THE EFFECT OF LIFECOURSE SOCIOECONOMIC POSITION AND HEALTH ON TRAJECTORIES OF COGNITIVE FUNCTION IN OLDER ADULTS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Background: Studies suggest that SEP across the lifecourse may influence health, and more specifically cognitive health, through several pathways. However, few studies examining the effect of SEP on cognition have benefited from the use of longitudinal data and most have been confined to specific subpopulations of older adults or have been limited to restricted geographic areas. This overall goal of this dissertation research was to apply a lifecourse approach to the conceptualization and modeling of the social and economic determinants of cognitive performance, and attempt to further understand the relationship between disadvantage at different life stages and cognitive health in adulthood. The study aims are based upon what is known about longitudinal changes in cognitive performance among older adults and the existing studies that examine the effect of heath conditions and lifecourse SEP on cognition. ***Methods:*** The samples for these analyses were drawn from the Health and Retirement Study (HRS), a nationally representative, prospective panel study of adults over 50 years of age. Performance on the episodic memory tasks administered at each wave was used as the cognitive functioning measure. Measures of SEP and health status were obtained from self-reported survey data. Mixed models with random effects, also known as growth curve models, were used to characterize individual trajectories of memory function and to examine the relationship of SEP and health to initial level of cognitive function and rate of change. ***Results:*** Education was positively related to higher cognitive scores in older

age but was associated with faster decline over time. These effects were robust to adjustment for income, wealth, and occupation suggesting that education has a strong direct effect on cognition net of SEP in adulthood. Measures of childhood SEP were related to the absolute level of performance on memory-related cognitive tasks at age 65 but the effects were mediated by education and adult SEP. Results also suggest that upward social mobility can partially compensate for disadvantage early in life. Highest lifetime BMI was negatively associated with cognitive performance although this effect was mediated by BMI in later life and vascular-related health conditions. Highest lifetime BMI was associated with more rapid cognitive decline in models adjusted for current BMI. The effect of highest lifetime BMI on performance level and rate of change was modified by measures of childhood SEP, gender, and current obesity suggesting that the association between BMI and cognitive outcomes might not be the same for all groups. ***Conclusion:*** This research further supports prior work documenting the lasting impact of education on cognition and suggests that measures of lifecourse SEP and adiposity may also be significant predictors of cognitive performance and change in later life.

CHAPTER 1

INTRODUCTION

1.1 Introduction and Specific Aims

A growing body of literature has documented the association between education and other measures of socioeconomic position (SEP) and adult disease. With very few exceptions, the research shows that persons who are socioeconomically disadvantaged experience higher mortality rates for most major causes of death as well as greater morbidity. [Davey Smith et al., 1992; House et al., 1994; Kaplan et al., 1997; Lynch et al., 2000] The relationship between SEP and poor health has been found for cognitive outcomes as well. An increasing number of studies find that low SEP, including low-status occupations and low income, is a risk factor for poor performance on neurological tests as well as for developing Alzheimer's disease and dementia in old age. [Brunner 2005; Cerhan et al., 1998; Evans et al., 1997; Farmer et al., 1995; Holland et al., 1991; Koster et al., 2005; Stern et al., 1994] In an attempt to understand the etiology of cognitive health inequalities in adulthood, researchers have examined socioeconomic conditions experienced in early life theorizing that the effects of social disadvantage on cognition could originate in early childhood. Many of these studies have demonstrated that childhood SEP is an important determinant of disease risk later in life, including risk

for impaired cognitive functioning [Everson-Rose et al., 2003; Harper et al., 2002; Kaplan et al., 1997; Kaplan et al., 2001; Singh-Manoux et al., 2005; Turrell et al., 2002; van de Mheen et al., 1998] However, most research examining the effect of SEP on cognition among older adults has not benefited from the use of longitudinal data. In addition, findings on the association between SEP factors and age-associated cognitive change have been conflicting and have often been examined in specific subpopulations of older adults or have been limited to restricted geographic areas. As a result, few studies have investigated potential effect modifiers of the relationship between SEP and cognition such as birth cohort, gender, and race/ethnicity. Although several health conditions are known risk factors for poor cognitive outcomes in later life, previous research has ignored the potential for SEP to modify the relationship between health-related risk factors and cognition. This dissertation examines the relationship between SEP across the lifecourse, health, and cognitive functioning in later life within a nationally representative sample of older Americans. Specifically, this research addressed the following aims:

Specific Aim 1 – (1) To examine the effect of education and other measures of socioeconomic position on cognitive performance and decline, (2) to determine to what extent the effect of education is mediated by socioeconomic status in adulthood, and (3) determine whether these relationships are modified by birth cohort, gender, and race/ethnicity.

Hypothesis 1a: Higher levels of education, through both direct and indirect mechanisms mediated by socioeconomic status in adulthood, would be

associated with better cognitive performance and protective against cognitive decline.

Hypothesis 1b: The effect of education and adult SEP will differ by race/ethnicity, gender, and birth cohort.

Specific Aim 2 - (1) To determine whether there is a direct effect of childhood SEP on cognitive performance later in life or whether it is mediated entirely through education and measures of SEP in adulthood, (2) to evaluate whether there are gender or cohort differences in the effects of childhood SEP and education on cognitive performance and decline, and (3) to determine whether accumulation of socioeconomic disadvantage and social mobility from childhood to adulthood affect cognitive function.

Hypothesis 2a: Higher SEP in childhood would be associated with higher cognitive performance and in middle and older age and slower age-related decline.

Hypothesis 2b: The effect of childhood SEP on cognition will differ by gender and birth cohort.

Hypothesis 2c: Measures of adult SEP will mediate the relationship between childhood SEP and cognitive function.

Hypothesis 2d: Upward social mobility from childhood to adulthood will result in better cognitive performance in later life and less-rapid decline than remaining in the lower SEP groups across all life stages.

Specific Aim 3 - (1) To determine whether measures of childhood SEP are associated with highest lifetime BMI, (2) to ascertain whether the effect of BMI on cognition is mediated by vascular-related health problems and BMI in later life, (3) to evaluate whether gender, obesity at baseline, and measures of SEP in childhood and adulthood modify the association between BMI in midlife and cognition.

Hypothesis 3a: Lower SEP in childhood will be associated with higher lifetime BMI.

Hypothesis 3b: Higher lifetime BMI will be associated with lower cognitive scores and more-rapid decline.

Hypothesis 3c: Vascular conditions and current BMI will mediate the relationship between highest lifetime BMI and cognition.

Hypothesis 3d: The effect of highest lifetime BMI will vary by gender, current obesity, and SEP.

1.2 Background

Cognitive Aging

The goal of research related to cognition and aging is to produce inferences about how and why changes in cognitive ability occur when they do, as well to relate change or the absence of change to distal outcomes where possible. To address this goal, researchers and methodologists in cognitive aging have focused on changes that occur in individual levels of cognitive performance, mean levels of performance in groups, and variability in individual and group performance. [Dixon et al., 2004] Examining specific

trajectories of cognitive change is important because not all cognitive abilities decline with age and not all persons experience decline. Irrespective of what cognitive construct is being measured, the assumption is that performance in these areas changes across the lifecourse. [Dixon et al., 2004]

While numerous studies have shown marked patterns of decline in many cognitive functions in older age, not all abilities decline or decline equally. Although methodological differences between cross-sectional and longitudinal research have caused debate among investigators of cognitive aging, a number of findings appear to be consistent. Both cross-sectional and longitudinal studies have found significant declines in cognitive abilities such as encoding new memories or information, working memory, and processing speed, while short-term memory, autobiographical memory, semantic knowledge, and emotional processing remain fairly stable with increasing age. [Hedden et al., 2004] Similarly, aging does not necessarily imply decline in cognitive performance in any domain. In fact, not all persons experience decline in cognitive ability with age. Although average performance on most cognitive tasks declines with age, many older persons experience very little change whereas others experience dramatic deterioration. [Christensen 2001]

In an effort to define age-related neural changes, researchers have focused on how age-related changes in cognitive performance and behavior map onto changes in neural structure and function. The aging of the brain, and pathology resulting from age-associated injury to the brain, is believed to underlie the declines in speed and memory performance. [Christensen 2001] Cross-sectional studies have shown significant age differences in cerebrospinal fluid (CFS) as well as total brain, hippocampal, frontal and

temporal lobe volumes. [Resnick et al., 2003]] Brains of older adults tend to have lower volumes of grey matter than brains of younger adults with most of the decline resulting from lower synaptic densities. [Resnick et al., 2003; Terry 2000]Memory deficits have been shown to be associated with damage to the hippocampus and medial temporal lobe region whereas decreases in cognitive speed have been related to white matter hyperintensities. [Buckner 2004; Gunning-Dixon et al., 2000] Crystallized intelligence, as demonstrated by tests of vocabulary, information accumulation, and other knowledge-based activities, often does not decline with age and is presumably represented in areas of the brain that do not deteriorate until late in life or until a threshold of functional loss has been achieved. [Christensen 2001]

Prior Approaches to Cognitive Aging Research

Much of the prior research in cognitive aging has been dominated by cross-sectional comparisons of young adults in the 20s and older adults in their 60s to 80s, in part because this approach offers the most efficient means of comparison. Most of these studies, as well as their longitudinal counterparts, have focused on comparing average performance across groups using cross-sectional methods or examining changes in average performance within groups over time using a longitudinal approach. However, longitudinal studies with a person-centered methodology can provide key information that cross-sectional studies cannot such as estimates of individual rates of decline, associated risk factors for decline, and exploration of heterogeneity within a population over time.

Investigating age associated change in cognitive functioning is challenging for several reasons, primarily because it is difficult to separate the effects of "normal aging"

from those due to pathological processes that often accompany age. Second, many classic studies of cognitive aging use a correlational method in which a set of variables is used to predict age differences, as in a cross-sectional design, or age changes, as in a longitudinal design, of some measure of cognition [Verhaeghen 2004] Reporting a measure of correlation is limited in that it is a linear measure of association and offers no information about the strength of an association. In cross-sectional research it is also unclear whether two factors are correlated by joint association with a third confounding factor. Although previous studies have contributed greatly to our understanding of the process of cognitive change in aging, many prior analyses included data only from clinical samples with limited sample size and representativeness thereby reducing generalizability. What is also not clear from the literature on cognitive change and aging is whether a set of variables that may be strong predictors of individual differences in performance level have any use in explaining change. [Verhaeghen 2004]

Education and Cognition

Studies suggest that SEP across the lifecourse may influence health, and more specifically cognitive health, through several pathways. It has been theorized that education, an often-used measure of SEP, may be protective against cognitive decline or may modify the expression of cognitive decline and dementia by contributing to brain reserve capacity. [Katzman 1993] The brain reserve capacity hypothesis suggests that education somehow provides a reserve facility, through either biologic or behavioral mechanisms, which modifies disease expression by allowing for adaptive functioning in spite of the existence of neuropathology and thus delays the risk of cognitive impairment or

dementia in older age. [Buckner 2004; Stern et al., 1994; Stern et al., 1999; Whalley et al., 2004]

With respect to cognitive change, education is hypothesized to protect against decline either because the rate of decline is slower among the highly educated or because the initiation of decline is delayed to older ages relative to less educated. [Christensen et al., 2001] Evans et al. reported that more years of formal education were associated with smaller declines in cognitive function over a 3-year follow-up period among community-dwelling adults ages 65 or older after adjustment for age, sex, language of interview, county of birth, income, and occupation. [Evans et al., 1993] Lower education has also been shown to be a significant predictor of diagnosed cognitive impairment after controlling for age, sex, stroke, and baseline mental status. [White et al., 1994] The relationship between education and cognitive impairment or dementia has also been found across racial groups. [Callahan et al., 1996] However, not all studies examining the relationship between education and cognitive decline have resulted in consistent findings. According to a review article by Anstey et al., previous longitudinal studies examining the association between education and cognitive change can be grouped into four groups based on their outcomes: 1) studies in which the rate of decline is slower for the more highly educated; 2) studies which failed to find an effect of more rapid decline for the better educated; 3) studies in which the effect of education on decline was restricted to one or more subgroups; and 4) studies in which the effect was restricted to certain cognitive domains. [Anstey et al., 2000] Similarly, the protective effects of higher education may be limited to specific cognitive domains. In a large community of sample of older adults followed for over 3 years, Christensen et al. found that lower education was predictive of

greater decline on the Mini-Mental State Examination (MMSE) and on tests of language and knowledge, but not on tests of cognitive speed, memory, or reaction time. [Christensen et al., 1997]

Lifecourse Socioeconomic Position

The relationship often found between education and cognition could also be a reflection of other processes early in life. Education may be a marker for environmental experiences that have an effect on cognition and vary with education. [Albert 1995] Alternatively, higher education could be on the pathway between higher SEP in childhood and higher cognitive ability later in life. Evidence shows that childhood socioeconomic factors influence cognitive development and abilities in children. [Roberts et al., 1999] Thus, it is possible that the effects of these developmental advantages or disadvantages persist into middle and old age. If this is true, then measures of SEP in childhood should be related to cognitive status as an adult. The mechanisms of this association are likely complex, with parental education influencing their children's cognitive development through the quality and frequency of parent-child interactions and though economic and material factors. [Kaplan et al., 2001]

Studies on the influence of early life predictors of later life outcomes have proposed several models to describe the relationship between disadvantage at different life stages and health and cognition as an adult. These models are usually grouped into three categories: critical period models, accumulation models, and pathway models. [Ben-Shlomo et al., 2002; Graham 2002] Critical period models explore whether there is a critical period of risk, usually during developmentally sensitive periods in childhood, during which early life conditions have long-term health effects beyond their impact on

later status. Accumulation models propose that there is an accumulation of risk and exposure over the lifecourse that begins in childhood and persists into adulthood. In these models, disadvantage at different time periods has a cumulative dose/response effect on health outcomes. According to these models, the greatest risk of poor health in adulthood is generated by having poor circumstances throughout life. Pathway models, which can be viewed as another type of accumulation model, suggest that circumstances early in life lead to other similarly adverse or beneficial exposures in the pathway to adult health. In these models the effect of disadvantage is indirect, with poor childhood SEP influencing social trajectories into and throughout adulthood by restricting educational opportunities, which in turn influence employment and socioeconomic circumstances and health behaviors in adulthood. [Graham 2002]

Social epidemiologic research has established the importance of considering the accumulation of advantage and disadvantage across the lifecourse when investigating the effect of SEP on health outcomes. [Ben-Shlomo et al., 2002; Kuh et al., 2003; Singh-Manoux et al., 2005] Researchers have also argued that a lifecourse approach is important to understanding social variations in health because it implies a reciprocal relationship between SEP and health and allows that poor circumstances at one life stage can be moderated by better circumstances earlier or later in life. [Graham 2002] These lifecourse models have been applied to research on how socioeconomic exposures across different life stages influence cognition in middle and late age. Some studies have shown that cognitive functioning in adulthood is independently affected by both early and later life circumstances suggesting that childhood SEP has a lasting effect on cognition beyond its impact on educational attainment and later SEP, while others found that childhood SEP has

no direct effect on cognition but a substantial indirect effect mediated though education and adult SEP. [Kaplan et al., 2001; Singh-Manoux et al., 2005; Turrell et al., 2002] Previous research on the effect of SEP on health in the HRS has demonstrated that childhood and adult SEP are important independent predictors of physical and mental health in later life. [Alley et al., 2007; Cagney et al., 2002; Luo et al., 2005] However, these studies have either been restricted to subgroup analyses of a single birth cohort or were limited to cross-sectional analyses and did not investigate cognitive change.

Other research has found support for models that propose the importance of social trajectory or mobility. [Luo et al., 2005; Turrell et al., 2002] Adults who had low childhood SEP and then experienced upward mobility had better health outcomes, including cognitive performance, than those with similar childhood circumstances but limited or no upward mobility. [Luo et al., 2005]] Similarly, in a study of Finnish men, socioeconomic mobility across the lifecourse predicted performance on tests of verbal fluency, memory, and the MMSE such that upward mobility decreased risk of poor cognitive performance and partially compensated for disadvantage in childhood whereas those experiencing downward mobility into low education and/or income groups exhibited worse performance.[Turrell et al., 2002] However, another study on the relative effects of education and socioeconomic status in adulthood and Alzheimer's disease found that the association between education and AD incidence was not mediated by low adult occupation-based SES regardless of the adult socioeconomic mobility pattern. [Karp et al., 2004]

The influence on early life circumstances on cognitive change has been less well studied. Results from the Nurses' Health Study found that educational attainment

predicted cognitive function and decline although there was little association with other markers of socioeconomic status, including household income and childhood SSP (measured using father's occupation). [Lee et al., 2003] It should be noted that this study is restricted to community dwelling, older woman, all of whom are well educated (15 years of education minimum). The contribution of childhood SEP to cognitive functioning and change in later life independent of level of education and adult socioeconomic status is not well characterized in an economically diverse population.

It is also possible that low socioeconomic pathways both mediate the relationship between cognition and other dimensions of inequality, including gender and race/ethnicity. There is evidence of race and ethnic differences in cognitive function both cross-sectionally and longitudinally. [Sloan et al., 2005] Additionally, education and income have been found to confer fewer health benefits for Blacks and Hispanics than for Whites. [Luo et al., 2005] Childhood SEP and social mobility have been shown to have similar heath effects for both men and women; however, educational attainment had a larger impact and adult income a smaller impact on cognitive functioning scores for woman than men. [Luo et al., 2005] More research is needed to clarify to what extent relationships between lifecourse socioeconomic status and cognitive functioning and decline vary by gender and ethnicity.

