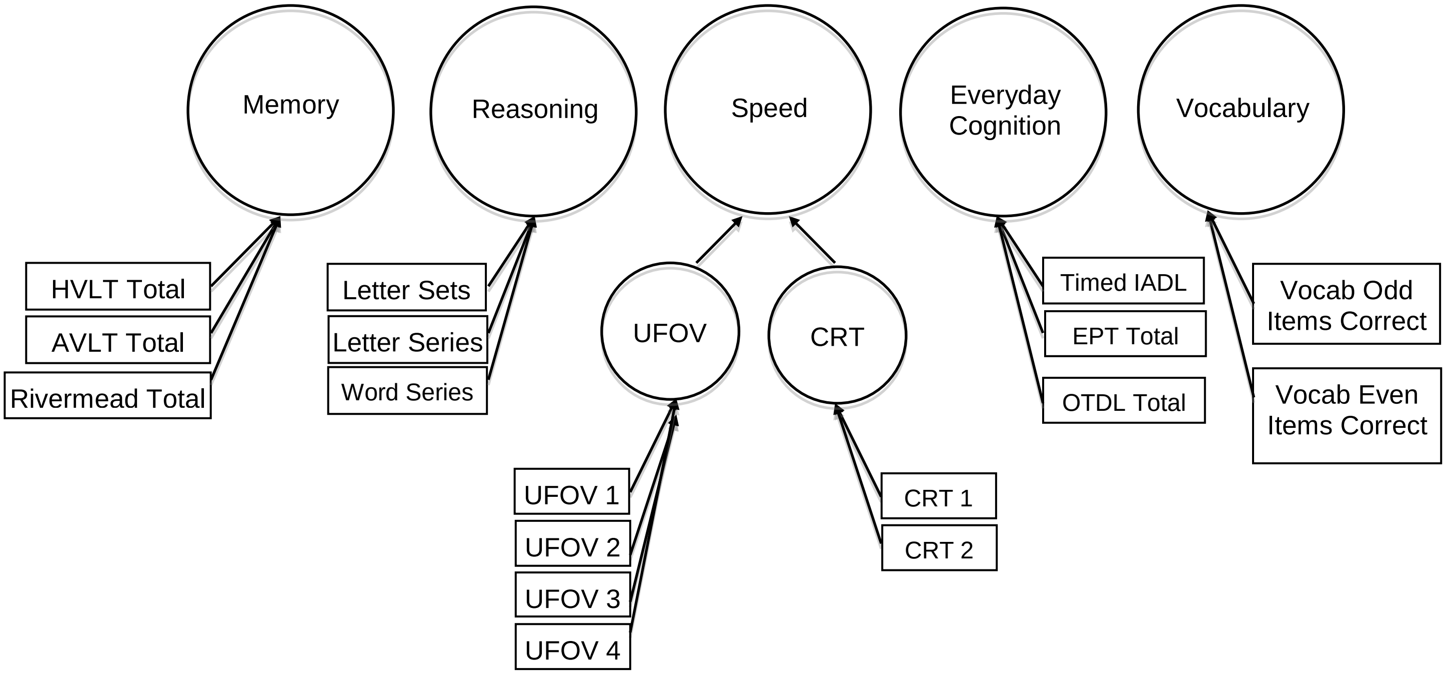

Figure 4-2. Baseline cognition measurement model; correlations were estimated among each of the five cognitive factors.

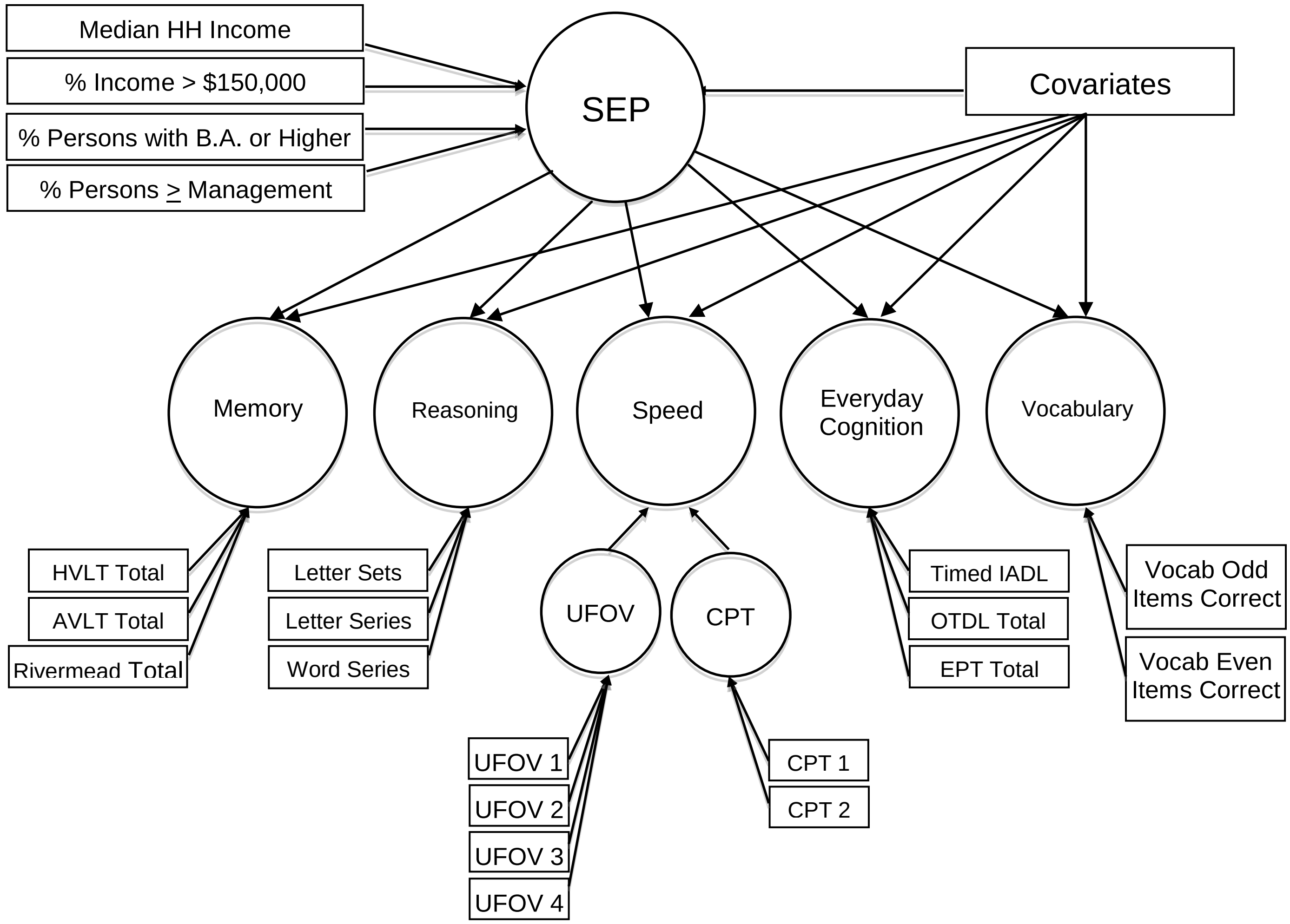

Figure 4-3. Schematic of the Aim 1 predictive model of baseline cognition. Regression paths were estimated from all covariates (gender, age, education, race) to Memory, Reasoning, Speed, Everyday Cognition, and Vocabulary.