Obesity and Health Conditions

Health conditions also play a large role in the trajectory of cognitive change with age and there is significant overlap in the risk factors for Alzheimer's disease and other forms of dementia. High levels of cholesterol, hypertension, diabetes, stroke, physical inactivity, and smoking have all been implicated as risk factors for dementia-related

diseases – many operating through cardiovascular mechanisms. [de la Torre 2002] Recently, research has shown that body mass index (BMI) and obesity in middle-age are also associated with cognitive impairment and dementia. Again, a lifecourse approach is important to understanding the relationship between overweight and obesity and the causes of cognitive impairment because the role and timing of BMI as a risk factor changes throughout life. Some research has found that weight loss in later life precedes dementia and that low BMI is associated with dementia cross-sectionally, [Barrett-Connor et al., 1998; Gustafson et al., 2003] while prospective studies have shown that high BMI in midlife is a risk factor for poor cognitive outcomes in older age. These studies have shown that individuals who were overweight or obese in midlife had a higher risk of Alzheimer's disease (AD) and vascular dementia (VaD), independent of the presence of cardiovascular disease, diabetes comorbidities, and stroke. [Kivipelto et al., 2005; Rosengren et al., 2005; Whitmer et al., 2007] Being overweight or obese increases the risk for developing the vascular disorders that are associated with AD and cognitive impairment and this may be one pathway thought which high BMI affects cognitive performance. [Gustafson 2006; Kopelman 2000] Other possible mechanisms of the association between obesity and dementia include the harmful effects of hormones, adipocyte secreted proteins, and inflammatory cytokines on the brain. [Whitmer 2007]

As with cognition, obesity also appears to be strongly determined by socioeconomic status. Persons of low socioeconomic status in adulthood are at increased risk for weight gain and the development of overweight and obesity. [Ball et al., 2005; Sobal et al., 1989] Research also suggests that childhood socioeconomic disadvantage has a lasting effect on weight in adulthood, independent of adult socioeconomic status.

[Ball et al., 2006; Blane et al., 1996; Brunner et al., 1999] Specifically, population-based studies of women have shown that parental occupation is strongly associated with adult weight, while measures based on maternal education were more predictive of weight change. [Ball et al., 2006; Lahmann et al., 2000] The enduring connection between markers of SEP and obesity as well as SEP and cognition suggest that the relationship between BMI and cognition might be more pronounced in certain socioeconomic subgroups.

1.3 Research Design and Methods

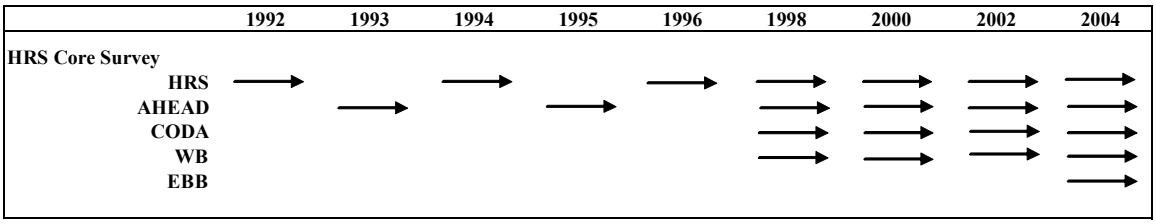
Study Population and Data

This research was conducted by analyzing publicly available data from The Health and Retirement Study (HRS) and Asset and Health Dynamics Among the Oldest Old Study (AHEAD), now collectively referred to as the HRS. The HRS is a nationally representative, prospective panel study of community-dwelling adults in the contiguous United States over 50 years of age with oversamples of African-Americans and Hispanics. [Heeringa et al., 1995] The study is funded by the National Institutes of Aging and conducted by the Institute for Social Research at the University of Michigan. To date the study is a combination of five cohorts: the AHEAD cohort of persons born between 1890 and 1923); the Children of the Depression Age (CODA) cohort of those born between 1924 and 1930; the original HRS cohort of those born between 1931 and 1941; the War Babies (WB) cohort of those born between 1942 and 1947; and the Early Baby Boomer (EBB) cohort of those born between 1948 and 1953 which was added in 2004. To date, seven waves of data have been collected from the HRS cohort; six waves from the AHEAD cohort; four from the CODA and WB cohorts; and one wave from the

EBB cohort. For the present research, only respondents from the first four cohorts will be used as the youngest cohort has only a baseline interview to date. With the inclusion of the four oldest cohorts, the HRS consists of over 22,000 cases. Additional detail about the design of the HRS is available elsewhere. [Heeringa et al., 1995; Juster et al., 1995]

Interviews are conducted with sampled respondents and their spouses, irrespective of age, every two years. Interviews began in 1992 for the original HRS cohort, in 1993 for the AHEAD cohort, and in 1998 for the CODA and War Babies cohort and have continued through 2004. Figure 1 is a graphical representation of the HRS data collection waves from 1992 to 2004.

Figure 1.1. HRS Data Collection Waves from 1992 to 2004



Interviews are conducted by telephone for most respondents less than 80 years of age and face-to-face for persons 80 years of age or older. Proxy respondents are interviewed when sampled respondents are unable to participate themselves. Although an attempt is made to conduct interviews with the sampled individuals themselves whenever possible, proxy interview to be conducted when an individual is unable to do so because of physical or cognitive limitations, and also occasionally when the individual is unwilling to be interviewed but consents to having someone else (almost always their spouse) be interviewed as their proxy. Approximately 10% of all HRS respondents and

14% of those 70 years of age and older are interviewed using a proxy. A small number of proxy interviews, starting with AHEAD 1995, have been triggered by a low score on a test of the respondent's cognitive abilities. In these cases the interviewer is encouraged (via an interviewer prompt) to either terminate the interview and start again with a proxy informant or continue with the assistance of a caregiver. Beginning in 2002, for cases in which the respondent was not able to complete the entire interview due to cognitive limitations, an attempt was made to administer the cognitive performance section of the interview to the respondent.

Baseline and reinterview response rates have been consistently high throughout the HRS. Baseline response rates range from a low of 70% for the WB cohort to 81.4% for the original HRS sample. The overall response rate at any follow-up wave is a mixture of the response of three types of persons: those who participated in the prior wave (referred to as re-interview cases), those who were eligible to participate in the prior wave but did not (referred to as re-contact cases), and new spouses who become eligible for the first time. Follow-up response rates are on average in the low to mid-90% range.

Cumulatively, 16% of the original HRS sample had been found to be deceased by the 2004 wave, based on information from the interviewers and from the National Death Index which is used to validate the vital status of the HRS respondents. Over 50% of the AHEAD sample died in the decade between their baseline interview wave in 1993/94 and the most recent interview wave in 2004. For the CODA and WB samples, the cumulative proportions that died between their baseline in 1998 and 2004 were 17.9% and 3.5% respectively.

For the purposes of this study, only interviews with self respondents, or case with self-reported cognition data, will be used. Table 1.1 shows the number of self respondents in the HRS by cohort and interview wave.

Table 1.1. Number of HRS Self Respondents by Sample and Interview

Sample	1992/93	1994/95	1996	1998	2000	2002*	2004*
Total	19386	16817	10225	19341	17517	16131 (161)	15088 (212)
HRS	11883	10691	10225	9723	9137	8797 (67)	8553 (88)
AHEAD	7503	6126		5069	4196	3392 (55)	2790 (64)
CODA				2189	1960	1766 (20)	1631 (25)
WB				2360	2224	2176 (10)	2114 (14)

* Additional proxy respondents with self reported cognition data in parentheses

HRS Cognitive Measures

In the HRS, cognitive performance is assessed using a variety of cognitive tests that tap different cognitive abilities. For these analyses performance on the episodic memory tasks in which respondents are asked to recall a list of 10 common nouns immediately after hearing them (immediate recall) and after approximately five minutes (delayed recall) was considered. These tasks were selected because they have been shown to be sensitive measures of cognitive change. [Small et al., 1999] For the episodic memory tests, respondents are asked to recall a list of 10 common nouns immediately after hearing them (immediate recall) and after approximately five minutes of additional test administration (delayed recall). Prior principal-components factor analyses showed that these recall tasks loaded on a single factor so scores on these tests were combined to create a composite score for use in the analyses. [Ofstedal et al., 2005]

Statistical Analysis

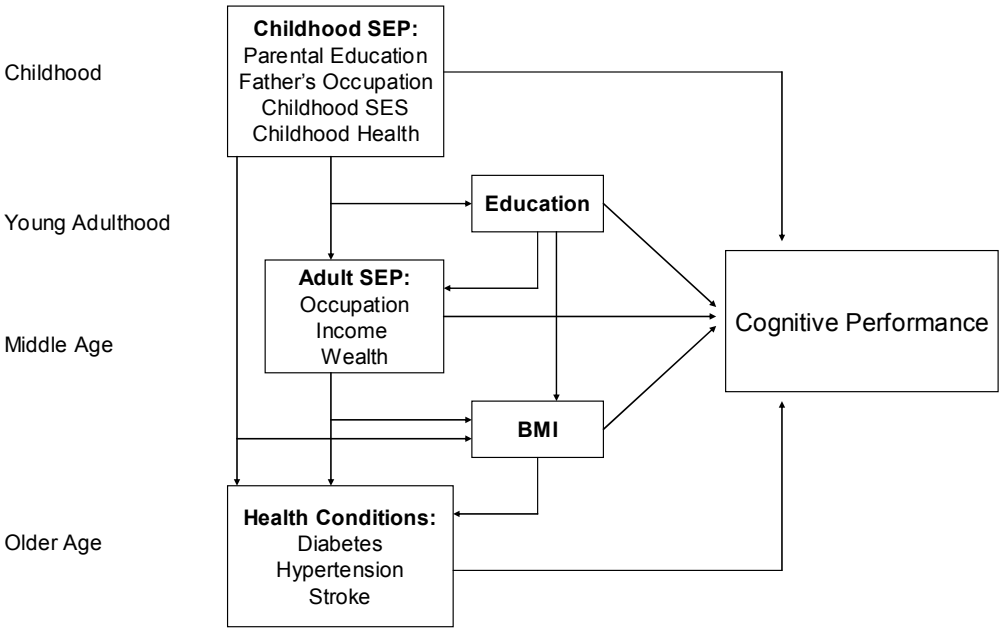
To addresses these aims, I used mixed models with random effects, also known as growth curve models, to characterize individual trajectories of memory function and to examine the relationship of SEP and health to initial level of cognitive function and rate of change. [Laird et al., 1982] With this approach, the effect of the predictors of interest on baseline level and change is estimated while more properly adjusting for within-person variability in level and change by incorporating a separate set of random effects. Individuals are assumed to follow the mean path of the group except for random effects, which cause the initial level of cognitive performance to be higher or lower and the rate of change to be faster or slower, as described in more detail elsewhere. [Wilson et al., 2002] An advantage of this approach is that accommodates unbalanced data structures, both in terms of number of testing occasions and differences in intervals between assessments, and enables full use of data for all respondents with at least one valid cognitive score.

Conceptual Framework

Much of the inconsistency in the findings of the association between education, SEP, and cognitive change reflects the challenges of measuring cognitive decline given the heterogeneity in level, rate of change, and survival among older adults and especially those with dementia or AD. As mentioned previously, the cognitive domains included in an assessment are important in that the findings appear to be dependent in part on the type of test that is utilized. In addition, the design of the study and the method that is used to model the relationship between SEP and level of performance and rate of change also affects the interpretation of results. Whether or not covariates that may confound or

mediate the relationship between SEP and cognitive change are included in the analysis would impact the relative importance of other predictors in the causal pathway. Figure 1.2 provides the conceptual framework used for the investigation of the research aims. For Aim 1, education is hypothesized to have a direct effect on cognition and an indirect effect by influencing the more proximate factors of SEP in adulthood. For Aim 2, childhood SEP is posited to also have both direct and indirect influences on cognitive performance. In Aim 3, BMI influences cognition directly and also mediated by vascular disease. Measures of lifecourse SEP that are related to both BMI and cognition are proposed confounders and/or effect modifiers.

Figure 1.2. Conceptual Framework for the Pathways Linking Lifecourse SEP, Health, and Cognitive Performance



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CHAPTER 2

THE EFFECT OF EDUCATION AND ADULT SOCIOECONOMIC POSITION ON COGNITIVE CHANGE AMONG OLDER ADULTS

2.1 Abstract

The association between education, socioeconomic position (SEP), and cognitive change was examined in a large nationally representative sample of adults over age 50 using growth curve models. Using longitudinal data from the Health and Retirement Study we also examined the extent to which the effect of education and SEP on memory-based cognitive performance differed by gender, race/ethnicity and birth cohort. More years of education was associated with higher initial performance on the cognitive tasks but was not protective against cognitive decline. The effect of education was only minimally attenuated after adjusting for household income, wealth, and longest occupation. The rate of age-related decline was slightly faster for women and slower for later birth cohorts and blacks, but overall the effects were small and subgroups experienced nearly parallel trajectories of cognitive aging. The relationship between education and cognition was similar for whites and blacks and for men and women when controlled for other measures SEP. However, Hispanics gained less benefit from each year of education than non-Hispanics and more recently born cohorts experienced less advantage from education than those born and educated earlier. Adjusting for education

or other measures of SEP did not eliminate gender-related differences in cognitive aging nor the significant disparity in cognitive performance experienced by racial and ethnic minorities. These findings suggest that education has a significant and direct role on cognitive performance and decline net of the indirect effect mediated by socioeconomic status in adulthood.

2.2 Introduction

A growing body of literature has documented the association between education and other measures of socioeconomic position (SEP) and adult disease. With very few exceptions, the research shows that persons with lower education levels or who are socioeconomically disadvantaged, experience higher mortality rates for most major causes of death as well as greater morbidity. [Davey Smith et al., 1992; Feinstein 1993; House et al., 1990; Kaplan et al., 1997; Lynch et al., 2000] The relationship between measures of SEP and poor health has been found for cognitive outcomes as well. An increasing number of studies find that low SEP, including low education, low-status occupations, and low income, is a risk factor for poor performance on neurological tests as well as for developing Alzheimer's disease and dementia in old age. [Brunner 2005; Cerhan et al., 1998; Evans et al., 1997; Farmer et al., 1995; Koster et al., 2005; Stern et al., 1994] The question arises as to whether education is contributing to this general pattern of SEP-related health differentials or whether the association between education and cognition relates specifically to the processes and product of education itself.

It has been theorized that education may be protective against cognitive decline or may modify the expression of cognitive decline and dementia by contributing to brain reserve capacity. [Katzman 1993] The brain reserve capacity hypothesis suggests that

education somehow provides a reserve facility, through either biologic or behavioral mechanisms, which modifies disease expression by allowing for adaptive functioning in spite of the existence of neuropathology and thus delays the risk of cognitive impairment or dementia in older age. [Buckner 2004; Stern et al., 1994; Stern et al., 1999; Stern 2002; Whalley et al., 2004] With respect to cognitive change, education is hypothesized to protect against decline either because the rate of decline is slower among the highly educated or because the initiation of decline is delayed to older ages relative to those who are less educated. [Christensen et al., 2001] Another possible explanation for the effect of education on cognitive functioning is that education may be a marker for environmental experiences that have an effect on cognition and vary with education. [Albert 1995] Educational attainment is associated with occupation and other measures of socioeconomic status as an adult which are also predictors of cognitive performance and change.

However, not all studies examining the relationship between education and cognitive decline have resulted in consistent findings. According to a review article by Anstey et al., previous longitudinal studies examining the association between education and cognitive change can be classified into four groups based on their outcomes: 1) studies in which the rate of decline is slower for the more highly educated; 2) studies which failed to find an effect of more rapid decline for the better educated; 3) studies in which the effect of education on decline was restricted to one or more subgroups; and 4) studies in which the effect was restricted to certain cognitive domains. [Anstey et al., 2000]

Much of the inconsistency in the findings of the association between education, SEP, and cognitive change reflects the challenges of measuring cognitive decline given the heterogeneity in level, rate of change, and survival among older adults and especially those with dementia or AD. The cognitive domains included in an assessment are also important in that the findings appear to be dependent in part on the type of test that is utilized. In addition, the design of the study and the method that is used to model the relationship between SEP and level of performance and rate of change also affects the interpretation of results. Longitudinal studies offer well-known advantages over cross-sectional studies in that cross-sectional studies may confound cohort effects with age effects; however, few studies examining the effect of SEP on cognition among older adults have benefited from the use of longitudinal data.

Whether or not covariates that may confound or mediate the relationship between SEP and cognitive change are included in the analysis would impact the relative importance of other predictors in the causal pathway. Another limitation of much of the prior research is the use of study samples that are limited to specific subpopulations of older adults - usually well-educated and high-functioning or residing in restricted geographic areas. These groups may vary greatly in educational attainment and opportunities as well as other environmental exposures that may have a significant impact on their relationship to cognitive outcomes. [Albert 1995; Alley et al., 2007; Christensen et al., 2001; Evans et al., 1993; Lee et al., 2003; Lyketsos et al., 1999]

In addition, little attention has been placed upon whether the effects of education and other SEP measures on cognition vary by gender, race and ethnicity, or birth cohort. Some studies have found that low education is more deleterious for African-Americans

than whites and that high income does not confer an advantage to racial minorities. [Jones 2003] Additionally, persons of Hispanic origin have been shown to not experience commensurate gains in cognitive function with increasing education. [Cagney et al., 2002] These results underscore the importance of investigating group differences in the effect of predictors on cognitive change in older age. Using longitudinal data from a nationally representative sample of adults over age 50, we examined the effect of education and other measures of SEP on cognitive performance and change and determine whether these relationships are modified by birth cohort, gender, and race/ethnicity. We hypothesized that higher levels of education, through both direct and indirect mechanisms mediated by socioeconomic status in adulthood, would be associated with better cognitive performance and protective against cognitive decline. Furthermore, we expect these effects to vary significantly across demographic subgroups.

2.3 Methods

Study Population and Data

Data for these analyses came from the Health and Retirement Study (HRS) and Asset and Health Dynamics Among the Oldest Old Study (AHEAD), now collectively referred to as the HRS. The HRS is a nationally representative, prospective panel study of community-dwelling adults in the contiguous United States over 50 years of age with oversamples of African-Americans and Hispanics. [Heeringa et al., 1995] The study is funded by the National Institutes of Aging and conducted by the Institute for Social Research at the University of Michigan.