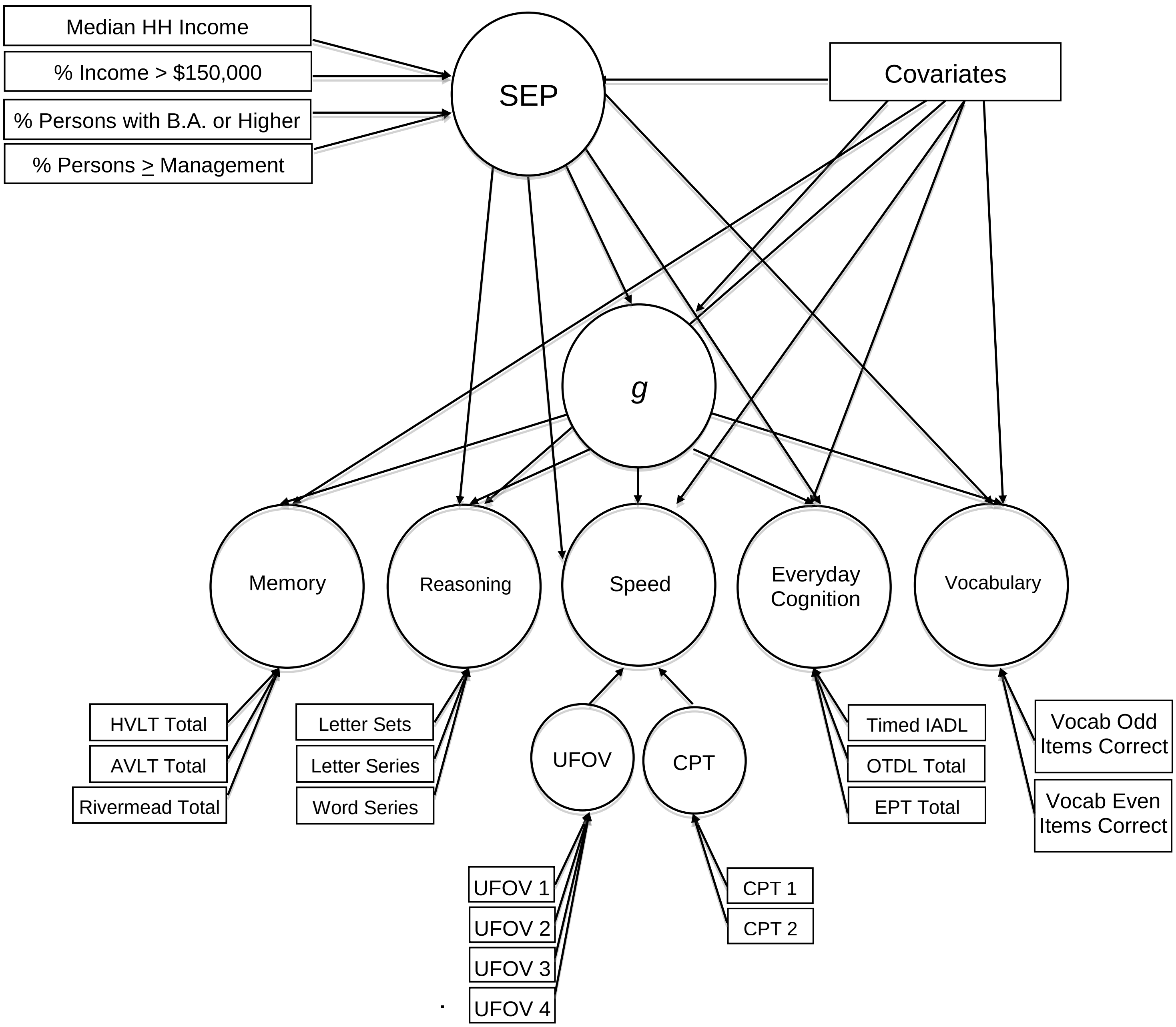

Figure 4-4. Schematic of the Aim 1 predictive model of baseline cognition, including general cognition as a higher-order factor. Regression paths were estimated from all covariates (gender, age, education, race) to g, Reasoning, Speed, Everyday Cognition, and Vocabulary. Regression paths could not be estimated to the Memory factor.

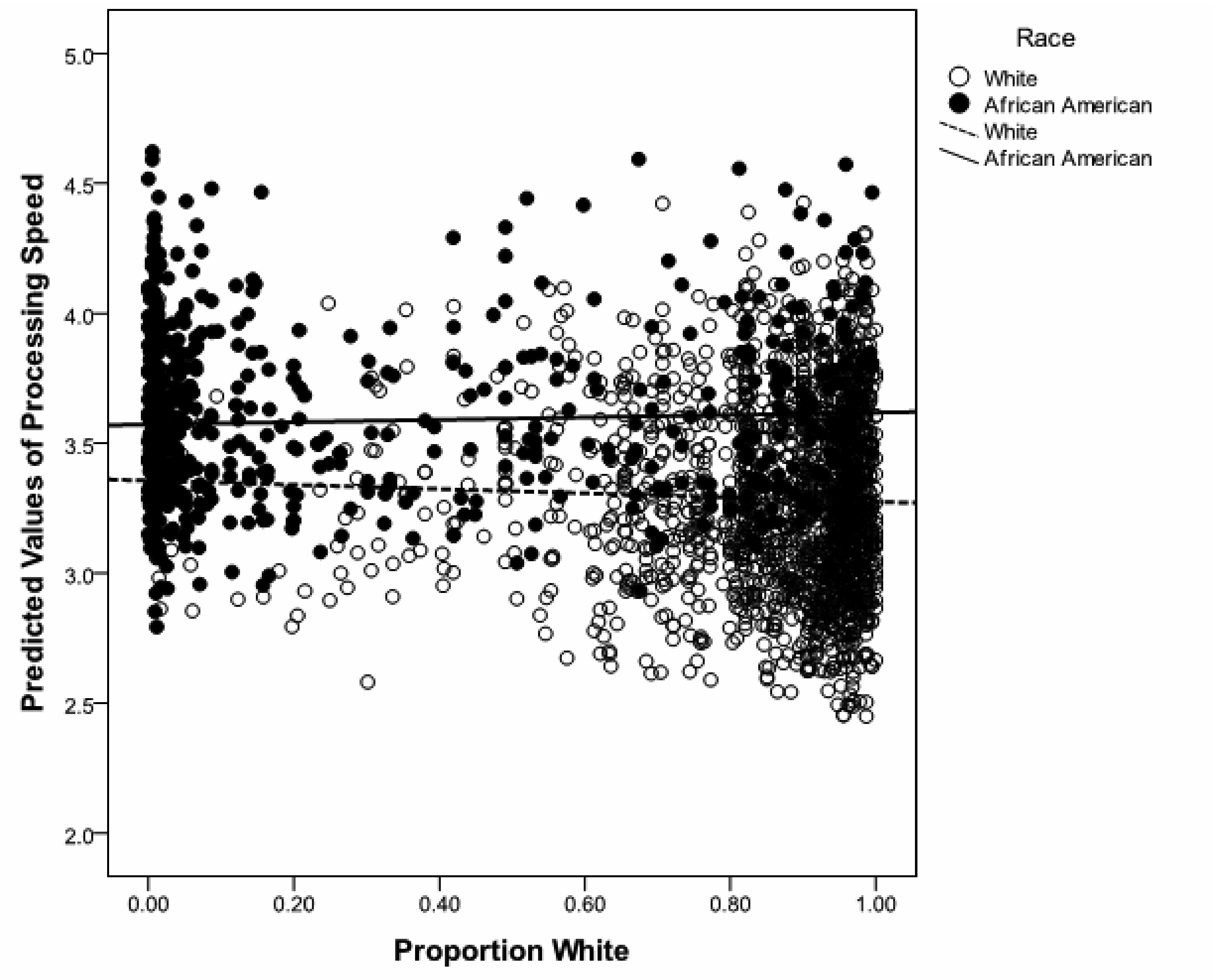

Figure 4-5. Association of neighborhood racial composition (proportion of whites) with model-based predicted values (i.e., controlling for other predictor effects) of processing speed for Whites and African Americans.

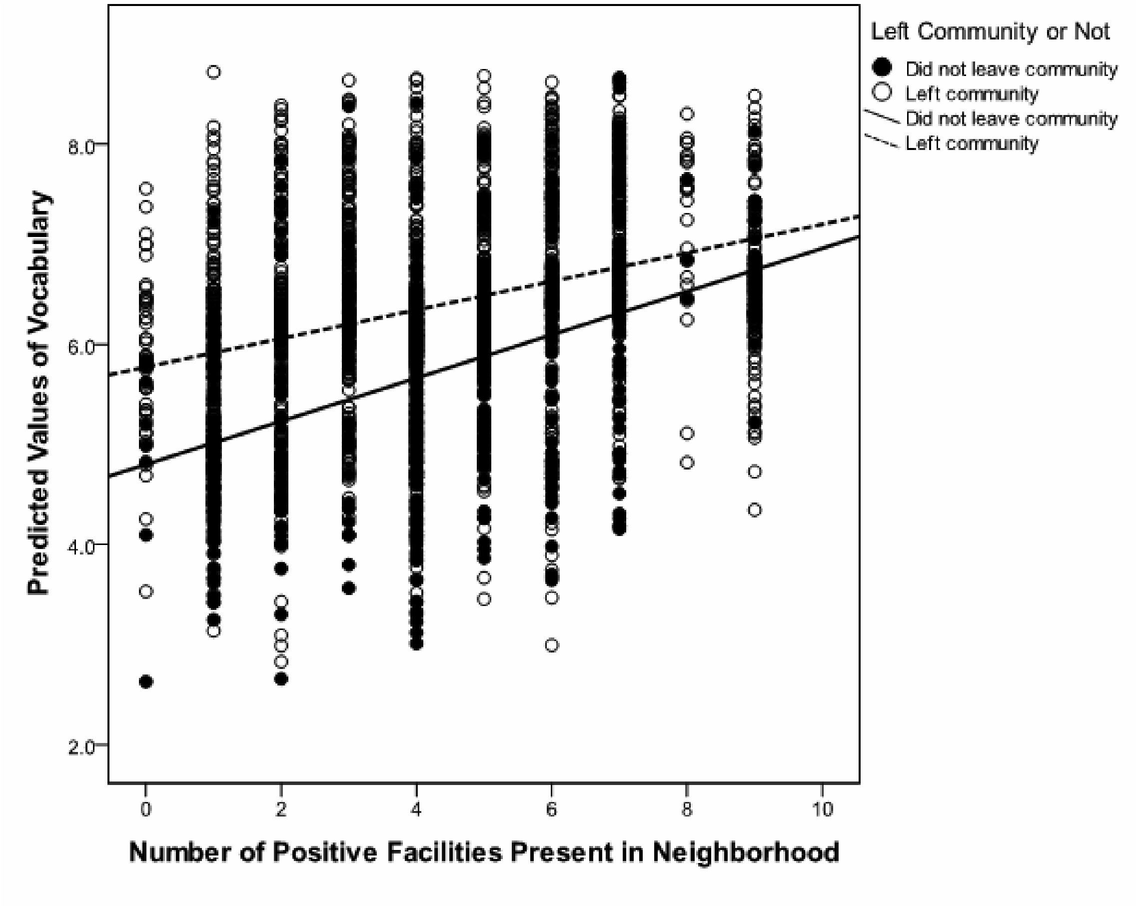

Figure 4-6. Association of number of positive neighborhood facilities with model-based predicted values (i.e., controlling for other predictor effects) of vocabulary for those who had left the neighborhood during the previous week versus those who had not).

CHAPTER 5
DISCUSSION

Overview

The overall goal of the present study was to better understand the relationship between neighborhood socioeconomic position and general and specific aspects of late life cognitive level and response to training, beyond the effects of individual-level predictors, in a geographically-diverse sample of community-dwelling older adults. The study also examined how certain types of facilities within the neighborhood might mediate the effects of SEP on cognition. To accomplish this goal, there were two specific aims. The first aim sought to determine whether neighborhood SEP (as a combined construct including neighborhood-level income, education, and occupational attainment) independently predicted first-order (Memory, Reasoning, Speed, Everyday Cognition, and Vocabulary) and second-order (*g*) cognitive factors in the ACTIVE dataset, after accounting for the effects of individual-level demographics, affective and physical functioning. The first aim additionally investigated whether neighborhood SEP predicted pre- to post-test change in composite scores of Memory, Reasoning, and Speed, for participants who respectively participated in these cognitive intervention groups.

The second aim, designed to address gaps in the literature regarding the mechanisms of neighborhood effects on cognition, explored whether the presence of facilities in the neighborhood believed to support cognition might mediate the relationship between neighborhood SEP and late life cognitive level. To achieve this aim, the presence or absence of several types of facilities related to cognition were summed and estimated as mediators of the relationship between neighborhood SEP and the general and specific cognitive measures in ACTIVE.

The results of the study revealed that 1) neighborhood SEP predicts cognitive level, particularly vocabulary, albeit with low effect size, 2) neighborhood SEP does not predict the response to training in the ACTIVE intervention, and 3) SEP has indirect effects on general cognition, memory, reasoning, speed, everyday cognition, and vocabulary through a set of neighborhood facilities. Additional follow-up analyses showed that individual-level race especially tended to reduce the effect of SEP on cognitive variables, and that race interacted with neighborhood racial composition in predicting processing speed. Analysis of urban, suburban, and rural area subtypes suggested that where certain facilities were negatively predictive of cognition (*g*, reasoning, and vocabulary), this relationship tended to be the strongest in urban areas. Follow-up analysis of the moderating effect of individual mobility suggested that the positive relationship between neighborhood facilities and vocabulary scores was stronger for those who had not moved beyond their immediate community in the past week, compared to those who had.

Aim 1: Predicting Late Life Cognitive Level with Neighborhood SEP

Overall findings from Aim 1 supported the hypothesis that, after controlling for individual-level demographic predictors, census-defined neighborhood socioeconomic position independently predicted differences in late life cognition as measured in ACTIVE. Neighborhood SEP predicted differences in the specific cognitive domain of vocabulary. A goal of this dissertation was to generally replicate previous findings (e.g., Wight et al., 2006, Lang et al., 2007) linking late life cognition and neighborhood SEP in a cross-sectional analysis. Aim 1 achieved this goal, therefore adding to the body of research reporting neighborhood-cognition associations in late life. The results of Aim 1 also extended upon existing findings by looking beyond general cognition or cognitive status (as measured in previous papers) to examine how neighborhood SEP predicts different aspects of cognitive function across specific domains.

Neighborhood SEP Predicts Vocabulary

After accounting for differences in general cognitive ability, neighborhood SEP predicts vocabulary. The association of neighborhood characteristics with this specific domain of cognition suggests the neighborhood may particularly play a role in 'crystallized pragmatics' of cognition. That is, vocabulary best captures crystallized intelligence, or the dimension of cognition related the accumulation of verbal knowledge, developed over a lifetime of experience in engaging with culture (e.g., Verhaeghen, 2003). Culture can be understood as the collection of psychological, social, material, and knowledge-based resources which are amassed and transmitted across generations of people, and contribute to human development (Baltes, 1997). Crystallized knowledge is driven by acculturation, and culture is an inherently social phenomenon. In the cognitive aging literature, crystallized knowledge is also the most stable cognitive domain in the presence of advancing age, compared to the fluid cognitive mechanics, such as information processing and problem solving, which become less efficient with age (Park et al., 2002). A review of vocabulary in aging in fact reported increasing vocabulary scores with advancing age, as well as with higher education (Verhaeghen, 2003). Vocabulary measures like the one used in this study, which required multiple-choice word recognition rather than production of word meanings, are especially robust to the effects of aging (Verhaeghen, 2003). For example the WAIS-R (Wechsler, 1981) vocabulary subtest requires production of word meanings, therefore relying on word finding abilities, which are more sensitive to failure in old age (e.g., Burke, MacKay, & James, 2000); the WAIS-R and other production measures are more likely to show age-related performance declines than multiple-choice recognition measures.

Vocabulary is not only stable with advancing age and produced over a long period of time, it is also highly correlated with childhood cognitive level (Deary, Whalley, Lemmon, & Crawford, 2000; Hoff, 2003; Deary, Whiteman & Starr, 2004; Deary and Batty, 2007). Vocabulary test scores are therefore often used to capture cognitive reserve or to estimate pre-morbid ability level (e.g., Lezak, Howieson, & Loring,1995; Richards & Sacker, 2003; Whalley, Deary, & Appleton, 2004), as it is most robust to not only aging but physical insults to the brain, including head trauma, medical conditions, and exposure to neurotoxins (Deary & Batty, 2007). Expressed differently, when cognition is measured in late life, vocabulary (and especially the measure used in this study, which is particularly insensitive to aging effects, in part because it relies on recognition rather than language production) is the strongest index of early life cognitive ability (e.g., Johnstone, Callahan, Kapila, & Bouman, 1999). This suggests that the present-day neighborhood-cognition association may reflect an earlier process involving childhood neighborhood and cognitive level, the residual effects of which are still present in later life. One way to verify this may be by investigating the association between vocabulary scores in ACTIVE and premorbid cognitive ability among ACTIVE participants as estimated by the Barona (Baron, Reynolds, & Chastani, 1984), a demographically-based index of premorbid intelligence. The Barona calculates premorbid ability by combining age, education, region of residence within the U.S., and occupation. Because occupational data was collected for a subset of ACTIVE participants at the second annual follow-up occasion, this is a potentially meaningful area for future analysis.

The specific prediction of crystallized knowledge by neighborhood SEP offers a clue toward one possible mechanism by which neighborhood influences late life cognition: that is, neighborhood may affect the development of crystallized intelligence by either offering opportunities for or placing constraints on an individual's capacity for socio-cultural engagement in the community environment. Neighborhood may influence cultural engagement in a variety of ways. For one, it may provide resources or facilities (Sampson et al., 2002) encouraging cultural interaction. Indeed, some of the facilities identified as having positive associations with cognition – fine arts schools, golf courses, recreational centers, and senior transportation centers – could be construed as supportive of engagement with culture and social interaction (or at least providing the mobility to be engaged). Neighborhood may also encourage acculturation through modeling and social comparisons. That is, high-SEP neighborhoods may support vocabulary because the greater concentration of neighbors with high educational and occupational attainment (as SEP was measured in this study) serve as social models of greater levels of achievement. This social modeling may in turn foster upward social comparisons (Festinger, 1954; Wood, 1996; Blanton, 2001; Collin, 1996; Taylor, 1989; Alicke, LoSchiavo, & Zerbst, 1997) in which an individual may desire or feel social pressure to be more like his or her neighbors to also achieve higher levels of education and occupation, resulting in enhanced engagement in activities that enhance cognitive skills and abilities. Positive community social processes may also foster socio-cultural interaction. Certainly, other researchers have hinted toward social processes (i.e., social interactions and ties, collective efficacy and social norms) as the mechanism linking neighborhoods with multiple outcomes (e.g. Leventhal & Brooks-Gunn, 2000; Sampson et al., 2002). A cohesive neighborhood community with good social capitol (Kawachi & Berkman, 2000) or collective efficacy (i.e., mutual trust, willingness of neighbors to intervene for the common good, and capacity for neighbors to work together to achieve collective desired goals) would be more able to maintain a safe, orderly, and socially open environment in which cultural exploration, social interactions and ties would be encouraged, and might promote social norms embracing cultural engagement and participation in activities that build verbal knowledge. Neighborhoods with higher SEP might have higher collective efficacy; it is known that neighborhoods with concentrated disadvantage have greater incidence of crime and greater residential instability, associations which are largely mediated by social processes such as collective efficacy (Sampson, Raudenbush, & Earles, 1997).