New respondents are added to the sample every six years to replenish the sample, to adjust for aging and attrition, and to maintain the steady state design. Currently, the

study is a combination of five cohorts: the AHEAD cohort of persons born between 1890 and 1923; the Children of the Depression Age (CODA) cohort of those born between 1924 and 1930; the original HRS cohort of those born between 1931 and 1941; the War Babies (WB) cohort of those born between 1942 and 1947; and the Early Baby Boomer (EBB) cohort of those born between 1948 and 1953, which was added in 2004. To date, seven waves of data have been collected from the HRS cohort; six waves from the AHEAD cohort; four from the CODA and WB cohorts; and one wave from the EBB cohort. Additional detail about the design of the HRS is available elsewhere. [Heeringa et al., 1995; Juster et al., 1995]

Interviews are conducted with sampled respondents and their spouses every two years, including those respondents who have entered nursing homes. Interviews began in 1992 for the original HRS cohort, in 1993 for the AHEAD cohort, and in 1998 for the CODA and War Babies cohort and in 2004 for the EBB cohort. Interviews were conducted by telephone for most respondents less than 80 years of age and face-to-face for persons 80 years of age or older and for baseline interviews. Interviews were conducted in both English and Spanish.

These analyses were limited to interviews with self respondents and cases with self-reported cognition data. Beginning in 2002, for cases in which the respondent was not able to complete the entire interview due to cognitive limitations, an attempt was made to administer the cognitive performance section of the interview to the respondent. Respondents at least 51 years of age who were not missing on baseline covariates and had at least one interview wave with a valid cognitive test were eligible for inclusion in the analyses. One member of each household was randomly selected for inclusion in the

final sample to avoid confounding from unmeasured household-level variables (N=17,875).

Outcome Measure

In the HRS, cognitive performance is assessed using a variety of cognitive tests that tap different cognitive abilities. Performance on the episodic memory tasks at each wave was used as the measure of cognitive performance for these analyses. These tasks were selected because they have been shown to be sensitive measures of cognitive change. [Small et al., 1999] For the episodic memory tests, respondents are asked to recall a list of 10 common nouns immediately after hearing them (immediate recall) and after approximately five minutes of additional test administration (delayed recall). Factor analysis has been performed on the HRS cognitive battery to examine the underlying construct of the performance tasks. The results of the analysis indicated that across waves, two factors with eigenvalues greater than one consistently emerged: (1) a memory factor, consisting of the immediate and delayed recall tasks, and (2) a mental status factor including the serial seven subtraction, backwards count, word / name recognition, and dates. [Ofstedal et al., 2005] Thus, performance scores on the two memory tasks were combined to create a composite score to use in the analyses. This composite measure was calculated using the unweighted average of the immediate and delayed recall tasks which was then rescaled to yield a score range of 0 to 100. Respondents who refused at the beginning of the test were assigned a zero on that portion of the test while respondents who refused during the test were given the score they had obtained up until that point. For most of the interview waves the same cognitive tests were administered; however, the verbal recall tests in the 1992 and 1994 interviews with the original HRS

cohort consisted of a list of 20 common nouns rather than 10. The distributions of scores on the 20-item tests are highly skewed with less than 5% scoring more than 10 on either test. To make these scores comparable to waves using the 10-item lists each test was rescaled so that a score of 10 or above was considered perfect score

Socioeconomic Measures

Education – Years of education were originally reported as a continuous variable with a maximum of 17. For the purposes of these analyses education was coded as [Years-12] to be approximately centered. In addition, education was also represented by a dummy variable indicating whether the respondent graduated from high school or achieved a GED and a variable for whether they graduated from college.

Income and Wealth – The income measure used was reported household income at first interview adjusted for inflation using the Consumer Price Index (CPI) calculated by the Bureau of Labor Statistics and normalized to 1992 dollars. Income was categorized into tertiles (< $17,500, $17,500 to $44,999, and $45,000 or more). Since some HRS respondents are retired at the time of interview, household wealth was chosen in addition to household income as a supplemental measure of adult economic circumstances. Wealth was measured using an assets-less-debts approach by subtracting debt from the sum of net worth as reported at the baseline interview - items such as value of the home, checking and savings accounts, individual retirement accounts, certificates of deposit, bonds, and shares of stocks or mutual funds. For comparability, wealth was also normalized to 1992 dollars. Three wealth categories containing as close as possible 33% of the sample were created (under $50,000, $50,000 to $149,999, and $150,000 or more). Income and wealth data were drawn from the RAND HRS data files - version F

which includes summary measures and imputed values for income and wealth compiled from an extensive battery of HRS questions. [St.Clair et al., 2006]

Occupation – Primary occupation was assigned using the occupation code (according to the 1980 US Census guidelines) for the job with the longest reported tenure (also available in the RAND HRS data files - version F). For cases in which no job with the longest tenure was identified, the occupation code for the current job was assigned. Occupation was classified into 1 of 4 categories: white collar (professionals, managers, salesmen, clerical and service industries); blue collar (operators, craftsmen, farmers); homemaker, or unemployed/other. The homemaker category consists of women who were employed for less than half of their adult life, were currently not working, and self-identified as housewives.

Covariates

Practice effects - Repeated administration of cognitive tests has been shown to result in practice effects such that there can be a boost in performance after the initial exposure to the test. To control for practice effects over time in these analyses, a dummy variable was included in the models to represent prior exposure to the cognitive test. Respondents were assigned a zero at their baseline wave of cognitive testing and a value of 1 at each subsequent test. The coefficient for this variable represents the average increase in test score between the baseline and first follow-up interview wave.

Race and ethnicity – To represent race and Hispanic ethnicity, respondents were classified into 1 of 3 categories: non-Hispanic white/other, non-Hispanic black, and Hispanic. Respondents who reported both African-American race and Hispanic ethnicity were assigned to the Hispanic group.

Age and Cohort – Age was coded as [Age at interview-65] / 10 to be approximately centered. Thus, the intercept represents the average cognitive performance at age 65 and the age coefficient represents the average change in cognitive score with each decade. Similarly, birth cohort was coded as [Birth Year-1930] / 10.

Statistical Methods

To addresses the aims of this paper, mixed models with random effects, also known as growth curve models, were used to characterize individual trajectories of memory function and to examine the relationship of education and other measures of SEP to the initial level of cognitive function and rate of change. [Laird et al., 1982] With this approach, the effect of the predictors of interest on baseline level and change is estimated while more properly adjusting for within-person variability in level and change by incorporating a separate set of random effects. Individuals are assumed to follow the mean path of the group except for random effects, which cause the initial level of cognitive performance to be higher or lower and the rate of change to be faster or slower, as described in more detail elsewhere. [Wilson et al., 2002] An advantage of this approach is that accommodates unbalanced data structures, both in terms of number of testing occasions and differences in intervals between assessments, and enables full use of data for all respondents with at least one valid cognitive score. All respondents contribute to the intercept term, whereas respondents with at least 2 valid cognitive tests contribute to the slope term.

Graphical methods were initially used to explore patterns of cognitive performance by age. Longitudinal changes in cognitive performance were then estimated using mixed models (PROC MIXED, SAS software, Version 9.1: SAS Institute Inc.,

Cary, NC) without adjustment for sampling weights. The models were estimated using the full-information maximum likelihood estimation with an unstructured covariance matrix for the random effects and included all data available (N=17,875, D=70,527). Cognitive function was first modeled solely as function of age, allowing random effects for both the intercept and age-based change. Linear models as well as models with more complexity, including quadratic and two-part linear spline models with knots at 65 and 70 years were estimated in an effort to best model the pattern of cognitive change with age. Fit was evaluated by comparing the log likelihood value and Bayesian information criterion (BIC) between models.

Next, models that included demographic variables and the effect of retest were considered. For these models random effects were allowed for the intercept, slope (age), and retest-effect. To examine the effect of education on cognition, the centered education variable and the variables for high-school and college graduation status, were entered into the model. The effect of income, wealth, and occupation were assessed separately and then added in the final model together to determine to what extent they mediated the effect of education. Finally, additional models with interaction terms were fit to examine whether the associations between cognitive function and education and SEP were consistent across cohorts and demographic subgroups.

An individual growth model in which change in cognitive score is a linear function of age is represented by the level-1 submodel shown below:

$$COG_{ij} = \pi_{0i} + \pi_{1i} [(AGE_{ij} - 65)/10] + \varepsilon_{ij}$$

where COG_{ij} is the cognition score for person i at time j and AGE_{ij} is the wave-specific age. In this model the intercept (π_{0i}) represents the value of i's cognition score at age 65

years (because age is centered) and the slope term (π_{1i}) is the rate of change in cognitive score per decade. This model assumes that a straight line adequately represents each person's true change over time and that any deviation from linearity observed in the sample data result from random error (ε_{ij}).

The level-2 submodels are shown below:

$$\pi_{0i} = \gamma_{00} + \gamma_{01}\text{EDUC} + \zeta_{01}$$

$$\pi_{1i} = \gamma_{10} + \gamma_{11}\text{EDUC} + \zeta_{11}$$

These models treat the intercept (π_{0i}) and the slope (π_{1i}) of an individual's growth trajectory as level-2 outcome that may be associated with predictor variables (Education level (EDUC) is used in this example). Each component also has its own residual (ζ_{01} and ζ_{11}) that allows the level-1 parameters of one individual (the π's) to differ from the parameters of others.

A series of models were also estimated adjusting for use of proxy at anytime during the study period and whether the respondent was deceased at the time of last contact with the household. Although both of these factors were significant predictors of level of cognitive performance and decline, they did not significantly affect any of the coefficient estimates and were not included in the final models.

Previous studies using the HRS data have shown that those who are more cognitively impaired are also less likely to participate in the study. [Rodgers et al., 2003] To investigate the possible impact of attrition on the estimates in these analyses, the distributions of age, gender, birth year, race /ethnicity, education, wealth, and occupation were examined by the number of interview waves with valid test scores. To assess whether dropouts (due to death or loss to follow-up) had different cognitive trajectories

than persons who remained in the study, longitudinal trends were estimated separately for respondents with 2 to 4 valid tests and respondents with 5 or more tests and then compared.

2.4 Results

Table 2.1 shows the characteristics of the study sample stratified by gender and race. The mean age of the entire sample was 64 years and the age distribution was fairly similar across groups, although women were three years older than men on average and black and Hispanic study participants were slightly younger than white respondents. The mean memory score at age 65 was about 50 points out of a possible score of 100 with white respondents out performing minority groups by about 8%. Education, represented both as years of education and the highest degree achieved, varied moderately by gender but quite significantly by race/ethnicity. Women had fewer years of education than men and were less likely to have a college education or degree. White respondents had more years of education than blacks or Hispanics and almost 50% of black respondents and 65% of Hispanic respondents did not complete high school in contrast to less than 30% of whites.

Gender and race/ethnic disparities were evident in total household income and net worth as well as in primary occupation. Men were more likely than women to have higher household incomes and net worth with men having 1.5 times the income of women and 1.4 times the amount of assets. In part, this is due to the higher likelihood of women to have outlived their spouses and live in single person households. White respondents had incomes almost twice of their black and Hispanic counterparts with nearly one third earning more than $45,000 annually. The economic disadvantage

experienced by blacks and Hispanics was even more evident in measures of household wealth. The mean net worth for white households was more than 3 times the mean for Hispanic households and 4 times that of black households. Almost 40% of white respondents were in the highest wealth tertile while less than 14% of blacks or Hispanics had the same level of wealth. Overall, men, black, and Hispanic participants were more likely to report a blue-collar primary occupation. Over 40% of women and white respondents reported a white collar occupation while less than 30% of blacks or Hispanics did. Homemakers made up approximately 12% of all women and almost 7% of the total sample. About 25% of the sample was either mostly unemployed or did not have a coded occupation because they didn't hold a job for more than 5 years at a time.

Table 2.2 shows the results from the multivariate analysis of change in cognitive function for all respondents. In the first step we estimated the amount of between- and within-person variance by estimating models that allowed random effects only for the intercept with no parameter for change over time (Model 1: Unconditional Means model). Most of the total variation in cognitive function was attributable to differences between persons (54%); however, there was a non-ignorable amount or variation between persons.

In the second step, we estimated models with fixed and random effects for the intercept and slope using age at testing as the basis of change taking into consideration models with nonlinear changes over age. Model 2 represents the linear age-based model, or unconditional growth model which was ultimately the best fitting model for change in memory function over time. A model with a quadratic age term was also attempted but produced negative variances and convergence problems. The two-part linear spline

models converged but did not improve the fit compared to the Model 2 (results not shown).

The linear model yielded both a significant time-constant intercept (mean performance at age 65) and age-dependent slope parameter representing decreases in means with each decade of age. The mean score at age 65 was 50.77 with a 9.4 point decrease in score per decade (Figure 2.1). Comparison of the residual variance between the unconditional means and growth model showed that 12% of the within-person variation was associated with linear time indicating that other time-varying predictors (such as retest) might be needed to improve the fit.

To account for sources of variability, gender, birth cohort, race/ethnicity, and a measure for retest to account for practice effects were added to the linear growth model (Model 3). Comparison of between-person variances and pseudo-R^2 statistics suggested that while the addition of covariates to this model did not affect the variance in initial status, these covariates accounted for an additional 24% of the variance in the rate of change and significantly improved the fit compared to the unconditional growth model. Retest and female gender were significantly associated with higher cognitive scores at age 65 while black race and Hispanic ethnicity were associated with significantly lower intercept scores. More recent birth cohorts had lower mean scores at age 65 but less pronounced decreases in function over time.

Adding a continuous variable representing years of education and dummy variables for high school and college degrees (Model 4a and Model 4b) significantly improved both the overall fit of the model and accounted for approximately 18% of the between-person variance in initial status. Years of education were positively related to

higher scores at age 65; the effect of each year of education being worth almost 2 points. Having a high school degreed conferred additional benefit above years of education while the effect of a college degree was not significant. Education was also related to the rate of decline in cognitive performance. The coefficients for both the interaction between age and years of education and high school degree were negative indicating that higher education was related to faster decline, although both were small relative to the effect of age.

The independent effects of income and wealth and primary occupation separate from education were examined as well (Models 5 and 6). Increases in income and wealth had a large positive impact on function at age 65 while income had a small negative impact on the age slope. Occupation was also strongly associated with cognitive score with white-collar workers scoring 10 points higher than unemployed and intermittently employed respondents and 8 points higher than blue-collar workers. Similar to education, higher occupational status was related to faster decline over time.

A final model examined the effect of education with simultaneous adjustment for other measures of SEP to determine whether education had a direct effect on cognition independent from its effect though its association with income, wealth, and occupation in adulthood. While the effect of income, wealth, and occupation were greatly attenuated with the inclusion of the education variables in the model, the effect of education remained significant and fairly robust to adjustment by other SEP measures.

Tables 2.3, 2.4, and 2.5 present multivariate models for change in cognitive function with interactions by cohort, gender, and race/ethnicity. The interaction between birth cohort and education was significant and remained so after the inclusion of other

SEP measures. The significant negative coefficient representing the interaction of cohort and education indicates that more recently born cohorts experience less advantage with each year of education than those born and educated earlier. The interaction of birth cohort with the effect of education on the slope of cognitive change was also significant demonstrating that Age X Education declines were slower per decade for more recently born cohorts. The interaction between birth cohort and college education was positive suggesting that the unexpected result of a 1.7 point disadvantage associated with having a college degree was offset by being born later. In contrast, more recently born cohorts experienced less advantage from higher status occupations.

Women experience decline at a slightly more rapid rate but have a higher retest benefit. The significant interaction between gender and years of education became insignificant when other education and SEP indicators were entered into the model and there were no gender-related differences in the effect of education indicators on the rate of cognitive decline. However, women reap significantly less benefit from higher levels of income and wealth compared to men and the effects of income, wealth, and occupation on rate of cognitive change varied significantly by gender but not always in the same direction.

The advantage of black race on the effect of education at age 65 and the interaction of race with the effect of education on decline became insignificant once other measures of SEP were included. In contrast, Hispanics gained less benefit from each year of education than non-Hispanics, an effect that remained unchanged with the inclusion of SEP measures in the model. There were no significant differences in the effect of income, wealth, or occupation on performance at age 65 or in rate of decline by

race/ethnicity. Adjusting for education or other measures of SEP did not eliminate the significant disparity in cognitive performance experienced by racial and ethnic minorities.

As shown in Table 2.1, there is evidence that the number of interview waves with valid cognitive scores differed by race and gender. Other analyses showed that the number of repeat cognitive tests also differed by education level and socioeconomic status indicators. Blacks, Hispanics, respondents with lower education and household income tended to be more highly represented in the portion of the sample with fewer than 4 testing occasions. However, the coefficient estimates for the fixed effects were similar for persons with 2 to 4 valid tests and for those with 5 or more valid cognitive tests (results not shown).

2.5 Discussion

This study examined the effect of education and other measures of SEP in adulthood on cognitive function in later life and whether these associations varied by birth cohort, gender, and race/ethnicity. We hypothesized that education would be associated with higher cognitive function score and would be protective against decline as has been found in several epidemiological studies of the education-cognition relationship. [Albert et al., 1995; Butler et al., 1996; Colsher et al., 1991; Farmer et al., 1995; Lyketsos et al., 1999] Additionally, we expected the effect of education to be partly mediated by income, wealth, and occupational status in adulthood but predicted it would remain a significant predictor of cognitive function even when models predicting cognitive function were adjusted by measures of SEP. Lastly, we expected a differential relationship between these factors and cognition across demographic subgroups.

Similar to a number of previous studies, the results presented here suggest that education has a significant and lasting effect on memory-based cognitive performance later in life. [Cagney et al., 2002; Evans et al., 1993; Stern et al., 1994; Stern et al., 1999] However, they did not support the theory that education has a protective effect against cognitive decline. Rather, these findings are similar to those reported by Christensen et al. and Alley et al. who found that education, while contributing a higher baseline level of performance in complex verbal memory tasks, was actually associated with faster decline over time. [Alley et al., 2007; Christensen et al., 1997] A cognitive-reserve-based model would suggest that education may provide individuals with more cognitive reserve in old age which in turn would require more that more neural pathology developed before memory was affected; however, once pathology progressed to a point at which the brain can no longer draw upon its reserve, function would decline more rapidly. The end result would be a shorter time between the initiation of memory loss and cognitive disability in respondents with higher educational attainment. [Stern 2002] Interestingly, both the number of years of education and high school degree status were independently associated with cognitive status. High school completion may be a marker of higher cognitive ability at a younger age or it could be a proxy for additional reserve that is associated with continued cognitive engagement though later-life occupation or leisure activity that is not included or well represented by the measures of occupational attainment or SEP used in these analyses.