Neighborhood Effects on Health

The extant neighborhood research has devoted considerable attention to neighborhood effects on late life health, including medical health, management of chronic medical conditions, and physical fitness (e.g., Brown et al., 2007; Cunningham & Michael, 2004), all of which are known to impact cognitive functioning and brain integrity (Fillit et al., 2002). In the introduction chapter of this dissertation, it was hypothesized that neighborhood may impact cognition by way of its known effects on physical health and fitness. It can then be surprising for vocabulary to be the specific cognitive domain most related to neighborhood SEP. As discussed above, vocabulary been linked to socio-cultural engagement throughout the lifespan (Baltes, 1997) more so than to physical health, cardiovascular fitness, or brain health. Evidence of vocabulary's vulnerability to the impact of poor health and fitness on brain function and cognition in late life (e.g., Kramer et al., 2004) is questionable. In fact, while links between the age-related declines in the cognitive 'mechanics' (e.g., processing speed, working memory, episodic memory) and age-related structural and functional brain changes (e.g., reductions in prefrontal cortical volume, white matter integrity and cerebral perfusion) have received much attention in the literature, the question of whether neuroanatomical differences in aging predict measures of vocabulary or verbal knowledge is an identified gap in the literature (Raz, 2000). This may be so because vocabulary is well recognized as age-invariant, and therefore investigators may expect it to be unaffected by age-related brain changes (Raz, 2000). Certainly the general pattern of aging involves loss of neural circuits, white matter integrity and synaptic plasticity (Yankner, Lu, & Loerch, 2008) with stable or increasing verbal abilities (e.g., Park et al., 2002). There is also evidence suggesting neural mechanisms responsible for semantic processing or filtering verbal information are less affected by age (Madden, Turkington, Coleman, Provenzale, DeGrado, & Hoffman, 1996).

Neighborhood effects on health may yet be one potential mechanism by which neighborhood predicts cognition, although that was not a goal of analysis in the present study. Neighborhood SEP predicted general cognitive ability, represented by the variance shared among measures of vocabulary, memory, reasoning, everyday cognition, and processing speed. Neighborhood may affect general cognition because of the way that it supports or constrains physical health and fitness. But the additional separate association between SEP and vocabulary suggests that although neighborhood affects late life health, which affects cognition, neighborhood may also contribute to cognition in other ways that are related to acculturation.

Cross-Sectional versus Longitudinal Influences

However, it must be noted that vocabulary is the product of verbal knowledge acquired through socio-cultural engagement experienced over the life span. It is possible then that the relationship between neighborhood SEP and vocabulary, observed cross-sectionally in this data, is not necessarily the result of a present-day environmental influence on cognition. Instead, present-day neighborhood SEP may itself reflect the outcome of another, life long, influence. Looking back to the early-life neighborhood research and the well-documented neighborhood-cognition relationships at that stage, the critical influence on late life cognition may in fact be childhood neighborhood SEP, and the observed neighborhood-cognition relationship in this current dissertation study might be an echo of this relationship during a critical period of development. There is evidence that early life socioeconomic indicators predict late life cognitive outcomes. In the cognitive aging literature, Wilson and colleagues (2005) reported that parental education during childhood independently predicted cognitive activity across the lifespan and into old age. Berkman and Glymour (2006) found that the county of residence during primary schooling, by way of the laws guiding educational requirements in that county, predicted individual differences in both educational attainment and late life cognitive performance.

Childhood neighborhood SEP may have long-lasting effects on cognition due to lack of upward mobility across the lifespan for some and sustained privilege for others, and there is evidence from the developmental sociology literature to support this notion. For example, cumulative advantage/disadvantage (CAD; Dannefer, 2003; O’Rand,

2003) theory describes “a set of social dynamics that operate on a population” in which early events (and particularly, advantages) influence future events and advantages, culminating in a systematic tendency for divergence among individuals in health, status, or other characteristics. That is, early advantage can breed future advantage and early disadvantage can breed future disadvantage (not forgetting, though, personal agency and resilience; Schafer, Shippee, & Ferraro, 2009), and these divergent forces create increasing disparities between groups over time. Life course theory (Elder, 1998) similarly conceives of individual development as the product of socially and historically-defined events and roles enacted by an individual over the life span, emphasizing the influence of early events on future decisions and events. These theoretical perspectives influenced Baltes’ (1987) discussion of cognitive trajectories across the life span, which has influenced the interpretation of the current findings. These theories also influenced the development of Cumulative Inequality (CI) theory, in which Ferraro and Shippee (2009) integrated CAD and life course theories under a social gerontology framework, stating that: 1) social systems generate inequality, which is manifested over the life course through demographic and developmental processes; 2) disadvantage increases exposure to risk, but advantage increases exposure to opportunity; and 3) life course trajectories are shaped by accumulation of risk, available resources, and human agency. In other words, early life exposures to advantage or disadvantage, including at the neighborhood level, may initiate a chain of person-environment interactions across the course of a life that maintain or even widen socio-cultural and cognitive disparities in late life.

It is important to recognize the potential influence of these processes in the present-day associations observed between neighborhood and cognitive level, especially vocabulary. If advantage and disadvantage accumulate over the lifespan with early conditions predicting later conditions, then differences in neighborhood SEP in early life may predict differences in neighborhood SEP in late life, and it may be for this reason that late life neighborhood SEP and vocabulary are related. However, it is also to make clear that discussion of prior life influences, in this cross-sectional analysis, is speculative.

There is strong evidence of persistent and growing socioeconomic and health disparities in late life (Smith, 1997; House, Lantz, & Herd, 2005; Schoeni, Martin, Andreski, & Freedman, 2005), although others have also noted the likelihood that health inequalities in late life may also be underestimated because the accumulation of disadvantage also leads to earlier mortality, which would create an underrepresentation of true late life socioeconomic and health disparities (Beckett, 2000; Ferraro & Shippee, 2009). While CI theory has not been applied to cognitive aging *per se*, cognition has been argued to be the outcome of a life-long trajectory modified by exposures to enrichment and challenge, opportunity and risk, across the life span (e.g., Hertzog et al., 2009; Baltes, 1987). Context shapes the opportunities and risks a person encounters: for example a neighborhood may provide opportunities for socio-cultural engagement through facility-type resources such as recreational centers or schools, or may provide opportunities through social processes encouraging engagement (Sampson et al., 1997). It may be that individuals exposed to greater advantage earlier in life (e.g., are born in a high-SEP neighborhood) not only develop better cognitive abilities (e.g., by way of exposure to highly-educated neighbors or attending a high quality school), but because of their initial advantage are also exposed to more opportunities (e.g., acquiring a high level of occupational attainment in an intellectually stimulating job) producing socio-cultural advantages later on, which would likely again support improvements in vocabulary, and might also increase the likelihood of choosing to live in a high-SEP neighborhood in late life because they have the resources to do so.

Aging in Place

Longitudinal discussions of neighborhood and aging must also consider the issue of aging in place. Although this variable was not included in data collection, it is likely that the current residence of many ACTIVE participants was also the home in which they lived the majority of their adult lives, as aging research has increasingly reported on the tendency of many older adults to remain in their same residences as they go through later life (Callahan, 1992). Whether it is due to choice (e.g., desire to remain at home) or circumstance (e.g., lack of resources to move), there appears to be a growing concentration of older adults remaining in their community; as the older population grows due to a reduced mortality rate in recent decades and certain communities see a loss of younger adults due to economic dislocation, some U.S. cities have become areas of relative concentration of older adults (National Institute on Aging Public Announcement, 1992, PA-92-062). Communities with high concentrations of older adults may also face challenges in the delivery of services to meet elderly needs (e.g., Longino & Bradley, 2003). Regardless of the reason, aging in place can have potentially beneficial effects through maintained social ties and a greater sense of stability, reducing life stress, or can pose potential threats, especially in the event of change in the surrounding neighborhood conditions (e.g., rising crime or area-level poverty, existing social connections moving or passing away), change in the individual's level of need (e.g. functional limitations or physical disability; Ball, Perkins, Whittington, Connell, Hollingsworth, King, Elrod, & Combs, 2003). Research on clinical outcomes for those aging in place is mixed; for example, Lang and colleagues (2007) found no additional impact on cognition between those who had relocated in the past 5-10 years and those who had not. On the other hand, a nursing research study comparing those who aged in place had stable or improved cognition and activities of daily living and reduced depression over an 18-month period relative to older adults who relocated to nursing homes (Marek, Popejoy, Petroski, Mehr, Rantz, & Lin, 2005).

Race

Relevant to the potential effects of cumulative advantage and disadvantage on cognition is the finding in this dataset that, in most cases, the addition of race as a covariate eliminated the effect of neighborhood SEP on cognition. Differences between blacks and whites have been identified on measures of intelligence (e.g., Heaton, Ryan, Grant, & Matthews, 1996; Kush, Watkins, Ward, Ward, Canivez, & Worrell, 2001) and on cognitive batteries (e.g., Zsembik & Peek, 2001; Manly, Jacobs, Touadji, Small, & Stern, 2002; Duff, Patton, Schoenberg, Mold, Scott, & Adams, 2003). Lower cognitive performance among blacks persists across the working life span (Avolio & Waldman, 1994) and into late life, as older black Americans demonstrate impairments on cognitive testing more often than older white Americans (Unverzagt, Hall, Torke, & Rediger, 1996; Manly et al., 1998; Carlson, Brandt, Carol, & Kawas, 1998). However, it has been argued that late life cognitive differences between blacks and whites may stem from early life disparities in educational attainment and educational quality, as measured by reading level attainment; several studies have demonstrated that racial disparities in cognitive performance can be attenuated or eliminated by controlling for reading level, after matching or controlling for education (e.g., Manly, Touradji, & Tang, 2003; Manly, Byrd, & Touradji, 2004, Aiken Morgan, Marsiske, & Whitfield, 2008). Black Americans are on average less likely to have received the same amount of formal education as white Americans (e.g., Harper & Alexander, 1990), as members of the cohort from which the ACTIVE sample was drawn were most likely subject to school segregation and related inequalities in education expenditures, length of school year, and student-teacher ratios (Loewenstein, Argüelles, Argüelles, & Linn-Fuentes, 1994; Whitfield & Wiggins, 2003; Manly et al., 2002).

There is therefore good reason to suspect that black ACTIVE participants experienced unequal educational quality in early life relative to the white participants, and previous studies have demonstrated differences in reading level attainment that, when included as model covariates, eliminate differences in cognitive performance (Aiken Morgan et al., 2008). These findings lend additional support to the notion that the present-day relationship between neighborhood SEP and cognition represents the "echoes" of early life disparities, especially in the case of racial disparities and segregation.

It is also important to note that the ACTIVE study sample likely underestimates race-based cognitive differences in the general population, as its exclusion criteria (e.g., substantial functional decline, substantial cognitive decline (MMSE < 24), or certain medical conditions such as stroke or high-fatality cancer) restricted the levels of cognitive function and medical health in the sample to higher ranges than would be represented in the general population. This exclusion of lower-functioning individuals would likely have especially affected the representativeness of blacks in the ACTIVE sample, given there are documented late life racial disparities in cognitive functioning and medical health, in which blacks are especially disadvantaged (e.g., Whitfield 2002), effectively equating the races on these outcomes in the ACTIVE sample despite their inequality in the larger population. ACTIVE sample selection may additionally underestimate race differences in cognition relative to the general population in that, contrary to population-based reports (Harper & Alexander, 1990), ACTIVE participants did not differ by race in educational attainment (Aiken Morgan et al., 2008). Blacks were in fact slightly more educated than whites in this sample, but this difference was not statistically significant. In a sample of *N*=2,802, this non-significant difference essentially represented an equating of the two races for years of education.

Effects of Neighborhood SEP on Response to ACTIVE Training

A second goal of Aim 1 was to examine whether, beyond baseline cognitive performance, neighborhood SEP could predict differences in the extent to which participants improved following one of the ACTIVE cognitive interventions. This analysis did not show a relationship between SEP and any of the responses to training – Memory, Reasoning, or Speed – relative to other participants who did not receive the training. This finding suggests that although neighborhood SEP does have a relationship to and potential influence on cognitive level and vocabulary, it does not have any observable influence on the potential for cognitive improvement following a short-term intervention. This is consistent with other work suggesting that indices of sociocultural advantage (e.g., education) predict level but not rate of change in cognitive aging (Lindenberger & Baltes, 1997). It is also consistent with the Aim 1 findings for cognitive level, that is, that neighborhood predicts crystallized but not fluid cognitive abilities, which were the abilities targeted by training. Those fluid abilities are more clearly related to brain health and the potential for neural plasticity (development of new neural circuits), reinforcing the notion that current neighborhood SEP's relationship to late life cognition may be more related to cultural than biological developmental processes. Taken together, the Aim 1 finding that neighborhood SEP more strongly predicts the crystallized than fluid cognitive abilities and does not predict fluid-ability training gains hints that overall, neighborhood SEP may be less important for new (fluid, present-day) information processing than it is related to past information processing (crystallized, over the lifetime, as is the case in vocabulary development).

The kind of neighborhood an ACTIVE participant came from had no effect on how much that person might benefit from the cognitive intervention. This finding may be useful in the future, should community organizations seek to implement cognitive interventions like ACTIVE's within their own neighborhoods (given the growing interest over recent years in healthy cognitive aging and cognitive exercise, this is a reasonable possibility). Planning committees seeking to optimize a cognitive intervention's benefit by placing it in areas of greatest potential response would want to consider that residents from areas of any level of socioeconomic position may be equally likely to benefit from intervention.

Aim 2: Facilities

Ad hoc-classified sets of neighborhood facilities had significant positive or negative associations with cognition. Importantly, although these facilities were significantly related to neighborhood SEP, the relationships between SEP and cognition did not change when facilities were estimated as mediators of those relationships. This suggests that these facilities had a unique relationship to cognition above and beyond its relationship with SEP. Specifically, participants living in neighborhoods with fitness and recreational centers, senior transportation services, golf courses, fine arts schools, mental health physician and practitioner offices, optometrist's offices and miscellaneous health centers tended to have better performance on general cognition, reasoning, everyday cognition, and vocabulary. Participants living in neighborhoods with civic and social organizations, services for elderly and disabled persons, specialty hospitals, dentist offices, language schools, artist offices, museums, sports teams and clubs, and fish markets tended to have poorer cognitive scores in all domains; these associations partly mediated the relationships between neighborhood SEP and general cognition, memory, speed, everyday cognition, and vocabulary.

The findings from Aim 2 must be interpreted with considerable caution given that 1) they were obtained following a *post hoc* combination of facilities generally related to better or poorer cognition, - these combinations were therefore derived opportunistically and findings may not generalize to other samples, and 2) these findings were observed cross-sectionally. Therefore it is impossible to determine in this dataset whether the relationship of SEP to cognition is truly *because* of the presence of these facilities in the neighborhood, or whether these sets of variables might be related for a different reason not captured in the present study. However, it lends at least some support to the possibility that the types of facilities present in the neighborhood might be important in influencing late life cognition, and may be part of the reason why neighborhood SEP predicts late life cognitive level. Certainly this study was limited in the way facilities could be quantified in the dataset and the level of geographic specificity at which this could be obtained (i.e., only rough counts of categories of establishments were available and only at the 5-digit ZCTA level), but it provides some preliminary frame of reference for future investigations.

Considering these cautions, there is nonetheless value in seeking to understand why these particular sets of facilities were positively and negatively related to cognition. The uniqueness of their associations suggests that although these facilities predict cognition, they do not mediate the relationship between cognition and SEP, because their inclusion in a multiple mediator regression model had no effect on SEP's association with cognition. This dissertation's hypothesis – that SEP is related to cognition because SEP represents the extent to which the neighborhood affords facilities supportive of cognition – is then rejected. The results suggested that cognition-supporting facilities are not necessarily present in the neighborhood because of the affluence of the area, and facilities that are negatively associated with cognition are not necessarily related so because of area-level socioeconomic disadvantage. The idea that certain neighborhood facilities support cognition by promoting, may still explain why some facilities were positively related to cognition: of those that were classified in this set, three are clearly supportive of physical health (optometrist's offices, HMO medical centers, miscellaneous health centers), two are clearly supportive of psychosocial health (mental health physicians and practitioners), and three could be construed as supportive of both physical and psychosocial health (fitness and recreational centers, golf courses, senior citizen transportation services), and were categorized as such by the classification consensus panel.