It has been suggested that education may simply be a proxy for other lifecourse factors or exposures that mediate reserve and risk for cognitive decline. For example, living in poverty or certain types of occupations may limit access to quality health care,

may be associated with health behaviors that have a negative consequence on cardiovascular and cognitive health, or might be associated with an increased risk for toxic of environmental exposures. In an attempt to disentangle the effect of some of these factors, other measures of adult SEP were included in the model. Income, wealth, and lifetime occupation were also associated with cognitive function but caused only a small decrease in magnitude in the effect of education. This suggests that educational attainment has a strong direct effect on cognition independent of its correlation with higher SEP in adulthood. Income, wealth, and occupation were all significant predicators of cognitive performance indicating that these SEP markers, along with education, are not interchangeable with respect to their effect on cognitive functioning. Of these other measures of SEP, occupation had the largest impact on improved cognitive performance at age 65 and also contributing toward a more rapid decline with increasing age. This result has been found in another study examining the relationship between memory decline and occupation. [Stern et al., 1999] The synergistic effect of education and occupation suggests that these factors contribute separately toward reserve and capacity, but likely in similar ways. A better measure of the cognitive involvement or skill required for each occupation class would help to clarify the relationship between occupation and cognitive reserve.

Other demographic factors also contributed significantly to the differences in cognitive performance and rate of change. Male gender, later birth cohort, black race, and Hispanic ethnicity were all negatively associated with cognitive performance at age 65. The effect of gender was robust to controls for SEP measures while the effect of cohort increased almost 2-fold once these indicators were entered into the model. A

larger portion of the disparity in cognitive performance by race/ethnicity was explained by differences in educational attainment as well as to some extent by income, wealth, and occupation. However, significant differences remained in the full model especially between non-Hispanic whites and non-Hispanic blacks implying that additional factors might be able to explain the racial difference in cognitive performance. The rate of age-related decline was slightly faster for women and slower for later birth cohorts and blacks, but overall the effects were small and subgroups experienced nearly parallel trajectories of cognitive aging.

The magnitude of the association between education and cognition was similar for whites and blacks and for men and women when other measures SEP were used as controls. However, there was a differential effect of education across ethnicity and birth cohort. Education did not confer the same benefit for Hispanics as for whites and blacks. They experienced a 40% smaller return for each year of education which remained stable after adjustment for SEP measures. Perhaps nativity, country of education, or how many years residing in the United States may help to explain the differences in relationship between education and cognition between Hispanics and non-Hispanics. It should be noted that relative to the other groups, the sample size for Hispanics was quite small and may limit the potential for additionally stratified analyses.

The effect of birth cohort on age-related cognitive decline and on the education-cognition relationship warrants additional discussion and underscores the complexity in studying both age and cohort effects simultaneously. More recently born cohorts had lower cognitive performance scores at age 65 than older cohorts but appear to decline at a slower rate. Moreover, there was a significant interaction between birth cohort and

education that persisted after adjustment for SEP factors. Each year of education seems to provide less advantage to younger cohorts with the difference in score at age 65 between a respondent born in 1930 and one in 1940 being equivalent to nearly 6 years of education. This effect may be due to changes in the quantity and quality of education over time. Whereas more than a quarter of respondents born between 1890 and 1923 do not have above an 8th grade education, over 75% of respondents born after 1930 have a high school degree and 40% have at least some college education. Although it is commonly noted that there has been an increase in the quality of education over time with each subsequent cohort, it seems that these additional years are not contributing in the same way toward cognitive performance. Perhaps including other measures of education quality, such as literacy, would help to deconstruct the various components of education that may contribute to cognitive reserve or are related to innate ability and may help to elucidate the disparate effect of education by cohort. [Manly et al., 2003]

However, there are several alternate explanations for this finding. It is possible that the trajectory of cognitive change in memory performance is not linear as modeled here, but may be more curvilinear in shape with increasing decline with advancing age. Although the quadratic change model did not behave well with these data, it is very likely that this might be a more accurate way to represent age-related change in a multi-cohort sample. Clearly, the effects of age and cohort are closely related and the relationship of each with cognitive change will be clearer with longer follow-up times and additional waves of observations. Most studies have not benefited from the large sample size and longitudinal design of the HRS and many researchers have avoided addressing the potential for confounding between age and cohort by limiting analyses to restricted age

groups; however, the relative importance of education as a protective mechanism against cognitive decline might change with each successive cohort and understanding this evolution of effect will be important piece of the education-cognition association. At the very least, it is clear that gender and education are both highly correlated with birth cohort so results from models examining these effects separately are likely to be confounded.

Many factors have contributed to the conflicting and discordant findings across the body of research on education and cognition. The type of test used to measure cognitive performance is crucial since not all domains decline at the same rate. Additionally, other factors may bias results found in other studies toward finding slower decline and preservation of functioning among those with more education including practice effects, the non-random effect of attrition, and the way in which the relationship between performance and rate of change is treated by the statistical model that is employed. In these analyses, we tired to control for practice effects by using a time-varying covariate for retest. Since prior exposure to a cognitive test can improve a respondent's scores at the next test administration, it is important that these effects are accounted for in any model of longitudinal change with repeated test administration. Indeed, results from this study show that there is a differential effect of retest by gender, race, and cohort.

Results from this study may also have been affected by methodological limitations of the HRS. Although providing important information about performance and longitudinal change in cognitive performance, the HRS cognitive measures are limited in their dimensionality compared to the more extensive batteries used in clinical

studies. However, this is a limitation that is not uncommon to other large-scale multipurpose surveys. In this study we focused on the use of the immediate and delayed recall items since results from a factor analysis has shown these items to be highly related to an underlying memory factor. [Ofstedal et al., 2005]

A second important limitation is the potential effect of attrition on the sample that varies somewhat across waves. Although the HRS attempts to interview through use of a proxy when needed, and in later waves has tried to collect self-reported cognition data on those who are interviewed by proxy, not all respondents who are unwilling or unable to be interviewed are represented by proxy. Some respondents are lost to follow-up, some refuse, and others die between interview waves. Many reasons for attrition are related to education and cognitive impairment; those who are more cognitively impaired or have lower educational attainment are also less likely to participate in the study. [Rodgers et al., 2003] Attrition due to cognitive impairment may bias the sample toward a more cognitively intact group and away from seeing an effect of lower education on faster rates of decline if one existed if this group of respondents had a higher mortality risk. We have attempted to minimize the confounding effects of attrition by controlling for socioeconomic characteristics related to the selection bias but it is difficult to completely account for the differential selection due to attrition and mortality and these results may not be generalizable to older adults with moderate to severe impairment who never completed a self-interview at any wave. Adjustment for use of proxy at anytime during the study period and whether the respondent was deceased at the time of last contact with the household did not significantly affect any of the coefficient estimates.

Similarly, the use of respondent recall of education, income, wealth, and occupation data is not an ideal or objective data source since the quality of such information may vary by cognitive performance. However, because of the use of proxy informants where possible, this type of recall error should be minimal and would not result in a systematic bias in either direction.

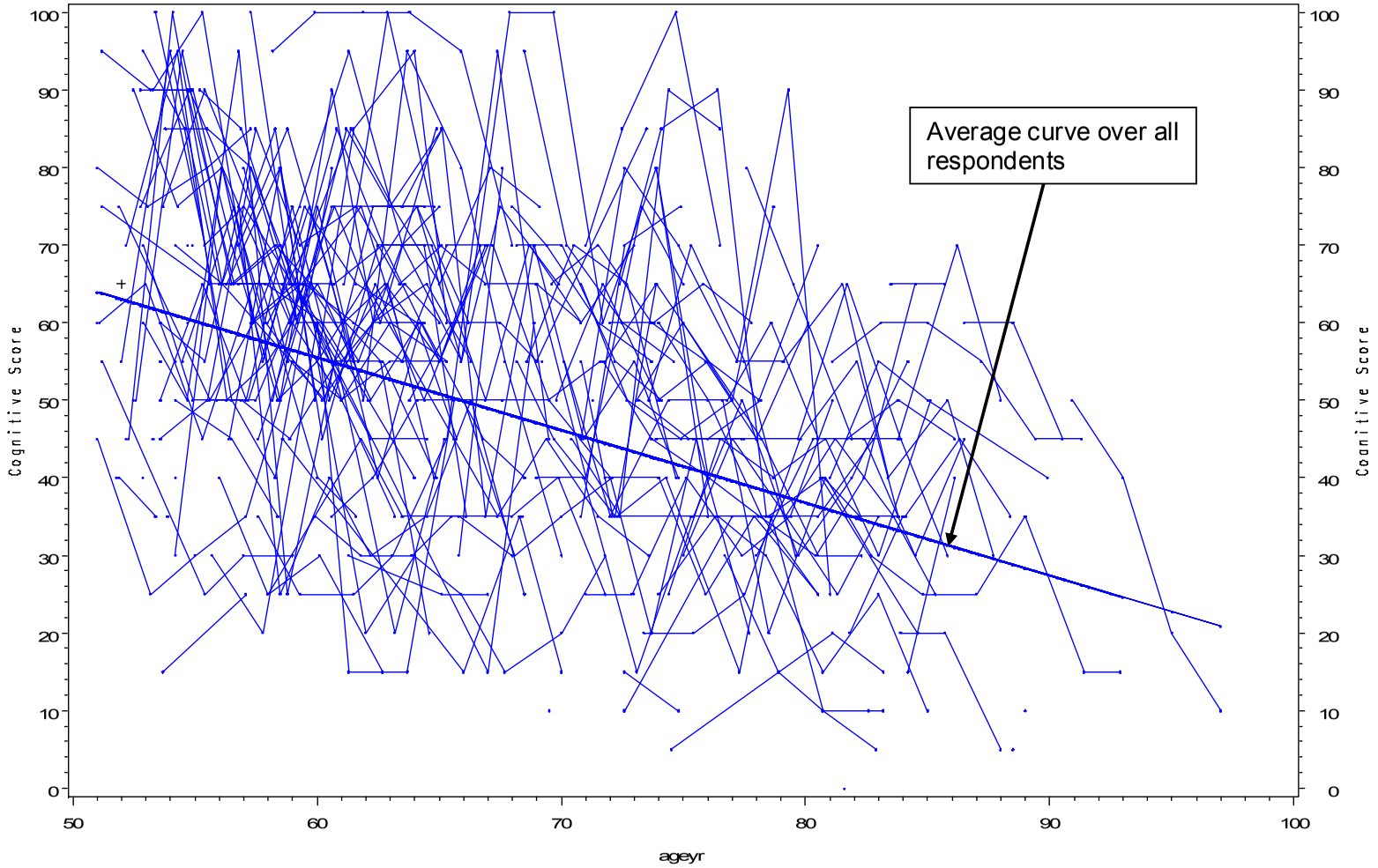
Lastly, the growth-curve approach used in these analyses did not incorporate sampling weights in the estimation of the models. The inability to use weights with the SAS PROC MIXED procedure carries a risk if sampling is informative (i.e. related to the outcome even after conditioning on covariates) or if the model is misspecified and has a non-linear functional form.

In spite of these limitations, this study extends previous research on education and cognitive change in several ways. Educational attainment, both the number of years and whether one graduated from high school, were important predictors of cognitive performance on memory tasks at age 65 as were gender, race/ethnicity, birth cohort, prior experience with the test, occupation, and household income and wealth. The rate of cognitive change varied by education (years and high school status), gender, race, cohort, and occupation. The effect of education was robust to adjusting for later life SEP factors indicating that it conferred an additional benefit on initial performance other than through its effect on SEP in adulthood. Additionally, the effect of education on initial cognitive performance did not vary by gender or race but differed largely by birth cohort and Hispanic ethnicity. There was also a differential effect of occupation on cognition for women and by cohort. After adjustment for education and other measures of SEP, significant differences in cognitive performance and rate change remained by gender,

race/ethnicity, and cohort which may in part reflect differences in the quality of education or lifetime mental stimulation though work or other activities. Additional research should explore other measures that better address the meaning of education in populations in which quality is variable and confounded by demographic factors as well as focusing on furthering the understanding of the effect of birth cohort on the education-cognition relationship.

The main strengths of these analyses are the extensive longitudinal data from the HRS and its large population-based sample. The nationally representative sample of the HRS provides greater geographic representation than prior epidemiologic studies of cognitive change and dementia, and greater generalizability to populations that might not normally be represented in clinical-based samples. The long follow-up period and representativeness of these data affords a unique opportunity to investigate trajectories of cognitive change and whether certain risk factors have an effect on these trajectories and outcomes in a meaningful population-based sample. It also provides a first step toward an examination of the effects of both age and cohort on change in cognitive functioning. Additionally, the use of growth curve modeling takes advantage of the complex longitudinal nature of the data and allowed us to make full use of data for all subjects with at least one valid cognitive test. These results add to previous research on education and cognitive function and change that have used cross-sectional data or longitudinal data with limited age or geographic representativeness.

Figure 2.1. Association of Age with Cognitive Function



* Individual curves represent a random sample of 150 respondents

Table 2.1. Descriptive Statistics by Gender and Race of Respondents Over Age 50 at Their Baseline Interview in the Health and Retirement Study[a]

	Total (n=17,875)	Men (n=7,771)	Women (n=10,104)	White (n=13,413)	Black (n=2,963)	Hispanic (n=1,499)
Mean age, yrs (SD)	64.10 (11.02)	62.23 (10.24)	65.53 (11.37)	64.74 (11.13)	62.77 (10.74)	61.00 (9.75)
Mean memory score at baseline[b], (SD)	50.53 (22.13)	50.00 (21.07)	50.94 (22.90)	52.94 (22.01)	42.39 (21.04)	45.00 (20.35)
Mean birth year, yr (SD)	1931.03 (12.35)	1933.08 (11.65)	1929.45 (12.65)	1930.31 (12.36)	1932.32 (12.18)	1934.87 (11.71)
Education, yrs (SD)	11.82 (3.46)	12.09 (3.61)	11.62 (3.32)	12.46 (2.92)	10.68 (3.64)	8.38 (4.69)
Education category (% distribution)						
Incomplete high school	31.98	29.76	33.69	24.54	48.94	65.11
Complete high school	32.07	29.30	34.19	35.11	26.16	16.54
Some college	18.56	18.92	18.28	20.10	15.05	11.67
College graduate	8.53	10.35	7.14	9.79	5.26	3.74
Post college	8.86	11.67	6.70	10.47	4.59	2.94
Mean household income, 1992 $ (SD)	38714.96 (58377.52)	48021.75 (63153.95)	31557.09 (53328.87)	43627.30 (64224.24)	23936.43 (28204.31)	23971.52 (35981.19)
Household income tertiles (% distribution)						
< $17,500	38.52	26.41	47.84	32.33	56.29	58.77
$17,500 - $44,999	34.36	37.00	32.33	36.11	29.63	28.09
≥ $ 45,000	27.12	36.60	19.82	31.56	14.07	13.14
Mean household wealth, 1992 $ (SD)	194104.54 (599580.48)	232046.33 (530577.05)	164923.45 (646180.95)	237134.76 (680605.36)	58916.98 (132245.47)	76290.27 (202280.78)
Household wealth tertiles (% distribution)						
< $50,000	39.21	33.99	43.22	30.05	67.87	64.51
$50,000 - $149,999	28.20	28.97	27.61	30.19	22.27	22.08
≥ $150,000	32.59	37.05	29.17	39.76	9.85	13.41
Occupation (% distribution)						
White collar	38.50	36.35	40.15	42.39	29.02	22.41
Blue collar	30.04	44.43	18.96	25.56	41.28	47.83
Homemaker	6.70	---	11.86	6.78	3.85	11.67
Unemployed / other	24.76	19.21	29.03	25.27	25.85	18.08
Mean number of waves tested, (SD)	3.95 (2.20)	3.80 (2.22)	4.06 (2.17)	4.03 (2.18)	3.72 (2.22)	3.68 (2.25)
Known deceased at last contact, (%)	24.88	25.03	24.76	24.96	28.11	17.75
Ever required a proxy interview, (%)	14.19	16.66	12.29	13.26	16.47	18.01

[a]Mean and standard deviation are presented for continuous variables; percentage is presented for categorical variables. Estimates are unweighted.