However, all of the facilities initially selected for examination were considered (and agreed upon by consensus) to support physical and/or psychosocial health, and only 9 of the 39 facilities selected had positive relationships to cognition. Thus, it is possible that these particular facilities were related to cognition for another reason. For instance, the reason the majority of the other facilities examined did not predict differences in cognition could simply be due to insufficient variability in the geographic distribution of those facilities in this dataset. It may be that the other facilities were either far too commonly-distributed (i.e., there were no census tracts that did not have such facilities), or too uncommonly-distributed (i.e., only a handful of tracts had those facilities) to have the heterogeneity of variance statistically needed to predict differences in cognition. This was certainly true of some facilities that did not predict cognition: for example, only 1.8% of census tracts did not contain at least one grocery store, 2.8% did not contain a pharmacy, and 1.3% did not contain a church; on the other hand, only 2.3% of census tracts contained a zoo or botanical garden, and 0.8% contained a nature park. Facilities that did predict cognition tended to have more even distributions: for example among the “positive facilities,” 53% of tracts had fine arts schools, 47% had golf courses, 78% had fitness and recreational centers, 30% had senior transportation services, 44% had miscellaneous health centers, and 51% had mental health physicians. Among the “negative facilities,” 20% of census tracts had fish markets, 10% had language schools, 14% had specialty hospitals, 79% had services for the elderly and disabled, 23% had museums, and 88% had civic or social organizations.

The negative indirect effect of SEP on cognition through other facilities is more challenging to explain, given the initial selection of these facilities based on their perceived potential to support cognition. However in retrospect, facilities such as museums, sports teams and clubs, and fish markets may be less supportive than originally believed. These three facilities, especially given that data was collected mostly in major metropolitan areas, suggest location in a core urban area, which often may also be an area of concentrated disadvantage (e.g., Sampson et al., 1997). Other "negative" facilities also represent services targeting a particular population need, such as services for the elderly or disabled, civic and social organizations, language schools, and specialty hospitals. Higher counts of these facilities might highlight areas in which services are being placed to serve residents with special needs – and often facilities providing services to residents with the greatest needs are placed in undesirable areas because residents of more desirable or affluent neighborhoods resist their placement (Margulies, 1992; Gleeson, 1994; Schively, 2007).

Neighborhood SEP significantly predicted more cognitive domains in these Aim 2 analyses than it did in Aim 1, which predicted only vocabulary. This is most likely due to the fact that in the Aim 1 structural equation model, cognitive factors were partitioned into domain-specific and general cognitive variance, and so the overall cognitive data variance was structured differently than in the Aim 2 analysis. In Aim 2, cognitive abilities were structured more in the way they are typically measured and closer to their "natural state," that is without the partialling-out of general cognition. Memory, reasoning, speed, everyday cognition and vocabulary, as they are measured and as they were estimated in Aim 2, captured both general cognitive variance and variance unique to their specific cognitive domains.

Limitations

This study possessed several limitations. First, there were limits to the conceptual and geographic specificity at which the facilities variables could be collected, as mentioned above. Ideally, the analysis would have considered the presence or absence of such facilities but their proximity to study participants (i.e., distance from home rather than presence in the ZIP code). This type of analysis is very time-consuming, and while it was beyond the scope of the proposed dissertation project, it is a viable future direction for exploration. The analysis also would ideally have addressed the extent to which participants actually used these facilities, but since facility data were collected post hoc, participant use data were not available. Second, the cross-sectional nature of the study clearly limits the conclusions to describing relationships among variables at a given "slice of time" rather than identifying causal or temporal relationships between variables. Thus, while there is a relationship between SEP and cognition mediated by facilities, in this dataset it is not possible to know whether higher neighborhood and more "positive" facilities leads to better cognition, or whether individuals with higher cognition tend to choose to live in neighborhoods with higher SEP and more "positive" facilities. The speculation that cumulative advantage across the life course leads to better cognition and residence in higher-SEP neighborhoods in late life, while based on existing theoretical and empirical findings, remains a speculation at best for now. However, a longitudinal assessment of the directions of these relationships may be possible, pending data availability on residential transitions; this possibility is discussed in greater detail in the Future Directions chapter.

Follow-Up Findings

Urban, Suburban, or Rural

The present study investigated some additional factors suspected to be important in neighborhood-cognition relationships. First, the type of area in which the participants lived (urban, suburban, or rural) was considered. This investigation revealed that the relationship of SEP to cognition did not differ depending on whether the neighborhood was in an urban, suburban, or rural area, based on non-significant residualized interactions of SEP and dummy-coded categorical (urban, rural) variables. However, there were several instances in which the relationship between facilities and a cognitive outcome was partly explained by the area type. Specifically, where certain facilities were associated with poorer general cognition, reasoning, or vocabulary (this was also marginally true for everyday cognition), they tended to be most strongly related in urban-like areas (i.e., areas located within major cities, in which 50% or more of that area contained 1,000 people per square mile or more).

Because these sets of facilities were combined atheoretically, it is a challenge to interpret what they might mean in urban or rural areas. The relationship of poorer cognition with “negative” facilities in urban areas is especially difficult to interpret given that these facilities were theoretically believed to support *better* cognition when selected for the study. However, investigating the list of “negative” facilities, several of these items appear to be present more often in urban than in suburban or rural areas (e.g., museums, sports teams and clubs, language schools, civil and social organizations, services for the elderly and disabled). Perhaps the stronger relationship between negative facilities and poorer cognition in urban areas is due to the fact that these facilities are more likely to be found in urban areas, and individuals in urban-like areas tend to have poorer cognition.

Individual Race, Neighborhood SEP, and Community Racial Composition

Prior neighborhood research has suggested that individual race status may interact with certain neighborhood characteristics, including community-level racial/ethnic composition, to influence health outcomes (e.g, Yen et al., 2009). As such, one set of follow-up analyses characterized the interactions of individual race with neighborhood SEP and with community-level race in predicting cognitive outcomes. No effects were found for the neighborhood racial composition or the interaction of race with neighborhood SEP, and prior literature has also reported these effects are inconsistent (Morenoff & Lynch, 2003). On the other hand, effects were observed for the interaction of race with neighborhood racial composition in predicting processing speed. The directions of these effects suggested that for both races, processing speed tended to be very slightly better for those who lived in neighborhoods with racial compositions more similar to their own race. That is, Whites from neighborhood with a greater proportion of other Whites tended to have faster processing speed, and African Americans from neighborhoods with a lower proportion of Whites tended to have faster processing speed. Said differently, participants who lived in neighborhoods with a racial composition more different from their own race status tended to perform more poorly on processing speed. These effects were so weak that they should not be interpreted as highly meaningful. However the direction of the effects may speak to the well-recognized association between minority status and stress (e.g., Greer, 2008, Greer & Brown, 2011), which has been purported to contribute to racial and ethnic differences in health in late life (Bulatao & Anderson, 2004). Especially considering the processing speed is likely the cognitive ability most expected to be directly impacted by health-related effects on neural integrity, especially the white matter tracts (e.g., Sapolsky, 1996; Turken, Whitfield-Gabrieli, Bammer, Baldo, Dronkers, and Gabrieli, 2008), the interaction effect observed here could potentially represent minority stress-related effects on late life health, and therefore on basic processing speed.

Mobility

It was reasonable to believe that the strength of the relationship between neighborhood and cognition may differ depending on whether or not an individual is mobile beyond the boundaries of his or her neighborhood. Therefore, another follow-up analysis assessed whether individual mobility outside of the immediate community moderated the neighborhood-cognition relationship. There were significant main effects of mobility for all cognitive outcomes; however this finding is not particularly informative given that cognition and life space mobility are already known to be related (e.g. James, Boyle, Buchman, Barnes, & Bennett, 2011). Again the effect of SEP on cognition did not differ by whether or not the individual had left the community, and generally this was also true for neighborhood facilities, but in one instance the positive relationship between positive facilities and vocabulary was stronger for those who did not move beyond the boundaries of their immediate communities compared to those who did. In this case it may be that for those whose mobility is limited to the immediate community, the types of facilities available in the neighborhood becomes more important because one is relatively restricted to using only those facilities.

Contributions of the Present Study

This study's findings advance our understanding of the relationship between neighborhood and cognition beyond what is presently published. One will recall that the existing U.S. literature documents only a relationship between neighborhood socioeconomic status and MMSE score, a rough measure of cognitive status, i.e., cognitively healthy versus impaired (Wight et al., 2006; Sheffield and Peek, 2009). This association offers little insight regarding which aspects of cognition are related to neighborhood characteristics (and therefore, what it is about cognition for which neighborhood might matter), because it describes only broad differences in cognitive status. The present study did not investigate neighborhood effects on MMSE in particular because, relative to the truly population-based studies by Wight and colleages (2006) and Sheffield and Peek (2009), ACTIVE recruited an older sample with an explicitly limited MMSE score range (23-30) in order to target healthy older adults. As a result, the ACTIVE dataset very likely does not contain the same range of variance in MMSE scores as the previous studies, and is better designed to examine more fine-grained differences in cognitive performance among healthy individuals.