[b]Mean composite memory score ranges from 0 to 100

Table 2.2. Repeated Multivariate Analysis[a] of Change in Cognitive Function

	Model 1: Unconditional Means		Model 2: Unconditional Growth - Linear Rate of Change in Cognitive Function		Model 3: Rate of Change Adding Retest, Gender, Cohort and Race/Eth Effects		Model 4a: Education Effect		Model 4b: Adding High School and College		Model 5: Income and Wealth		Model 6: Occupation		Model 7: Education adjusted for SEP	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects																
Initial Status																
Intercept at Age 65	48.2538	0.1305	50.7658	0.1200	50.7493	0.2181	49.9529	0.2055	47.1532	0.3482	43.1364	0.3082	45.4476	0.4022	40.8495	0.4955
Control Variables																
Retest [b]					3.3560	0.1574	3.3647	0.1555	3.3652	0.1555	3.1964	0.1567	3.1309	0.1575	3.1046	0.1562
Gender					5.4186	0.2229	5.8216	0.2046	5.8144	0.2047	6.7218	0.2179	4.6929	0.2178	6.0974	0.2097
Cohort [c]					-4.6813	0.1839	-6.2867	0.1808	-6.3809	0.1807	-5.4242	0.1851	-5.9199	0.1901	-7.0097	0.1890
Race / Ethnicity																
Non-Hispanic White					---	---	---	---	---	---	---	---	---	---	---	---
Non-Hispanic Black					-11.1688	0.2977	-7.9417	0.2794	-7.5876	0.2806	-7.6845	0.3019	-9.6504	0.2906	-6.1367	0.2861
Hispanic					-10.3281	0.3966	-2.2671	0.3928	-2.1426	0.3966	-6.5909	0.3940	-8.1697	0.3889	-1.2916	0.3931
Main Effects																
Education [d]							1.8444	0.0340	1.4776	0.0590					1.2484	0.0593
High School									3.7448	0.3460					2.7116	0.3439
College									0.3000	0.3588					-0.5928	0.3591
Income																
Lowest Tertile											---	---			---	---
Middle Tertile											3.8049	0.2812			1.5192	0.2690
Highest Tertile											6.8286	0.3390			2.7585	0.3310
Wealth																
Lowest Tertile											---	---			---	---
Middle Tertile											3.0844	0.2835			1.7941	0.2673
Highest Tertile											5.5449	0.3033			2.9051	0.2899
Occupation																
White Collar													10.2141	0.4286	5.8335	0.4177
Blue Collar / Homemaker													2.9332	0.4266	3.5521	0.4065
Other													---	---	---	---
Rate of Change																
Age (slope per decade)			-9.4191	0.0909	-13.6901	0.2104	-13.8335	0.2063	-13.2116	0.3038	-12.7917	0.2839	-11.8308	0.3303	-11.3636	0.4125
Gender					-0.7832	0.1807	-0.8902	0.1724	-0.9228	0.1727	-0.7471	0.1805	-0.3171	0.1785	-0.7716	0.1771
Cohort					0.9485	0.0787	1.2432	0.0778	1.2577	0.0781	0.9160	0.0828	1.2111	0.0932	1.2929	0.0936
Race / Ethnicity																
Non-Hispanic White					---	---	---	---	---	---	---	---	---	---	---	---
Non-Hispanic Black					1.3942	0.2416	1.7257	0.2381	1.6085	0.2388	0.9535	0.2479	0.9034	0.2388	1.3179	0.2426
Hispanic					0.9820	0.3360	0.4974	0.3439	0.3433	0.3475	0.5556	0.3375	0.4174	0.3338	0.3052	0.3456
Education [d]							-0.2595	0.0267	-0.1863	0.0457					-0.1259	0.0457
High School									-0.7522	0.2775					-0.5739	0.2761
College									-0.2344	0.2960					-0.4294	0.2988
Income																
Lowest Tertile											---	---			---	---
Middle Tertile											-1.0515	0.2263			-0.6873	0.2227
Highest Tertile											-0.9970	0.2953			-0.3474	0.2967
Wealth																
Lowest Tertile											---	---			---	---
Middle Tertile											-0.3480	0.2206			-0.2876	0.2135
Highest Tertile											0.0895	0.2452			0.2203	0.2407
Occupation																
White Collar													-2.6550	0.3223	-1.7463	0.3182
Blue Collar / Homemaker													-1.9603	0.3033	-1.7390	0.2932
Other													---	---	---	---
Random Effects																
Variances																
Between Individuals																
In initial status	233.5500	3.2394	169.0700	2.8332	168.4700	3.9960	138.5300	3.6744	137.4300	3.6610	153.3800	3.8292	156.3500	3.8698	132.3100	3.6017
In rate of change			16.0932	1.6764	12.1096	1.5064	11.8834	1.3896	11.7084	1.3807	11.2992	1.4467	11.1261	1.4662	10.6241	1.3542
Retest variance					61.5840	3.4788	60.2572	3.4407	60.3029	3.4395	60.5895	3.4526	60.3679	3.4570	59.2007	3.4214
Within-person																
Residual errors	198.0900	1.2196	174.1500	1.1193	160.4200	1.1745	160.4700	1.1728	160.4700	1.1725	160.4900	1.1733	160.6400	1.1754	160.6100	1.1724
Total Variance	431.6400		359.3132		402.5836		371.1406		369.9113		385.7587		388.4840		362.7448	
Goodness of Fit																
-2LL	601823.3		590871.6		587373.7		584564.9		584439.7		585972.7		586254.6		583844.8	
AIC	601829.3		590883.6		587407.7		584602.9		584485.7		586022.7		586296.6		583914.8	
BIC	601852.6		590930.4		587540.1		584750.9		584664.9		586217.4		586460.2		584187.5	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using *N* =17,875 with D=70,527; shaded cells are not significant at p < 0.05

[b] Retest is dummy coded so that 0=Initial Testing, and 1=Retesting

[c] Birth Cohort is centered at 1930 and divided by 10 so change represents one decade

[d] Education (years) is centered at 12 years

Table 2.3. Repeated Multivariate Analysis[a] of Change in Cognitive Function with Cohort Interactions

	Model C1a: Education (years)		Model C1b: Adding High School and College		Model C2: Education adjusted for Income, Wealth and Occupation	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects						
Initial Status						
Intercept at Age 65	50.3525	0.2079	47.4321	0.4059	41.3673	0.5553
Main Effects						
Education [d]	2.0295	0.0415	1.6557	0.0729	1.3895	0.0736
Cohort X Education	-0.2977	0.0495	-0.2611	0.0911	-0.2335	0.0926
High School			4.1337	0.4383	2.9102	0.4375
Cohort X High School			-1.3670	0.5715	-1.1016	0.5749
College			-0.5455	0.4883	-1.6091	0.4913
Cohort X College			1.5144	0.5696	1.7128	0.5777
Income						
Lowest Tertile					---	---
Middle Tertile					1.4946	0.3426
Cohort X Middle Tertile					-0.3173	0.4324
Highest Tertile					3.2510	0.4388
Cohort X Highest Tertile					-0.4023	0.5286
Wealth						
Lowest Tertile					---	---
Middle Tertile					2.0229	0.3537
Cohort X Middle Tertile					-0.9757	0.4295
Highest Tertile					2.8244	0.3867
Cohort X Highest Tertile					-0.5491	0.4600
Occupation						
White Collar					5.9442	0.4436
Cohort X White Collar					-1.7016	0.5541
Blue Collar / Homemaker					3.0740	0.4229
Cohort X Blue Collar / Hmkr					-1.2916	0.5271
Other					---	---
Rate of Change						
Age						
Age (slope per decade)	-13.8772	0.2063	-12.7067	0.4567	-9.3667	0.6521
Education [d]						
Age X Education	-0.4129	0.0472	-0.2843	0.0853	-0.2303	0.0869
Cohort X Age X Education	0.1354	0.0204	0.1488	0.0376	0.1197	0.0378
High School						
Age X High School			-1.6938	0.5045	-1.4152	0.5079
Cohort X Age X High School			0.2386	0.2511	0.0523	0.2510
College						
Age X College			0.5302	0.5358	0.5120	0.5415
Cohort X Age X College			-0.6013	0.2519	-0.7180	0.2553
Income						
Age X Lowest Inc					---	---
Age X Middle Inc					-1.0229	0.3951
Gender X Age X Middle Inc					-0.1012	0.1960
Age X Highest Wlth					-0.6930	0.4795
Gender X Age X Highest Inc					0.2053	0.2637
Wealth						
Age X Lowest Wlth					---	---
Age X Middle Wlth					-1.1366	0.3965
Cohort X Age X Middle Wlth					0.01647	0.1862
Age X Highest Wlth					-0.3263	0.4249
Cohort X Age X Highest Wlth					-0.0678	0.2077
Occupation						
Age X White Collar					-2.8828	0.5147
Cohort X Age X White Collar					0.3602	0.2526
Age X Blue Collar / Hmk					-2.6355	0.4997
Cohort X Age X Blue Collar / Hmk					-0.1226	0.2205
Age X Other					---	---
Random Effects						
Variances						
Between Individuals						
In initial status	137.7100	3.6529	136.6900	3.6398	131.8800	3.5800
In rate of change	11.2030	1.3739	10.8840	1.3639	9.3898	1.3342
Retest variance	58.7763	3.4228	58.9193	3.4231	57.9808	3.4055
Within-person						
Residual errors	160.6500	1.1743	160.6500	1.1740	160.8700	1.1748
Total Variance	368.3393		367.1433		360.1206	
Goodness of Fit						
-2LL	584422.6		584283.7		583672.0	
AIC	584466.6		584343.7		583780.0	
BIC	584638.0		584577.4		583780.1	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=17,875 with D=70,527; all models are adjusted for retest, retest X cohort, gender, cohort, and race/ethnicity; shaded cells are not significant at $p < 0.05$

[b] Retest is dummy coded so that 0=Initial Testing, and 1=Retesting

[c] Birth Cohort is centered at 1930 and divided by 10 so change represents one decade

[d] Education (years) is centered at 12 years

Table 2.4. Repeated Multivariate Analysis[a] of Change in Cognitive Function with Gender Interactions

	Model S1a: Education (years)		Model S1b: Adding High School and College		Model S2: Education adjusted for Income, Wealth and Occupation	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects						
Initial Status						
Intercept at Age 65	50.7159	0.2314	48.1140	0.4896	40.8856	0.7713
Main Effects						
Education [d]	1.7491	0.0456	1.3779	0.0849	1.1386	0.0857
Gender X Education	0.2020	0.0621	0.2079	0.1138	0.2121	0.1152
High School			3.2042	0.5385	2.5448	0.5324
Gender X High School			0.8916	0.6993	0.1806	0.6966
College			1.2543	0.5052	0.2405	0.5136
Gender X College			-1.8105	0.7125	-1.4430	0.7154
Income						
Lowest Tertile					---	---
Middle Tertile					2.3954	0.4285
Gender X Middle Tertile					-1.6183	0.5518
Highest Tertile					4.2557	0.4966
Gender X Highest Tertile					-2.7445	0.6661
Wealth						
Lowest Tertile					---	---
Middle Tertile					1.1330	0.4026
Gender X Middle Tertile					1.2322	0.5344
Highest Tertile					1.8220	0.4261
Gender X Highest Tertile					2.0705	0.5698
Occupation						
White Collar					5.8994	0.6854
Gender X White Collar					-0.1306	0.8469
Blue Collar / Homemaker					3.8283	0.6532
Gender X Blue Collar / Hmkr					-0.5811	0.8149
Other					---	---
Rate of Change						
Age						
Age (slope per decade)	-13.6793	0.2090	-13.4504	0.4198	-10.8878	0.5983
Education [d]						
Age X Education	-0.2277	0.0378	-0.2087	0.0699	-0.1498	0.0708
Gender X Age X Education	-0.0749	0.0485	0.0067	0.0891	0.0232	0.0903
High School						
Age X High School			-0.3091	0.4606	-0.2364	0.4577
Gender X Age X High School			-0.7251	0.5748	-0.4517	0.5741
College						
Age X College			0.0951	0.4404	-0.4342	0.4525
Gender X Age X College			-0.4061	0.5918	0.0488	0.5995
Income						
Age X Lowest Inc					---	---
Age X Middle Inc					-1.3066	0.3666
Gender X Age X Middle Inc					1.1001	0.4606
Age X Highest Wlth					-0.9577	0.4527
Gender X Age X Highest Inc					1.1866	0.5912
Wealth						
Age X Lowest Wlth					---	---
Age X Middle Wlth					0.4267	0.3496
Gender X Age X Middle Wlth					-1.2552	0.4393
Age X Highest Wlth					0.8540	0.3781
Gender X Age X Highest Wlth					-1.3002	0.4835
Occupation						
Age X White Collar					-2.0383	0.5023
Gender X Age X White Collar					0.2854	0.5961
Age X Blue Collar / Hmkr					-2.5892	0.4733
Gender X Age X Blue Collar / Hmkr					1.4064	0.5577
Age X Other					---	---
Random Effects						
Variances						
Between Individuals						
In initial status	138.0900	3.6663	137.0200	3.6519	131.9900	3.5936
In rate of change	11.7515	1.3852	11.5694	1.3782	10.2939	1.3459
Retest variance	59.6462	3.4321	59.6617	3.4292	58.6716	3.4126
Within-person						
Residual errors	160.4800	1.1727	160.4700	1.1722	160.6000	1.1721
Total Variance						
Goodness of Fit						
-2LL	584503.9		584368.8		583746.8	
AIC	584547.9		584428.8		583854.8	
BIC	584719.3		584662.6		584275.5	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using *N* =17,875 with D=70,527; all models are adjusted for retest, retest X gender, gender, cohort, and race/ethnicity; shaded cells are not significant at $p < 0.05$

[b] Retest is dummy coded so that 0=Initial Testing, and 1=Retesting

[c] Birth Cohort is centered at 1930 and divided by 10 so change represents one decade

[d] Education (years) is centered at 12 years

Table 2.5. Repeated Multivariate Analysis[a] of Change in Cognitive Function with Race / Ethnicity Interactions

	Model R1a: Education (years)		Model R1b: Adding High School and College		Model R2: Education adjusted for Income, Wealth and Occupation	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects						
Initial Status						
Intercept at Age 65	50.1857	0.2124	47.8099	0.4143	41.4008	0.5990
Main Effects						
Education [d]	1.9190	0.0436	1.6722	0.0850	1.3738	0.0855
Black X Education	0.1837	0.0873	0.1342	0.1515	0.2239	0.1528
Hispanic X Education	-0.5969	0.0878	-0.7536	0.1472	-0.5968	0.1489
High School			3.3410	0.4383	2.4061	0.4346
Black X High School			-0.4009	0.8539	-0.2097	0.8500
Hispanic X High School			1.8635	1.1720	1.7838	1.1747
College			-0.5134	0.4458	-1.1237	0.4418
Black X College			0.7160	1.1091	0.0742	1.1152
Hispanic X College			0.6680	1.7054	1.2648	1.7064
Income						
Lowest Tertile					---	---
Middle Tertile					1.0681	0.3290
Black X Middle Tertile					1.7928	0.6865
Hispanic X Middle Tertile					0.4870	0.9327
Highest Tertile					2.4774	0.3781
Black X Highest Tertile					1.4276	0.9994
Hispanic X Highest Tertile					-1.4468	1.4707
Wealth						
Lowest Tertile					---	---
Middle Tertile					2.0499	0.3153
Black X Middle Tertile					-1.3056	0.7086
Hispanic X Middle Tertile					-0.9846	0.9354
Highest Tertile					3.0885	0.3234
Black X Highest Tertile					-1.4408	0.9770
Hispanic X Highest Tertile					0.3058	1.2443
Occupation						
White Collar					6.0320	0.5002
Black X White Collar					-0.9257	1.0420
Hispanic X White Collar					-1.2031	1.5681
Blue Collar / Homemaker					3.6286	0.5008
Black X Blue Collar / Hmkr					-0.0126	0.9448
Hispanic X Blue Collar / Hmkr					-0.9555	1.3427
Other					---	---
Rate of Change						
Age						
Age (slope per decade)	-13.7481	0.2075	-12.9562	0.3453	-11.2646	0.4701
Education [d]						
Age X Education	-0.2553	0.0332	-0.1804	0.0634	-0.1250	0.0636
Black X Age X Education	-0.1820	0.0667	-0.2540	0.1142	-0.1918	0.1159
Hispanic X Age X Education	0.01645	0.07285	-0.0975	0.1222	-0.1054	0.1237
High School						
Age X High School			-0.9549	0.3404	-0.7753	0.3378
Black X Age X High School			0.7316	0.7222	0.7550	0.7219
Hispanic X Age X High School			1.9492	1.0661	1.9593	1.0771
College						
Age X College			-0.2707	0.3528	-0.5040	0.3525
Black X Age X College			1.5539	0.9806	1.7228	0.9962
Hispanic X Age X College			-0.0246	1.5072	0.2362	1.5154
Income						
Age X Lowest Inc					---	---
Age X Middle Inc					-0.4530	0.2586
Black X Age X Middle Inc					-1.1512	0.6170
Hispanic X Age X Middle Inc					0.6385	0.8928
Age X Highest Wlth					-0.1656	0.3262
Black X Age X Highest Inc					-0.0926	0.9762
Hispanic X Age X Highest Inc					-1.4700	1.4347
Wealth						
Age X Lowest Wlth					---	---
Age X Middle Wlth					-0.1425	0.2448
Black X Age X Middle Wlth					-0.1116	0.6016
Hispanic X Age X Middle Wlth					-2.2906	0.8280
Age X Highest Wlth					0.3624	0.2626
Black X Age X Highest Wlth					-1.4561	0.8805
Hispanic X Age X Highest Wlth					0.0914	1.1717
Occupation						
Age X White Collar					-1.8404	0.3647
Black X Age X White Collar					0.2150	0.8126
Hispanic X Age X White Collar					0.9640	1.2598
Age X Blue Collar / Hmk					-1.9220	0.3482
Black X Age X Blue Collar / Hmk					0.5304	0.6765
Hispanic X Age X Blue Collar / Hmk					1.0129	0.9592
Age X Other					---	---
Random Effects						
Variances						
Between Individuals						
In initial status	137.9500	3.6674	137.0300	3.6559	131.9200	3.5969
In rate of change	11.7886	1.3876	11.5775	1.3788	10.3633	1.3520
Retest variance	59.6074	3.4331	59.7001	3.4320	58.4762	3.4130
Within-person						
Residual errors	160.4800	1.1728	160.4800	1.1724	160.5900	1.1723
Total Variance						
Goodness of Fit						
-2LL	584471.2		584348.2		583731.6	
AIC	584521.2		584422.2		583877.6	
BIC	584716.0		584710.5		584446.3	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using *N* =17,875 with D=70,527; all models are adjusted for retest, gender, cohort, and race/ethnicity, and race/ethnicity X retest; shaded cells are not significant at $p < 0.05$

[b] Retest is dummy coded so that 0=Initial Testing, and 1=Retesting

[c] Birth Cohort is centered at 1930 and divided by 10 so change represents one decade

[d] Education (years) is centered at 12 years

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CHAPTER 3

THE EFFECT OF CHILDHOOD SOCIOECONOMIC POSITION AND SOCIAL MOBILITY ON COGNITIVE FUNCTION AND CHANGE AMONG OLDER ADULTS

3.1 Abstract

Education and early-life conditions are related to cognitive development and cognitive function in adulthood. However, findings on the association between these factors and age-associated cognitive change have been conflicting and have often been examined in specific subpopulations of older adults or in samples limited to restricted geographic areas. This study aims to: 1) examine the relationship between measures of childhood socioeconomic position (SEP) and trajectories of cognitive function in later life within a nationally representative sample of adults over age 50 and investigate whether these effects are mediated by later life SEP, 2) determine whether cohort and gender-related differences exist, and 3) investigate the effect of social mobility on cognitive performance and change. Using longitudinal data from the Health and Retirement Study we examined the relationships between measures of SEP, cognitive performance, and rate of cognitive change using individual growth curve models. We found a large linear age-based decline in cognitive performance with a positive retest effect. Both gender and cohort were significant predictors of performance and age-related

change. After controlling for practice, gender, race/ethnicity, cohort, and death and proxy effects, parental education and father's occupation were significant predictors of cognitive performance at age 65 but had differential effects on rate of cognitive change. Childhood health status also uniquely contributed to better cognitive performance. However, these effects were greatly attenuated after adjusting for education and to a lesser extant by other measures of adult SEP. Significant cohort interactions were found suggesting that there are important differences between groups in the effect of SEP on cognitive performance and change. These findings emphasize the lasting impact of childhood SEP on cognitive trajectories among older adults but also suggest that upward mobility can partially compensate for disadvantage early in life but does not protect against cognitive decline.