While neighborhood SEP's association with cognition, especially vocabulary, does not clearly identify a *mechanism* by which neighborhood might matter for cognition, it offers more informative clues than does an association with MMSE. It suggests that neighborhood may be especially important for supporting crystallized world knowledge, and in particular promoting cognitive reserve. Even if this relationship represents the echoes of a long-ago neighborhood influence from early life, it is nonetheless meaningful to identify neighborhood's support of cognition as a potentially cultural mechanism, a mechanism which may begin influencing cognition early in life and have long-lasting effects. Neighborhood as a cultural mechanism supporting cognition is also important for older adults: as age-related changes occur in brain health and the fluid cognitive mechanics become less effective, the support of world knowledge, cognitive reserve, and current cultural environment may become increasingly important as resources with which to compensate for losses in fluid abilities (Baltes, 1997; Stern, 2002). This study may also provide preliminary evidence that the types of establishments or facilities within a neighborhood may be important for cognitive outcomes, but given the nature of how these facilities were ultimately quantified, the findings from Aim 2 should be interpreted with caution.

Future Directions

As discussed in the main findings and limitations of this chapter, the present study was inherently limited in its conclusions because of its cross-sectional nature. Moreover, the relationship between neighborhood characteristics and Vocabulary suggests that the neighborhood-cognition relationship may be the product of a cumulative interaction of the individual with the socio-cultural environment over the life course. As such, next steps in this research should consider the dynamic interaction of neighborhood and individual cognition longitudinally, to better elucidate the possible direction of causal patterns in this relationship.

The ACTIVE study provides the opportunity to investigate these longitudinal questions in a future study. First, at the time this dissertation was conducted, ACTIVE collected its 10^{th} annual follow-up testing occasion, allowing possible examination of the interaction of relationships between neighborhood and cognition in 2000 with neighborhood and cognition in 2010. Furthermore, at this 10^{th} annual follow-up occasion, additional data was collected documenting the county in which each participant received his or her primary schooling. National historical data will allow investigators to use this new variable in the ACTIVE dataset to explore whether and how distal environmental influences (i.e., county-level SEP and educational laws during one’s primary schooling years) might predict contextual neighborhood characteristics and cognitive outcomes later in life. The investigators intend to pursue these new directions in neighborhood research on cognitive aging. The investigators could also explore, within the dataset in hand, 1) the effect of neighborhood residential instability in predicting cognitive outcomes, 2) the relationship of SEP to health status and chronic disease in ACTIVE, and how these health indicators might predict cognition, and 3) potentially, a predictive neighborhood-cognition model may estimate the relationship between SEP and MMSE, to more closely approximate the findings of previous studies.

Conclusions

The present study examined the relationship of neighborhood socioeconomic position with general and specific dimensions of late life cognition and response to cognitive training, and assessed whether the presence of facilities believed to support cognition might mediate this relationship. Results suggested that current neighborhood SEP does matter for cognitive level, and not for response to cognitive training. However, neighborhood SEP's effects on cognitive level are relatively weak, and are limited to crystallized cognitive abilities or vocabulary. The small effect of current neighborhood SEP is in part mediated by the types of facilities present in the neighborhood. Urban or rural residence, individual mobility, and the interaction of one's own race status with the neighborhood's racial composition also contribute to the relationship between neighborhood facilities and cognition. This study therefore identified several neighborhood characteristics related to late life cognition, highlighting that the influences of contextual factors on cognitive outcomes is likely a complex and interactive process. The discussion also considered the possibility that these cross-sectional findings likely represent the outcome of person-environment interactions across the lifespan. Future research should investigate these contextual influences on cognition longitudinally, taking into account both retrospective, early life contextual predictors of late life cognition, and prospective contextual predictors of cognitive trajectories throughout the decades of late life.

APPENDIX A
OVERVIEW OF SESSION TOPICS IN ACTIVE INTERVENTION GROUPS

Table A-1. Memory Training.

Session	Summary of Topics
1.	Describe how memory works and how to get the most out of training. Learn basic principles of remembering and strategies for improving memory.
2.	Focuses on using categorization to remember lists of things (e.g., shopping list, list of items to take on a trip).
3.	Introduces visualization strategies for picturing information to be remembered. Reviews categorization strategy from Session 2.
4.	Teaching and practicing the Method of Loci with "Memory Man" visual aid for remembering long lists of unrelated items.
5.	Teaching and practicing organizational strategies for remembering text material (e.g., stories, news articles) by organizing into main ideas and details.
6.	Reviewing and practicing Method of Loci using the "Memory Man," story recall, and categorization.
7.	Practice categorizing word lists, recalling the gist and details of stories and everyday text, and using the Loci method with "Memory Man."
8.	Practice remembering Method of Loci with both "Memory Man" and with imagined body parts, practice remembering a short story and details from a financial document, and practice categorizing lists of related words.
9.	Practice recall for a list of related words, text recall, and Method of Loci with unrelated word lists.
10.	Discuss how to select memory strategies, review categorization, review text memory strategies focusing on main ideas and details, and review Method of Loci strategy for visualization. Practice all three strategies in provided exercises.

Table A-2. Reasoning Training.

Session	Summary of Topics
1.	Provide rationale for training; teaches strategies for identifying patterns in everyday activities (e.g. scan, underline, say aloud, draw a slash)
2.	Focus on finding and completing patterns in vertical format (e.g. calendars), and using pattern searching strategies to find information and record it elsewhere
3.	Continue using vertical formats to practice finding patterns; transition to using horizontal letter sets.
4.	Strategies for finding patterns in letter series, and using these strategies to find information in typical product instructions.
5.	Continue practice in finding patterns in letter series; introduce "skip" patterns. Practical exercise for using patterns to simplify retention of a TV schedule, and for using print conventions to organize and retrieve information from written material
6.	Exercises designed to give more practice on previously-introduced skills (e.g., finding, differentiating, and completing patterns, skills for organizing and accessing information).
7.	Continue practice on letter series, sets, and word lists. Practical exercise with using a complex table to find info using columns and rows.
8.	Continue reinforcing pattern-finding skill and provide practical exercise in reading a complex medical chart, also involves a speed-developing exercise.
9.	Present more practice on letter sets, letter series, and using a table to find information. Less material presented to allow extra long practice times.
10.	Review activities of the entire training series with exercises.

Table A-3. Processing Speed Training.

Session	Summary of Topics
1.	Group discussion of course outline, exercises to be practiced, and plan for monitoring training progress.
2.	Group discussion of slowing in everyday activities; group computer demonstration of UFOV Processing Speed task, followed by fixed practice protocol and (time permitting) variable practice protocol.
3.	Group discussion on dividing attention between two simultaneous activities; group demonstration of UFOV Divided Attention task followed by fixed and variable practice protocols.
4.	Group discussion focusing attention in the presence of distraction; group demonstration of UFOV Selective Attention task, followed by fixed and variable practice protocols.
5.	Review the material from the first four sessions, discuss learning strategies which have been helpful so far, and assess current skill on the UFOV tasks.
6.	Group discussion on driving as requiring quick responses and concurrent attention in multiple areas, and how the abilities targeted by training relate to driving ability. UFOV training structured based on Session 5 assessment.
7.	Group discussion on other important activities of daily living which rely on vision and the ability to pay attention, and how training might benefit these activities. UFOV training based on previous training improvements.
8.	Group discussion on reasons people may fall and how attention relates to falling. UFOV training based on previous training improvements.
9.	Discuss the importance of mobility for an independent lifestyle. UFOV training based on previous training improvements.
10.	Review and finalize material learned throughout training, and how it relates to activities of daily living; provide an overview of training progress and results. Participants complete a final assessment.

APPENDIX B
METHODOLOGICAL TREATMENT OF NEIGHBORHOOD FACILITIES

A list of 39 categories of facilities believed to be a supportive resource for cognitive health if used (i.e., by providing opportunities to promote physical health, intellectual or social engagement), defined by their NAICS label in the 2002 US Economic Census, was compiled in an online classification tool. Sixteen experts in cognitive development and/or contextual influences on health at the doctoral or pre-doctoral level were originally asked to classify the facilities as theoretically supportive of physical health, psychosocial health, or supportive of both. Specifically, they received the following instructions:

> Thank you for taking the time to help me classify the following 39 neighborhood establishments for my dissertation. Your feedback will guide the development of 3 neighborhood-level constructs:
>
> 1) Facilities supporting physical health (i.e. medical health and/or physical fitness)
> 2) Facilities supporting psychosocial health (i.e. emotional well-being, social engagement, and/or intellectual stimulation)
> 3) Facilities supporting both physical and psychosocial health.
>
> Please classify each establishment, to the best of your knowledge, based on your understanding of the factors supporting physical and psychosocial health. If you believe the establishment does not belong in any of the 3 constructs, please choose the fourth option (i.e., does not support physical or psychosocial health).