3.2 Introduction

A large volume of research has demonstrated that socioeconomic status is strongly associated with inequalities in health. The association between educational attainment and other measures of socioeconomic position (SEP) and adult disease, including cognition, is firmly established. Adults with lower levels of education are usually found to perform poorer on neurological tests and have the highest risk of Alzheimer's disease and dementia. Similarly, low SEP is related to cognitive impairment and dementia in old age. [Holland et al., 1991; Katzman 1993; Koster et al., 2005] It is usually theorized that education is protective against cognitive decline or may modify the expression of cognitive decline and dementia through either biologic or behavioral pathways. [Katzman 1993; Stern et al., 1994] Similarly, higher socioeconomic status in

adulthood may confer health benefits through improved living and working conditions, access to health services, and differences in lifestyles and behavior. But, the relationship often found between education and other adult SEP measures and cognition could also in part be a reflection of exposures processes early in life.

Evidence shows that childhood socioeconomic factors influence cognitive development and abilities in children so it is plausible that the effects of these developmental advantages or disadvantages persist into middle and old age. [Roberts et al., 1999] If this is true, then measures of SEP in childhood should be related to cognitive status as an adult. Previous research supports this hypothesis suggesting that maternal and paternal education levels contribute to cognitive functioning in adulthood. [Kaplan et al., 2001] However, the contribution of childhood SEP to cognitive performance and rate of decline in later life independent of both level of education and adult socioeconomic status is not well characterized in an economically diverse population.

Recently, social epidemiologic research has established the importance of considering the accumulation of advantage and disadvantage in both childhood and adulthood when investigating the effect of SEP on health outcomes. [Ben-Shlomo et al., 2002; Kuh et al., 2003; Singh-Manoux et al., 2005] This type of lifecourse approach has been applied to research on how socioeconomic exposures across different life stages influence cognition in middle and late age; however, the results have been somewhat varied. Some studies have shown that cognitive functioning in adulthood is independently affected by early life circumstances suggesting that childhood SEP has a lasting effect on cognition beyond its impact on educational attainment and later SEP, while others found that childhood SEP has no direct effect on cognition but a substantial

indirect effect mediated though education and adult SEP. [Kaplan et al., 2001; Singh-Manoux et al., 2005; Turrell et al., 2002]

Researchers have also argued that a lifecourse approach is important to understanding social variations in health because it implies a continuing relationship between SEP and health such that poor circumstances at one life stage can be moderated by better circumstances earlier or later in life. [Graham 2002] Lifecourse research has demonstrated that disease in adulthood can be influenced by this type of socioeconomic mobility; however, very few studies have investigated the extent to which social mobility, both inter-generational and intra-generational, contributes to socioeconomic-related inequalities in cognitive performance and change. [Hart et al., 1998; Power et al., 2005] Although it is difficult to disentangle the lifecourse processes of cumulative exposure and social mobility, previous cross-sectional studies examining social mobility and cognition have found that the negative impact of disadvantaged SEP in childhood can be overcome by upward social mobility later in life. [Luo et al., 2005; Turrell et al., 2002] Of the few existing studies investigating the effects of childhood and adulthood SEP on cognition, most have been limited to cross-sectional analyses and to date, there are no studies investigating social mobility and cognitive change.

The primary goals of this study are (1) to determine whether there is a direct effect of childhood SEP on cognitive performance later in life or whether it is mediated entirely through education and measures of SEP in adulthood; (2) to evaluate whether there are gender or cohort differences in the effects of childhood SEP and education on cognitive performance and decline; and (3) to determine whether accumulation of

socioeconomic disadvantage and social mobility from childhood to adulthood affect cognitive function.

3.3 Methods

Study Population and Data

The sample for these analyses was drawn from the Health and Retirement Study (HRS) and Asset and Health Dynamics Among the Oldest Old Study (AHEAD), an ongoing longitudinal study of older adults now collectively referred to as the HRS. The HRS is a nationally representative, prospective panel funded by the National Institutes of Aging and conducted by the Institute for Social Research at the University of Michigan.

The study population includes over 20,000 community-dwelling adults over age 50 residing in the contiguous United States study with oversamples of African-Americans and Hispanics. A new cohort of respondents is added to the sample every six years to adjust to maintain the steady state design and to account for aging and attrition. Currently, the study is a combination of five cohorts: the AHEAD cohort of persons born between 1890 and 1923; the Children of the Depression Age (CODA) cohort of those born between 1924 and 1930; the original HRS cohort of those born between 1931 and 1941; the War Babies (WB) cohort of those born between 1942 and 1947; and the Early Baby Boomer (EBB) cohort of those born between 1948 and 1953, which was added in 2004. To date, seven waves of data have been collected from the HRS cohort; six waves from the AHEAD cohort; four from the CODA and WB cohorts; and one wave from the EBB cohort.

Interviews are conducted with sampled respondents and their spouses or partners every two years, including those respondents who have entered nursing homes.

Interviews began in 1992 for the original HRS cohort, in 1993 for the AHEAD cohort, and in 1998 for the CODA and War Babies cohort and in 2004 for the EBB cohort. Interviews were conducted by telephone for most respondents less than 80 years of age and face-to-face for persons 80 years of age or older and for baseline interviews. Interviews were conducted in both English and Spanish. Additional detail about the design of the HRS is available elsewhere. [Heeringa et al., 1995; Juster et al., 1995]

These analyses were limited to interviews with self respondents and cases with at least one interview with self-reported cognition data. Respondents at least 51 years of age who were not missing on baseline covariates and had at least one interview wave with a valid cognitive test were eligible for inclusion in the analyses. Since the HRS did not begin asking questions about early childhood exposures until 1998, respondents also had to have at least one interview subsequent to 1998 to be included in the analyses. One member of each household was randomly selected for inclusion in the final sample to avoid confounding from unmeasured household-level variables (N=12,972).

Assessment of Cognitive Function

For these analyses, performance on the episodic memory tasks at each wave was used as the cognitive functioning measure. These tasks were selected because they have been shown to be sensitive measures of cognitive change. [Small et al., 1999] For the episodic memory tests, respondents are asked to recall a list of 10 common nouns immediately after hearing them (immediate recall) and after approximately five minutes of additional test administration (delayed recall). Prior principal-components factor analyses showed that these recall tasks loaded on a single factor so scores on these tests were combined to create a composite score. [Ofstedal et al., 2005] The composite score

was calculated using the unweighted average of the immediate and delayed recall tasks and was then normalized to a score range of 0 to 100. Respondents who refused at the beginning of the test were assigned a zero on that portion of the test while respondents who refused during the test were given the score they had obtained up until that point. For most of the interview waves the 10-noun recall tests were administered; however, the verbal recall tests in the 1992 and 1994 interviews with the original HRS cohort consisted of a list of 20 common nouns rather than 10. The distributions of scores on the 20-item tests are highly skewed with less than 5% scoring more than 10 on either test. Scores from these waves were rescaled so that a score of 10 or above was considered perfect to make these scores comparable to waves using the 10-item lists. This approach has been used in previous analyses from the HRS. [McArdle et al., 2007]

Measurement of Socioeconomic Position

Childhood SEP - SEP in childhood was examined using four items: 1) paternal and 2) maternal educational attainment, 3) self-reported financial status when the respondent was a child, and 4) father's occupation. Because of differences in question administration over time, parental education was coded as a dichotomous variable indicating whether the parents had ≥ 8 years of education. Family financial status was coded using a four-point response scale from "well-off" to "poor," in response to the question, "How would you describe your family's financial situation when you were a child?" For these analyses respondents in the lowest two categories were combined. Father's occupation was coded on the basis of respondent reports of father's primary occupation. Occupation was classified as white collar (professionals, managers, salesmen, clerical and service industries) or blue collar (operators, craftsmen, farmers)

and unemployed/other. Primary occupation was assigned using the occupation code according to the 1980 US Census guidelines. Respondents who reported they did not live with their father were excluded from the analyses.

Childhood health – Self-rated childhood health was originally coded using a five-point Likert response format ranging from "excellent" to "poor." Preliminary analyses showed that respondents in the two lowest childhood health categories had similar characteristics and average performance on the cognitive tests, thus they were combined into one group representing those in fair or poor health as a child.

Measurement of adult SEP- Socioeconomic position in adulthood was measured using respondent's education, occupation, and income and wealth at baseline. Education was measured in years with a maximum of 17. For these analyses, education was coded as [Years of education -12] to be approximately centered. In addition, education was also represented by two dummy variables indicating whether the respondent graduated from high school or achieved a GED and whether they graduated from college. The income measure used was reported household income at first interview. This figure was adjusted for inflation using the Consumer Price Index (CPI) calculated by the Bureau of Labor Statistics and normalized to 1992 dollars. Household wealth was chosen in addition to household income as a supplemental measure of adult economic circumstances. Wealth was measured using an assets-less-debts approach by subtracting debt from the sum of total assets as reported at the baseline interview - items such as value of the home, checking and savings accounts, individual retirement accounts, certificates of deposit, bonds, and shares of stocks or mutual funds. For comparability, wealth was also normalized to 1992 dollars. Income and wealth data were drawn from the RAND HRS

data files - version F which includes summary measures and imputed values for income and wealth compiled from an extensive battery of HRS questions. [St.Clair et al., 2006]

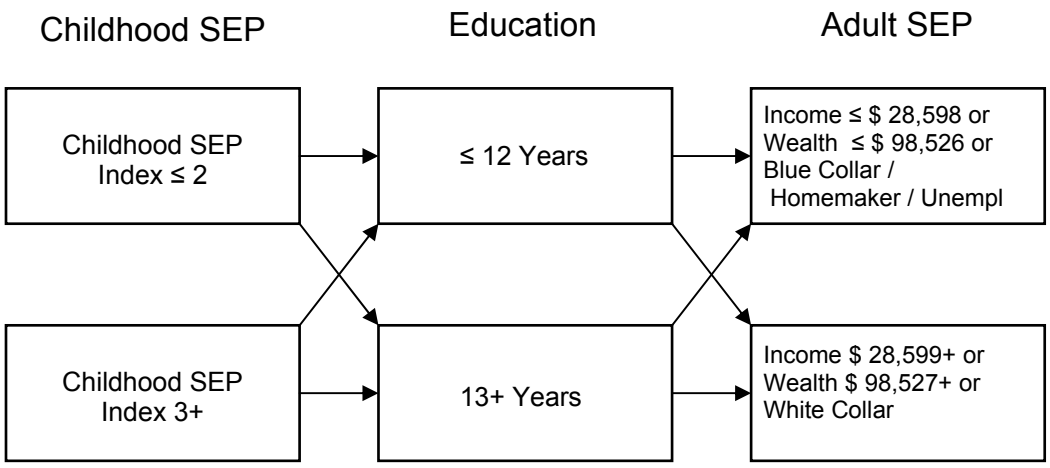
Primary occupation was assigned using the occupation code (according to the 1980 US Census guidelines) for the job with the longest reported tenure (also available in the RAND HRS data files - version F). For cases in which no job with the longest tenure was identified, the occupation code for the current job was assigned. Occupation was classified as a dichotomous variable representing either white collar occupations (professionals, managers, salesmen, clerical and service industries) or the combination of blue collar occupations (operators, craftsmen, farmers), homemakers, and unemployed/other. Homemakers were identified as women whose employment history comprised less than half of their adult life, were currently not working, and self-identified as housewives.

Lifecourse Socioeconomic Mobility

SEP mobility patterns – The availability of socioeconomic position at childhood, young adulthood, and older age enabled us to investigate of the influence of social mobility on cognitive function. In order to create distinct groups defined by patterns of social mobility, childhood socioeconomic measures were first summed to form an index. The index summed measures of maternal and paternal educational attainment (< 8 yrs, $\geq$ 8 years of education), father's occupation (blue collar, white collar), and a dummy variable representing whether the family financial well-being was average/well vs. varied/poor. This index was then dichotomized at the median. Other lifecourse measures were also dichotomized at the median to create two categories of education ($\leq$12 years, 13+ years), baseline household income, and wealth.

Eight SEP mobility trajectories were created by cross classifying the 2-level childhood socioeconomic position variable with respondent's education and either income, wealth, or white collar occupation as represented in Figure 3.1. This measure reflected the respondent's socioeconomic trajectory from childhood, through early adulthood, to mid and later life.

Figure 3.1. A lifecourse model with measurement of socioeconomic position at three periods in life resulting in eight possible trajectories [Adapted from Hallqvist et al., 2004]



Covariates

Practice effects - To control for practice effects from repeated administration of cognitive tests, a dummy variable was included in the models to represent prior exposure to the cognitive test. Respondents were assigned a zero at their baseline wave of cognitive testing and a value of 1 at each subsequent test. This variable represents the average increase in test score between the baseline and first follow-up interview wave.

Race and ethnicity – Respondents were classified into 1 of 3 categories: non-Hispanic white/other, non-Hispanic black, and Hispanic. Respondents who reported both African-American race and Hispanic ethnicity were assigned to the Hispanic group.

Age and Cohort – Age was coded as [Age at interview-65] / 10 to be approximately centered. Thus, the coefficient for age represents the average cognitive performance at age 65 and the average effect on cognitive change with each decade. Similarly, birth cohort was coded as [Birth Year-1930] / 10.

Death and Proxy Status – Two dummy variables were created to help account for differential attrition due to death and loss to follow-up. One variable represented whether the respondent was deceased at the time of last contact with the household. The other represented whether the respondent ever required the use of a proxy during interviewing.

Statistical Methods

We examined the effect of lifecourse SEP on change in cognitive function using a series of mixed models with random effects. [Laird et al., 1982] Similar to standard fixed-effect repeated-measures models, we estimated the overall rate of change of the group conditional on covariates. Unlike these models, the further addition of random effects incorporates individual differences from the overall pattern of the group. Individuals are assumed to follow the mean path of the group except for random effects, which cause the initial level of cognitive performance to be higher or lower and the rate of change to be faster or slower, as described in more detail elsewhere. [Wilson et al., 2002] This approach accommodates unbalanced data structures, both in terms of number of testing occasions and differences in intervals between assessments, and enables full use of data for all respondents with at least one valid cognitive score. Thus, all respondents contribute to the intercept term, whereas respondents with at least two valid cognitive tests contribute to the slope term. In addition, baseline level of cognition is

explicitly modeled as a source of random variability and a possible correlate of how rapidly cognition changes over time

Initially, graphical methods were used to explore patterns of cognitive performance by age. Longitudinal changes in cognitive performance were then estimated using mixed models (PROC MIXED, SAS software, Version 9.1: SAS Institute Inc., Cary, NC) without adjustment for sampling weights. The models were estimated using the full-information maximum likelihood estimation with an unstructured covariance matrix for the random effects and included all data available (N=12,972, D=57,399). Cognitive function was first modeled solely as function of age, allowing random effects for both the intercept and age-based change.

An individual growth model in which change in cognitive score is a linear function of age is represented by the level-1 submodel shown below:

$$COG_{ij} = \pi_{0i} + \pi_{1i} [(AGE_{ij} - 65)/10] + \varepsilon_{ij}$$

where COG_{ij} is the cognition score for person i at time j and AGE_{ij} is the wave-specific age. In this model the intercept (π_{0i}) represents the value of i's cognition score at age 65 years (because age is centered) and the slope term (π_{1i}) is the rate of change in cognitive score per decade. This model assumes that a straight line adequately represents each person's true change over time and that any deviation from linearity observed in the sample data result from random error (ε_{ij}).

The level-2 submodels are shown below:

$$\pi_{0i} = \gamma_{00} + \gamma_{01}VAR + \zeta_{01}$$

$$\pi_{1i} = \gamma_{10} + \gamma_{11}VAR + \zeta_{11}$$

These models treat the intercept (π_{0i}) and the slope (π_{1i}) of an individual's growth trajectory as level-2 outcome that may be associated with predictor variables (VAR). Each component also has its own residual (ζ_{01} and ζ_{11}) that allows the level-1 growth parameters to vary across individuals.

For these analyses we compared three progressively more complex models: linear, quadratic and cubic polynomials on age. In addition, two-part linear spline models with knots at 65 and 70 years were estimated in an effort to best model the pattern of cognitive change with age. Fit was evaluated by comparing the log likelihood value and Bayesian information criterion (BIC) between models. For the sample as a whole, change in cognitive performance was found to be best described by a linear function. Next, models that included demographic variables and the effects of retest, death, and proxy status were considered. For these models random effects were allowed for the intercept, slope, and retest-effect.

To this base model, we then examined the main effect as well as the interaction of each childhood SEP variable with age to test the degree to which each was associated with the absolute difference in cognitive function scores at age 65 as well as to test the effect of childhood SEP variables on the rate of change in cognitive function. Childhood SEP variables were first examined separately, and then simultaneously. We then reestimated the effects of the childhood variables on cognitive function and change in a series of models that included terms for years of education and variables for high-school and college graduation status. These models tested the degree to which the effects of childhood SEP were associated with cognitive function independent of the respondents' own educational attainment. We conducted similar analyses to assess whether the

relation of childhood SEP to cognitive performance and decline was mediated by the respondents' household income, wealth, or occupation. Finally, to examine whether the effects of early-life SEP were consistent across demographic subgroups, we fit additional models with the inclusion of interaction terms between childhood SEP and gender as well as childhood SEP and cohort.

The effect of social mobility on cognitive performance and change was examined by comparing separate models for each trajectory group; first by fitting an unconditional growth model then another model adjusting for the effects of retest, gender, cohort, race/ethnicity, death and proxy status.

3.4 Results

Of the 16,735 respondents who had at least one valid cognitive test score and had complete childhood SEP data, one respondent per household was selected for inclusion in the analyses. Table 3.1 presents the socioeconomic and demographic characteristics of the sample as well as the mean and standard deviation for the cognitive test at baseline. On average, respondents were age 63 years at baseline with an average birth year of 1932. Respondents had completed an average of 12.3 years of schooling with more than 40% attending some college. Almost 80% of the sample was white with non-Hispanic blacks and Hispanics respectively making up 12.76% and 7.85% of the sample. Women made up 55.8%, had completed fewer years of education, had lower household income and wealth, and reported lower childhood socioeconomic status in childhood than men. Respondents completed an average of 4.4 interview waves by the last data collection used in these analyses collected in 2004. The mean baseline memory score was 53.4 (SD, 21.51) points out of a possible score of 100.

The results of the multivariate analysis of change in cognitive function are shown in Table 3.2. We first estimated the amount of between- and within-person variance by estimating models that allowed random effects only for the intercept with no parameter for change over time (Model 1: Unconditional Means model). About half of the total variation in cognitive function was attributable to differences between persons (51.2%); however, there was a non-ignorable amount of variation within persons. Model 2 represents the linear age-based model, or unconditional growth model, which was ultimately the best fitting model for change in memory function over time. The linear model yielded both a significant time-constant intercept (mean performance at age 65) and age-dependent slope parameter representing decreases in means with each decade of age. Comparison of the residual variance between the unconditional means and growth model showed that nearly 13% of the within-person variation was associated with linear time indicating that other time-varying predictors (such as retest) might be needed to improve the fit.

To account for sources of variability, gender, birth cohort, race/ethnicity, death and proxy status were added to the linear growth model (Model 3). A time-dependent measure for retest was also added to the model to account for practice effects. Comparison of between-person variances and pseudo-R^2 statistics suggested that while the addition of covariates to this model did not affect the variance in initial status, these covariates accounted for an additional 45% of the variance in the rate of change and significantly improved the fit compared to the unconditional growth model.

Effect of Childhood SEP

The effect of early life conditions on cognitive function are presented in models 4a – 4d (Table 3.2). The top portion of the table shows the coefficients from the random-effects regression models demonstrating the fixed effects of childhood SEP on the absolute level of cognitive function after the effects of the demographic control variables were considered. Higher maternal education (8 or more years) was associated with a 3.24 point increase in the mean score at age 65, whereas higher paternal education was associated with a 2.33 point increase. However, having a father with a white-collar occupation was associated with a 4.11 point increase in score. In addition, both childhood SES and health were significantly associated with higher cognitive performance.

The lower half of the table presents the coefficients from the longitudinal part of the model assessing whether childhood SEP is associated with change in cognitive function over time. The interactions between time and maternal education, childhood SES, and father's occupation were nonsignificant, whereas the interactions with father's education and childhood health were significant. Both of these factors were inversely associated with change in cognitive function over time.

In Model 5 the variables for childhood SEP were simultaneously entered into the model. In this model, the effect of childhood SES on cognitive performance at age 65 was no longer significant and only paternal education remained a significant predictor of change in function over time.

Influence of Respondents' Education and Adult SEP

Table 3.3 presents the coefficients from the models that examined whether respondents' education or adult SEP mediated the observed relationship between childhood SEP and cognitive function. Including education as a covariate, represented both as years of education and highest degree achieved, decreased the coefficients for the effect of childhood SEP on cognitive functioning at age 65 by 45 to 75 percent, although with the exception of paternal education, these effects remained statistically significant. The effect of childhood SES became negative and significant once adjusted for respondents' education suggesting that increased childhood SES may have a deleterious effect on cognition education is included in the model. The interaction between time and paternal education became insignificant once the education variables were added to the model.

Models 7 – 9 present the effects of childhood SEP on cognition adjusted for respondents' household income and wealth at baseline, and main occupation in adulthood. As with education, including these variables as covariates weakened the effect of childhood SEP on cognitive performance and the effect of paternal education on cognitive change, although not to the extent of adjusting for education in the model. Model 10 shows the results when all childhood and adult SEP variables were mutually adjusted. In this model, with the exception of paternal education, measures of childhood SEP had a statistically independent effects on the level of cognitive function at age 65. In contrast, change in cognitive function with age was associated only with later-life measures of SEP including respondents' education, household income, and occupation.

Interactions with Demographic Variables

There were no significant interactions between childhood SEP and sex with or without adjustment for education and measures of adult SEP, indicating that the effect of childhood SEP on cognitive function does not differ significantly between men and women (results not shown). However, there were significant interactions between cohort and paternal education and cohort and childhood health on cognitive performance at age 65 suggesting that later born cohorts benefit less from higher levels of paternal education but slightly more from better health in early life (Table 3.4).

Social Mobility and Cognitive Function

Table 3.5 shows the unadjusted and age- and demographic-adjusted mean cognitive scores for the eight mobility trajectories from childhood to adulthood. The table shows a well-defined and graded pattern to the results with those in the stable low group, low SEP throughout childhood and adulthood, having the worst cognitive performance at age 65, while those in the stable high group obtained the highest scores. Respondents with low status in childhood who achieved an above median level of education and adult SEP had better cognitive performance at age 65 than respondents with a similar childhood background and less upward mobility. Conversely, respondents with a high childhood SEP but who then experienced downward mobility in adulthood had worse cognitive performance at age 65 than every other group with the exception of those in the stable low group. While the pattern in the coefficients for cognitive change is not as clear, change appears to be inversely related to social mobility with the stable high and more upwardly mobile groups experiencing faster decline with age than those in

the stable low or downwardly mobile groups. Consistent results were found regardless of whether household income, wealth, or occupation was used as the adult SEP measure.

3.5 Discussion

Using longitudinal data from the Health and Retirement Study, we assessed the hypotheses that indicators of childhood SEP would be associated with cognitive performance and change in middle and older age, that measures of adult SEP would be mediators of this relationship, and that social mobility from childhood to adulthood would be related to cognitive performance and change.

The first of these hypotheses was confirmed with all measures of childhood SEP, including both parents' education, father's occupation, childhood SES, and childhood health found to be related to the absolute level of performance on memory-related cognitive tasks at age 65. Additionally, father's education and childhood health were associated with cognitive change, although both inversely. However, in models adjusted for all measures of childhood SEP simultaneously, only father's education remained predictive of cognitive change and childhood SES no longer remained a significant effect on cognitive function at age 65.

The second hypothesis, that adult SEP mediated the relationship between childhood SEP and cognitive performance in older age, was also supported. Respondents' education and occupation, and household income and wealth, all mediated the effect of childhood SEP on cognitive performance, and more importantly on cognitive change. Educational attainment had a much stronger attenuating effect than the measures of adult SEP. These findings suggest that education specifically, more than material resources or social class, mediates the association between early life SEP and cognitive-

related outcomes. The independent and differential effects of education and the measures of adult SEP illustrates that although these constructs are related and are widely used interchangeably, they represent aspects of distinct socioeconomic domains that affect health inequalities through different mechanisms. Given the strong relationship between education and cognition it is not surprising that educational attainment has the most potent mediating effect on the relationship between childhood SEP and cognitive performance; although, this strong mediating relationship has also been found in studies on the childhood SEP on adult smoking and drinking, obesity, and cardiovascular disease. [Lawlor et al., 2006] However, several measures of childhood SEP including maternal education, childhood SES, father's occupation, and childhood health, had a lasting effect on memory test performance independent of the impact of the more determinative effects of education and SEP in adulthood. This provides additional evidence that early life circumstances are important influences in shaping adult cognitive health.

In contrast, our findings do not support the hypothesis that advantageous conditions in early life, as defined by better childhood health, higher parental education, or higher socioeconomic status, are associated with less rapid decline in cognitive function in older age. The lack of association between early life conditions and cognitive change has been found elsewhere in analyses using measures of memory, perceptual speed, and global cognitive function. [Everson-Rose et al., 2003] Although the specific mechanisms linking childhood SEP and cognition in older age are unclear, especially with regard to its effect on cognitive change, we would caution against interpreting these results as evidence that childhood SEP is unimportant in relation to adult cognitive

functioning. While it is possible that the functional changes in the brain that lead to cognitive decline are unrelated to early life socioeconomic factors, it is more likely that childhood SEP influences cognitive change through its effects on downstream circumstances and experiences in adulthood. Adjustment for indicators of adult SEP could be viewed as over-adjustment for socioeconomic factors in the pathway between childhood and adulthood. The attenuation of the impact of early life factors on cognition after adjustment for education and adult SEP, merely implies that later-life factors are more closely aligned with adult cognitive functioning. In addition, since this study focuses only on memory-based cognitive performance, the possibility that childhood SEP may be more strongly related to other cognitive measures cannot be ruled out.

While we hypothesized that the effects of childhood circumstances, specifically maternal and paternal education, would have differential effects on cognitive ability by gender, we found no evidence that gender interacts with childhood SEP to affect adult cognitive functioning. Although additional data are required to fully address the differences between cohorts, these results suggest that studying individuals born across several decades is important because the effects of childhood SEP on cognitive outcomes vary over time. [Davey Smith et al., 2004] Children in the lowest socioeconomic groups born in more recent decades, particularly after World War II, will have experienced better standards of living than those born earlier. [Lawlor et al., 2006] If associations in earlier born cohorts represent the effects of more extreme circumstance, then one would expect a weaker association between childhood SEP and cognition in studies of populations born more recently. The results from this study support this theory in part in that respondents from later born cohorts benefited less from higher paternal education than those born

earlier; however, they realized a slightly greater advantage from better childhood health.

The results of the mobility analysis further demonstrate that socioeconomic mobility over the lifecourse has important consequences for cognitive health. Respondents with disadvantaged circumstances in childhood who then achieved higher education and socioeconomic position in adulthood performed better on the cognitive tasks than those with similar childhood backgrounds who remained in the lower SEP groups at each lifecourse stage. These results suggest that upward mobility can partially compensate for disadvantage early in life. However, downward socioeconomic mobility had similar, but negative, consequences for cognitive performance suggesting that the benefits of higher SEP in childhood can be diluted by lack of educational attainment and subsequent downward mobility over the lifecourse. In contrast, consistently high SEP across the lifecourse and upward mobility were not protective against cognitive decline. In fact, respondents in the stable high and upwardly mobile groups experienced faster rates of decline that those in the stable low or downwardly mobile groups

Interestingly, these results on the effect of mobility on cognitive performance and change were consistent whether household income, wealth, or occupation was used as the marker of adult SEP. Although results from this study and pervious studies have showed that these factors have independent effects on cognitive performance later in life, they served as interchangeable proxies for socioeconomic position in adulthood for this portion of the analyses. However, the definition of the SEP groups was broad (below and above a median level) so it is not surprising that categorization by these factors would be similar given that income, wealth, and occupation are highly correlated.

How childhood socioeconomic conditions affect level of cognition in older age is unclear. The lifecourse approach posits that lower SES and deprivation early in life may have an independent effect on later life cognitive outcomes through a variety of mechanisms. [Kuh et al., 2003; Kuh et al., 2004] Childhood deprivation may 1) cause biological changes in childhood that continue to have a lasting effect into adulthood such as decreased cortical thickness, less dendritic branching, and reduced neuronal communication, 2) have an effect by tracking of low SES into adulthood which could in turn result in poor adult heath, or 3) may be the first risk factor in a lifelong accumulation of risk. [Guralnik et al., 2006] Given that the time from exposure to outcome is 50 years or more, a number of childhood or adult social, behavioral, or biological factors may have contributed to patterns of adult cognitive functioning. However, it seems clear that cognition is sensitive to the environment and influences of early life.

The conclusions of this study are strengthened by a number of factors. The large size and representativeness of the HRS enabled us to examine multiple influences on cognitive performance and change across the lifecourse in a diverse economic population. The nationally representative sample of the HRS provides greater geographic representation than prior epidemiologic studies of cognitive change and dementia, and greater generalizability to populations that might not normally be represented in clinical-based samples. The longitudinal nature of these data consisting of repeated measures of the same cognitive test battery affords a unique opportunity to investigate trajectories of cognitive change and whether certain risk factors have an effect on these trajectories and outcomes in a meaningful population-based sample. Additionally, the use of growth

curve modeling takes advantage of the complex longitudinal nature of the data and allowed us to make full use of data for all subjects with at least one valid cognitive test.

Although causality between lifecourse SEP and cognitive function in older age is implicit in the interpretation of these results, it is also possible that the association of SEP and cognition could be non-causal, arising because healthy individuals with better cognitive functioning are more likely to achieve higher education and social standing later in life. This type of selection effect theory suggests that individuals with better health or advantage early in life are more likely to achieve higher status and select into better occupations than individuals without these advantages. [Osler et al., 2007] It is possible that selection in this manner could produce the pattern of results presented in this paper. Obtaining measures of early-life cognitive performance would help to disentangle the causal and reverse-causal explanations of these results and would allow for a better picture of the relationship between SEP and cognitive functioning across the lifecourse. Moreover, collecting more specific or objective measures of SEP in childhood might also help to elucidate the social and biological mechanisms that link socioeconomic position at each lifecourse stage with cognitive function in adulthood.

A limitation to this study is the use of retrospective reports on parental education and occupation and other early-life circumstances. Although, recall of childhood health and family financial situation in childhood may be influenced by circumstances of adult health and socioeconomic status, it is less clear why respondent recall of parents' education and occupation would be subject to systematic bias. Additionally, if a recall bias was present, it is unlikely that it would produce the pattern of results observed here. It is also possible that the effects of adverse social circumstances in early childhood may

have manifested prior to the initiation of the HRS. Specifically, disadvantaged persons may have died prior to being eligible for inclusion in the study at mid-life and thus may be underrepresented in this sample.

Although the longitudinal design of this study, with an average of 4 waves of follow-up representing up to 12 years, is a significant strength, it is possible that the follow-up period was not long enough to establish the proposed relationship between childhood SEP and cognitive change. Additionally, although the data suggest there might be important differences by birth cohort, with these data it is not possible to come to definite conclusions about the potential moderating effect of birth cohort on the relationship between childhood SEP and cognition until there is more overlap in data collection at given ages across cohorts.

Additionally, the growth-curve approach used in these analyses did not incorporate sampling weights in the estimation of the models. The inability to adjust using sampling weights with the SAS PROC MIXED procedure makes the models more sensitive to model misspecification. There is a risk of this if either the sampling is informative (i.e. related to the outcome even after conditioning on covariates) or if the functional form of model is misspecified and has a quadratic rather than linear trend.

Despite these limitations, this research provides evidence that socioeconomic conditions early in life contribute to absolute levels of memory-based cognitive function in older age but are not protective of cognitive decline. Educational attainment resulted in greater attenuation of these associations, with later life SEP having a less marked mediating effect. While the present results suggest a lasting influence of childhood socioeconomic status on adult cognitive performance, it appears that low cognitive ability

is not an inevitable outcome of low socioeconomic status. The social mobility findings suggest that improved SEP in later stages of life is associated with higher cognitive performance as an older adult.

These results have implications for the effects of residual confounding on potential links between indicators of socioeconomic position and cognition. We have shown that memory-based cognitive functioning is influenced by childhood SEP, education, income and wealth, and occupation. Thus, when studies aim to determine the association between an exposure and cognition or cognition and an outcome adjusted for socioeconomic position, they may underestimate confounding by lifecourse socioeconomic factors if they only adjust for a single measure of socioeconomic position or measures from one stage of life.

The importance of this study lies in the measurement of socioeconomic position of over the lifecourse and the implementation of analytical techniques that take advantage of the longitudinal design of the data. Adopting a lifecourse perspective underscores the need to think about adult health in a larger context, one that transcends time as well as space and considers the positive and negative exposures that amass throughout a lifetime. However, a more thorough understanding of the pathways between childhood SEP and later life cognitive performance and change will require better and more specific measures of the childhood socioeconomic environment as well as a longer follow-up time. However, consistent with much of the previous research on the effects of childhood SEP on cognition in older age, the results presented here suggest that, in addition to the impact on adult SEP, cognitive performance in adulthood may also have origins early in

life and that upward social mobility may ameliorate the effects of childhood disadvantage.

Table 3.1. Descriptive Statistics of Respondents Over Age 50 at their Baseline Interview in the Health and Retirement Study

	Total (n=12,972)
Mean age, yrs (SD)	63.05 (10.43)
Mean memory score at baseline[b], (SD)	53.42 (21.51)
Mean birth year, yr (SD)	1932.25 (11.87)
Race / Ethnicity (% distribution)	
Non-Hispanic White / Other	79.39
Non-Hispanic Black	12.76
Hispanic	7.85
Childhood SEP	
Mother's education ≥ 8 yrs (%)	70.73
Father's education ≥ 8 yrs (%)	65.23
Financial status in childhood (% distribution)	
Well	6.86
Average	62.89
Poor / Varied	30.25
Father white collar job (%)	20.81
Childhood self-rated health (1-4), (SD)	3.21 (0.94)
Education, yrs (SD)	12.33 (3.30)
Education category (% distribution)	
Incomplete high school	25.29
Complete high school	32.91
Some college	20.70
College graduate	10.09
Post college	11.02
Mean household income, 1992 $ (SD)	44362.91 (66810.77)
Mean household wealth, 1992 $ (SD)	223933.67 (473996.74)
White collar occupation (%)	44.62
Mean number of waves tested, (SD)	4.42 (2.12)
Known deceased at last contact (%)	17.33
Ever required a proxy interview (%)	14.45

[a]Mean and standard deviation are presented for continuous variables; percentage is presented for categorical variables. Estimates are unweighted.