Raters were also invited to leave additional comments on the classification tool or to clarify their approach in a blank field at the bottom of the page. Initial inter-rater agreement on the online classification tool was moderate at best (Fleiss' kappa = 0.41, SE = 0.01). This appeared to be due to confounding from the Hybrid category, as facility classifications were frequently split between Hybrid and either PHY or PSY, suggesting raters tended to disagree about whether a facility promoted exclusively physical or psychosocial health, or promoted both. Because the majority of facilities (#/39) received ratings that were either all hybrid and PHY or hybrid and PSY, the hybrid category was dropped to simplify classification and improve rater agreement by forcing facilities into either the PHY or PSY category. If a facility was rated as either PHY or Hybrid by the majority of raters and did not receive more than one rating for the PSY category, it was classified as PHY; likewise if a facility was rated by the majority as PSY or Hybrid and did not receive more than a single rating for the PHY category, it was classified as PSY. Only two types of facilities (Continuing Care Retirement Facilities and Golf Courses) did not meet these criteria and were not included in this classification. This 2-category classification approach (which also took into consideration ratings of "does not support physical or psychosocial health) resulted in good rater agreement (Fleiss' kappa = 0.85, SE = 0.01).

However, subsequent combination of PHY and PSY facilities based on this consensus classification in confirmatory factor analyses resulted in poor model fit (e.g., PHY: $x2/df = 66.78$, $p < 0.001$; NFI = 0.57, TLI = 0.53, CFI = 0.58, RMSEA = 0.16, $p < 0.001$; PSY: $x2/df = 64.28$, $p < 0.001$; NFI = 0.40, TLI = 0.24, CFI = 0.41, RMSEA = 0.16, $p < 0.001$). These estimates of model fit were low enough that it was reasonable to expect attempts at optimizing the models would not be sufficient to obtain adequate model fit. Furthermore, variables representing the simple summation of facilities within each category, when tested in the multiple-mediator models described in Aim 2, carried no significant indirect effects of SEP on cognition (and with the exception of PSY on Everyday Cognition, also had no significant direct effects on any cognitive outcome).

Subsequent exploration of the neighborhood facilities variables focused on using exploratory factor analysis to inform construct development. Exploratory factor analysis yielded 12 total factors, the groupings of which were highly atheoretical and (as would be expected) did not classify according to how they would be anticipated to influence cognition (an abbreviated representation of the factor organization is illustrated in Table B-1). Exploratory canonical correlation analyses designed to identify relationship between sets of facilities and sets of cognitive measures yielded similarly atheoretical results.

Finally, the authors considered that the *number* of a given facility in an area may not be as important as *whether* at least one of a given facility was available in the area or not. Following this, the facilities variables were recoded as dichotomous "present-or-absent" variables. Then, to untangle the relationship between facilities and cognition at a finer level, the presence or absence of individual facilities in an area was correlated with individual measures of cognition. This level of inspection revealed that individual facilities tended to be significantly correlated in a consistent direction across multiple cognitive measures, but there was considerable variability in whether the selected facilities were positively or negatively correlated with cognition. The pattern of correlations suggested that rather than certain types of (i.e., physical or psychosocial health-supporting) facilities being associated with better cognition, the pattern of relationships tended to be such that the presence of certain facilities were usually associated with better cognition, but the presence of other facilities was usually associated with poorer cognition (Table B-2).

Due to this heterogeneity of associations between individual facilities and cognition, and the failure to develop a theory-guided confirmatory factor model, attempts to develop theoretically-based constructs of cognition-supporting facilities were redirected toward 1) investigating whether aggregated categories of facilities predicting either better cognition (i.e., "positive facilities") or worse cognition ("negative facilities") could mediate the relationship between SEP and cognition, and 2) investigating whether cognitive differences might be predicted by residence in an urban, suburban, or rural area (as explored in the follow-up analysis section). The summed categories of positive and negative facilities showed modest correlations with urban or rural area characteristics (Table B-3).

Table B-1. Abbreviated list of facilities' exploratory factor analysis structures.

Facility	1	2	3	4	5
Dentist Offices	**.93**	-.11	.07	-.11	.10
Fine Arts Schools	**.93**	.14	-.40	.05	-.14
Optometrist Offices	**.81**	-.04	-.12	-.11	.10
Fitness Centers	**.76**	.10	-.06	.12	-.05
MH Physician Offices	**.70**	.01	.13	.18	-.16
PT/OT/Speech Offices	**.56**	-/10	.33	.19	.01
MH Practitioner Offices	**.31**	-.03	.23	.12	.20
Theater Companies	-.09	**.93**	-.09	.24	-.05
Dance Companies	.01	**.80**	.18	-.38	-.23
Musical Artists	.21	**.59**	-.22	-.17	-.14
Civic/Social Organizations	.03	**.55**	.10	.11	.06
Religious Organizations	.16	**.52**	.05	.19	.09
General Hospitals	-.07	.20	**.82**	-.12	.11
Kidney Dialysis Centers	-.23	-.21	**.76**	.23	.24
Ambulatory Emergency Centers	.06	-.01	**.69**	-.12	-.36
Physician Offices	.46	.12	**.62**	-.12	-.04
Community Food Services	-.14	.07	.01	**.85**	-.04
Fruit/Vegetable Markets	.33	-.09	-.18	**.78**	-.02
HMO Medical Centers	-.01	.13	.18	**.59**	-.09
Specialty Hospitals	-.01	-.25	.06	-.14	**.61**
Sports Teams & Clubs	-.01	-.05	-.01	.004	**.91**
Fish/Seafood Markets	-.28	.02	-.08	.03	-.03
Supermarkets	-.08	-.15	.05	.02	-.24
Pharmacies	.41	.04	.16	.001	.24
Museums	-.07	.17	.04	-.05	.39
Nature Parks	-.10	.00	-.06	-.07	-.07
Services for the Elderly/Disabled	.15	.226	.14	-.001	.19
Zoos & Botanical Gardens	-.08	-.14	-.10	.21	.05

Table B-2. Correlations of individual facilities with cognitive measures.

	MMSE	Memory Composite	Reasoning Composite	Speed Composite	Everyday Cognition Composite	Vocabulary
Fitness and recreational centers	0.06**	0.07**	0.07**	0.00	0.07**	0.14**
Golf courses	0.04	0.04	0.07**	-0.03	0.08**	0.09**
Fine arts school	0.03	0.03	0.10**	-0.01	0.10**	0.13**
Senior transportation services	-0.01	0.01	0.06**	0.00	0.06**	0.10**
Mental health physician offices	0.06**	0.07**	0.14**	-0.03	0.14**	0.22**
Mental health practitioner offices	0.05*	0.05*	0.09**	-0.01	0.08**	0.15**
Optometrist offices	0.09**	0.05*	0.11**	0.00	0.11**	0.17**
HMO medical centers	0.03	0.03	0.02	-0.04*	0.10**	0.04**
Miscellaneous healthcare centers	0.04	0.01	0.10**	-0.02	0.10**	0.15**
Services for the elderly/disabled	-0.05*	-0.09**	-0.04*	0.07**	-0.08**	-0.03
Specialty hospitals	-0.05*	-0.03	-0.04*	0.04*	-0.07**	-0.03
Civic and social organizations	-0.01	-0.06*	-0.03	0.06**	-0.06**	0.00
Language schools	-0.06**	-0.03	-0.06**	0.07**	-0.09**	0.03
Dentist offices	-0.04*	-0.04*	-0.04*	0.05*	-0.07**	0.00
Museums	-0.02	-0.03	-0.04*	0.06**	-0.11**	0.00
Artists offices	-0.04*	-0.06*	-0.04	0.05*	-0.04*	-0.05*
Sports teams and clubs	-0.02	-0.02	-0.06*	0.03	-0.08**	-0.05*
Fish markets	-0.11**	-0.07**	-0.09**	0.03	-0.14**	-0.13**

Table B-3. Correlations of facilities classifications with area type.

	% Urban	% Urbanized Area	% Urban Cluster
Positive Facilities	-0.03	-0.33**	0.42**
Negative Facilities	0.24**	0.21**	-0.11**

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BIOGRAPHICAL SKETCH

Shannon Sisco graduated with Honors from Calvin College in Grand Rapids, Michigan, completing a Bachelor of Arts in Psychology with a minor concentration in Biology. She worked as a research associate in the Departments of Psychiatry and Neurology (Center for Stroke Research) at the University of Illinois-Chicago before completing a Master of Science in Psychology in 2008, through the University of Florida's Clinical and Health Psychology doctoral program. Since that time she has completed all didactic and research requirements of the program, with specialty clinical training in Neuropsychology, a certificate in Aging, and additional didactic training in Public Health.

Ms. Sisco was accepted into an American Psychological Association-accredited pre-doctoral internship in Clinical Psychology through the North Florida/South Georgia Veterans Health System. There she is currently receiving specialty clinical training in geropsychology, through a position sponsored by the Veterans Affairs Geriatric Research Education and Clinical Center (VA GRECC). Ms. Sisco will complete this capstone year of her doctorate in August 2012, at which time she will receive her Ph.D. in Psychology. She intends to pursue a research and clinical post-doctoral fellowship involving training in geriatrics and neuropsychology.