[b]Mean composite memory score ranges from 0 to 100

Table 3.2. Repeated Multivariate Analysis[a] of Change in Cognitive Function - Childhood SEP Measures

	Model 1: Unconditional Means		Model 2: Unconditional Growth Linear Rate of Change in Cognitive Function		Model 3: Rate of Change Adding Retest, Gender, Cohort, Race/Ethnicity, Death & Proxy Status Effects		Model 4a: Parent Education		Model 4b: Childhood SES		Model 4c: Father White Collar Job		Model 4d: Childhood Health		Model 5: All Childhood SEP Variables	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects																
Initial Status																
Intercept at Age 65	50.1111	0.1449	52.2949	0.1321	54.0637	0.2637	49.8059	0.3597	52.8459	0.3186	52.9265	0.2742	48.8766	0.4976	45.1458	0.5431
Main Effects																
Mother's Education							3.2407	0.3528							2.9194	0.3505
Father's Education							2.3334	0.3246							1.6033	0.3266
Childhood SES																
Well									3.1153	0.5069					0.3258	0.5177
Average									1.6500	0.2666					0.3148	0.2687
Poor / Varied									---	---					---	---
Father White Collar Job											4.1107	0.2913			3.0976	0.3019
Childhood Health [d]													1.5698	0.1278	1.3224	0.1270
Rate of Change																
Age (slope per decade)			-9.5600	0.1028	-14.4679	0.2304	-13.5734	0.2937	-14.2834	0.2714	-14.3600	0.2412	-13.7785	0.4026	-12.9089	0.4359
Mother's Education							-0.3997	0.2670							-0.4245	0.2667
Father's Education							-0.8076	0.2523							-0.7527	0.2549
Childhood SES																
Well									-0.3138	0.3985					-0.0418	0.4063
Average									-0.2573	0.2125					-0.0554	0.2150
Poor / Varied									---	---					---	---
Father White Collar Job											-0.0664	0.2323			0.0854	0.2412
Childhood Health [d]													-0.2098	0.1016	-0.1852	0.1014
Random Effects																
Variances																
Between Individuals																
In initial status	212.0200	3.3623	152.8400	2.9614	153.4400	4.4102	148.6200	4.3434	152.5400	4.3985	150.2600	4.3711	151.2100	4.3814	145.1400	4.3007
In rate of change			16.6131	1.8702	9.1259	1.5485	8.4191	1.5183	9.1254	1.5460	9.2815	1.5328	9.0830	1.5389	8.6141	1.5022
Retest variance					59.2887	3.7780	59.0362	3.7724	59.2379	3.7764	59.1662	3.7761	59.0499	3.7727	58.7086	3.7662
Within-person																
Residual errors	199.0300	1.3312	173.2300	1.2148	160.0800	1.2554	160.1500	1.2554	160.0900	1.2554	160.0800	1.2551	160.0900	1.2554	160.1400	1.2551
Total Variance	411.0500		342.6831		381.9346		376.2253		380.9933		378.7877		379.433		372.603	
Goodness of Fit																
-2LL	488013.3		479058.6		475524.8		475218.0		475467.6		475305.4		475372.0		474965.7	
AIC	488019.3		479070.6		475566.8		475268.0		475517.6		475351.4		475418.0		475031.7	
BIC	488041.8		479115.4		475723.7		475454.8		475704.4		475523.2		475589.8		475278.2	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using *N* =12,972 with D=57,399; shaded cells are not significant at p < 0.05

[b] Retest is dummy coded so that 0=Initial Testing, and 1=Retesting

[c] Birth Cohort is centered at 1930 and divided by 10 so change represents one decade

[d] Self-rated health in childhood (1-4)

Table 3.3. Repeated Multivariate Analysis[a] of Change in Cognitive Function - Childhood and Adulthood SEP Measures

	Model 5: All Childhood SEP Variables		Model 6: Childhood SEP Adjusted for Respondent Education		Model 6b: Adding High School & College		Model 7: Childhood SEP Adjusted for Income		Model 8: Chilchood SEP Adjusted for Wealth		Model 9: Childhood SEP Adjusted for Occupation		Model 10: Childhood SEP Adjusted All for Adult SEP Variables	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects														
Initial Status														
Intercept at Age 65	45.1458	0.5431	48.6715	0.5217	46.0499	0.6058	42.1938	0.5582	42.2757	0.5544	42.8321	0.6764	41.3416	0.7371
Main Effects														
Mother's Education	2.9194	0.3505	1.1512	0.3333	0.9742	0.3331	2.5071	0.3438	2.5554	0.3446	2.4349	0.3433	0.8376	0.3289
Father's Education	1.6033	0.3266	0.4570	0.3091	0.4024	0.3081	1.1885	0.3205	1.1834	0.3215	1.3046	0.3197	0.2155	0.3044
Childhood SES														
Well	0.3258	0.5177	-1.7018	0.4912	-1.6615	0.4894	-0.0127	0.5077	-0.2848	0.5103	0.1447	0.5068	-1.6310	0.4845
Average	0.3148	0.2687	-0.5021	0.2540	-0.5457	0.2532	0.1037	0.2635	0.1055	0.2642	0.3274	0.2627	-0.5439	0.2503
Poor / Varied	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Father White Collar Job	3.0976	0.3019	1.0436	0.2888	1.0905	0.2893	2.5907	0.2966	2.7745	0.2969	2.2361	0.2975	0.9114	0.2862
Childhood Health [b]	1.3224	0.1270	0.7589	0.1205	0.7313	0.1201	1.0948	0.1248	1.1189	0.1251	1.0952	0.1246	0.5947	0.1188
Education [c]			1.5999	0.0422	1.2446	0.0704							1.0686	0.0707
High School					3.7363	0.4034							2.9406	0.4015
College					0.4525	0.3902							-0.2398	0.3905
Income														
Lowest Tertile							---	---					---	---
Middle Tertile							3.6932	0.3079					1.2445	0.3036
Highest Tertile							7.1261	0.3247					2.4850	0.3494
Wealth														
Lowest Tertile									---	---			---	---
Middle Tertile									3.9074	0.2915			1.7944	0.2885
Highest Tertile									6.3513	0.3045			2.6136	0.3231
Occupation														
White Collar											7.0224	0.5156	4.3583	0.5032
Blue Collar / Homemaker											1.6412	0.5158	2.5626	0.4990
Other											---	---	---	---
Rate of Change														
Age (slope per decade)	-12.9089	0.4359	-13.8132	0.4309	-12.9406	0.4959	-12.2279	0.4548	-12.6965	0.4490	-11.8492	0.5198	-11.2073	0.5842
Mother's Education	-0.4245	0.2667	-0.0103	0.2610	0.0491	0.2612	-0.3014	0.2642	-0.4201	0.2640	-0.2418	0.2642	0.0789	0.2591
Father's Education	-0.7527	0.2549	-0.4182	0.2480	-0.4066	0.2476	-0.6472	0.2526	-0.6130	0.2524	-0.6619	0.2526	-0.3703	0.2459
Childhood SES														
Well	-0.0418	0.4063	0.2286	0.3962	0.2177	0.3956	-0.0516	0.4026	0.0705	0.4029	0.0016	0.4023	0.1717	0.3931
Average	-0.0554	0.2150	-0.0724	0.2097	-0.0741	0.2094	-0.0106	0.2130	-0.1095	0.2130	-0.0563	0.2128	-0.0952	0.2080
Poor / Varied	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Father White Collar Job	0.0854	0.2412	0.2893	0.2377	0.2854	0.2382	0.0675	0.2400	0.0405	0.2392	0.3619	0.2400	0.3216	0.2367
Childhood Health [b]	-0.1852	0.1014	-0.0651	0.0988	-0.0538	0.0986	-0.1271	0.1007	-0.1546	0.1004	-0.1086	0.1006	-0.0184	0.0980
Education [c]			-0.3128	0.0331	-0.1831	0.0551							-0.1392	0.0553
High School					-1.0978	0.3236							-0.9025	0.3232
College					-0.6542	0.3217							-0.7525	0.3259
Income														
Lowest Tertile							---	---					---	---
Middle Tertile							-1.0014	0.2424					-0.8300	0.2485
Highest Tertile							-1.2003	0.2769					-0.6094	0.3091
Wealth														
Lowest Tertile									---	---			---	---
Middle Tertile									-0.7493	0.2307			-0.1657	0.2339
Highest Tertile									-0.5233	0.2307			0.1643	0.2715
Occupation														
White Collar											-2.3192	0.3673	-1.6828	0.3640
Blue Collar / Homemaker											-1.4875	0.3493	-1.6141	0.3426
Other											---	---	---	---
Random Effects														
Variances														
Between Individuals														
In initial status	145.1400	4.3007	128.2200	4.0823	127.3000	4.0771	138.2500	4.2189	139.3600	4.2318	138.8000	4.2249	123.1500	4.0294
In rate of change	8.6141	1.5022	8.1211	1.4324	8.0718	1.4255	8.3786	1.4862	8.3922	1.4859	8.3284	1.4846	7.7552	1.4148
Retest variance	58.7086	3.7662	57.7505	3.7378	57.7758	3.7418	58.2022	3.7555	58.0201	3.7533	58.0118	3.7535	56.9671	3.7300
Within-person														
Residual errors	160.1400	1.2551	160.2200	1.2549	160.2200	1.2549	160.1600	1.2553	160.2100	1.2553	160.2300	1.2557	160.2800	
Total Variance	372.603		354.312		353.368		364.991		365.982		365.370		348.152	
Goodness of Fit														
-2LL	474965.7		473595.6		473504.3		474490.0		474516.9		474477.7		473182.3	
AIC	475031.7		473665.6		473582.3		474564.0		474590.9		474551.7		473284.3	
BIC	475278.2		473927.1		473873.6		474840.4		474867.3		474828.2		473665.3	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using *N* =12,972 with D=57,399 and adjusted for retest, gender, cohort, race/ethnicity, death and proxy status; shaded cells are not significant at $p < 0.05$

[b] Self-rated health in childhood (1-4)

[c] Education (years) is centered at 12 years

Table 3.4. Repeated Multivariate Analysis[a] of Change in Cognitive Function with Cohort Interactions

	Model 5: All Childhood SEP Variables		Model 6: Adding Respondent Education		Model 7: Adding High School & College	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects						
Initial Status						
Intercept at Age 65	45.0023	0.6660	49.1023	0.6543	46.3058	0.7630
Main Effects						
Mother's Education	3.0321	0.4367	1.1889	0.4218	0.9893	0.4213
Cohort X Mother's Educ	-0.9694	0.5308	-0.7452	0.5308	-0.6373	0.5327
Father's Education	2.0514	0.4204	0.8829	0.4028	0.8405	0.4017
Cohort X Father's Educ	-1.3379	0.5112	-1.1999	0.5050	-1.2122	0.5045
Childhood SES						
Well	0.3562	0.7204	-2.0948	0.6911	-2.0326	0.6890
Cohort X Well SES	0.8879	0.8084	1.4785	0.7972	1.4351	0.7965
Average	-0.0824	0.3564	-1.0591	0.3415	-1.1478	0.3409
Cohort X Average SES	0.5254	0.4253	0.9072	0.4183	0.9617	0.418
Poor / Varied	---	---	---	---	---	---
Father White Collar Job	3.2039	0.4060	0.6060	0.3952	0.7126	0.3963
Cohort X Father Job	0.2882	0.5014	1.0957	0.4953	1.0640	0.4963
Childhood Health [b]	1.3455	0.1723	0.6975	0.1654	0.6775	0.1649
Cohort X Childhood Hlth	0.0916	0.2008	0.1809	0.1986	0.1753	0.1984
Education [c]			1.7566	0.0543	1.3978	0.0901
Cohort X Education			-0.2145	0.0645	-0.2090	0.1099
High School					4.1996	0.5167
Cohort X High School					-1.1370	0.6767
College					-0.3962	0.5391
Cohort X College					1.4498	0.6232
Rate of Change						
Age (slope per decade)	-12.3187	0.6715	-13.6717	0.6887	-12.5625	0.8165
Mother's Education						
Age X Mother's Educ	-1.1522	0.4605	-0.5984	0.4654	-0.5005	0.4671
Cohort X Age X Mother's Educ	-0.0413	0.2387	-0.0925	0.2380	-0.1258	0.2383
Father's Education						
Age X Father's Educ	-1.6629	0.4424	-1.2898	0.4427	-1.2964	0.4427
Cohort X Age X Father's Educ	0.1521	0.2319	0.1298	0.2273	0.1230	0.2272
Childhood SES						
Age X Well	0.6726	0.7481	1.3008	0.7470	1.2737	0.7468
Cohort X Age X Well	0.1845	0.3659	-0.0622	0.3587	-0.0421	0.3580
Age X Average	0.1627	0.3704	0.4232	0.3696	0.4491	0.3697
Cohort X Age X Average	-0.3350	0.2004	-0.4093	0.1972	-0.4379	0.1970
Age XPoor / Varied	---	---	---	---		
Father White Collar Job						
Age X Father White Collar Job	0.4454	0.4129	1.1456	0.4191	1.1165	0.4219
Cohort X Age X Father Job	0.2700	0.2346	-0.0548	0.2306	-0.02599	0.2311
Childhood Health [b]						
Age X Childhood Health	-0.1003	0.1768	0.0508	0.1771	0.0503	0.1771
Cohort X Age X Childhood Hlth	0.0409	0.0947	-0.0236	0.0927	-0.0255	0.0925
Education [c]						
Age X Education			-0.4278	0.0598	-0.2887	0.1013
Cohort X Age X Education			0.1061	0.0281	0.1078	0.0483
High School						
Age X High School					-1.6233	0.5756
Cohort X Age X High School					0.3863	0.3106
College						
Age X College					0.1930	0.5833
Cohort X Age X College					-0.4534	0.2817
Random Effects						
Variances						
Between Individuals						
In initial status	144.7800	4.2956	127.7200	4.0800	126.7500	4.0670
In rate of change	8.4564	1.4973	7.8620	1.4260	7.7529	1.4191
Retest variance	58.3046	3.7635	57.2953	3.7377	57.3259	3.7366
Within-person						
Residual errors	160.1800	1.2555	160.2300	1.2551	160.2100	1.2548
Total Variance	371.721		353.107			
Goodness of Fit						
-2LL	474934.0		473538.4		473434.6	
AIC	475024.0		473636.4		473548.6	
BIC	475360.2		474002.4		473974.5	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=12,972 with D=57,399 and adjusted for retest, gender, cohort, race/ethnicity, death and proxy status; shaded cells are not significant at $p < 0.05$

[b] Self-rated health in childhood (1-4)

[c] Education (years) is centered at 12 years

Table 3.5. Socioeconomic Mobility and Cognitive Change[a,b]

Socioeconomic Mobility					Mean Score at Age 65		Mean 10-year Change in Score		Mean Score at Age 65 Adjusted for Retest, Gender, Cohort, Race/Ethnicity, Death, & Proxy Status		Mean 10-year Change in Score Adjusted for Retest, Gender, Cohort and Race/Ethnicity, Death, & Proxy Status	
	Childhood SEP	Education	Income	*n*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Stable Low	Low	Low	Low	3276	45.824	0.307	-7.939	0.205	46.310	0.623	-12.576	0.522
Downward	High	Low	Low	1545	50.335	0.414	-8.474	0.285	49.878	0.854	-14.068	0.732
	Low	Low	High	1397	50.630	0.354	-9.244	0.328	52.307	0.710	-14.725	0.666
	High	Low	High	1331	52.754	0.358	-9.561	0.354	53.519	0.778	-14.442	0.687
	Low	High	Low	671	53.934	0.620	-8.593	0.430	54.596	1.193	-17.440	1.126
	High	High	Low	994	55.216	0.498	-8.923	0.374	54.083	1.001	-13.470	0.950
Upward	Low	High	High	1112	56.502	0.392	-9.279	0.358	58.605	0.782	-15.489	0.717
Stable High	High	High	High	2646	57.941	0.255	-8.968	0.244	60.068	0.530	-15.067	0.470
	Childhood SEP	Education	Wealth									
Stable Low	Low	Low	Low	3111	45.109	0.285	-8.392	0.202	47.086	0.598	-13.851	0.505
Downward	High	Low	Low	1489	48.961	0.371	-8.841	0.290	50.254	0.857	-14.107	0.722
	Low	Low	High	1562	52.682	0.376	-9.599	0.300	50.614	0.696	-13.596	0.664
	High	Low	High	1387	54.491	0.365	-9.577	0.309	52.850	0.733	-14.738	0.662
	Low	High	Low	765	53.911	0.506	-8.702	0.411	56.911	1.125	-17.953	0.967
	High	High	Low	1121	54.230	0.419	-9.105	0.359	57.081	0.920	-15.241	0.856
Upward	Low	High	High	1018	57.100	0.434	-9.770	0.356	57.832	0.778	-15.228	0.755
Stable High	High	High	High	2519	58.446	0.261	-9.363	0.236	59.000	0.531	-15.166	0.477
	Childhood SEP	Education	Occupation									
Stable Low	Low	Low	Low	3593	45.493	0.274	-7.965	0.189	47.919	0.521	-13.521	0.454
Downward	High	Low	Low	1821	49.556	0.348	-8.437	0.255	50.824	0.686	-14.267	0.601
	Low	Low	High	1080	53.240	0.413	-9.165	0.403	51.927	0.938	-14.883	0.914
	High	Low	High	1055	54.746	0.405	-9.364	0.409	54.311	0.987	-15.555	0.906
	Low	High	Low	665	53.428	0.609	-8.174	0.407	55.961	1.108	-15.792	0.982
	High	High	Low	1105	54.685	0.464	-8.280	0.320	54.698	0.856	-14.412	0.773
Upward	Low	High	High	1118	56.614	0.396	-9.504	0.380	59.176	0.795	-16.941	0.760
Stable High	High	High	High	2535	58.141	0.265	-9.215	0.274	60.644	0.563	-15.009	0.522

[a] Values are from random-effects regression models fit with SAS 9.1 Proc Mixed without sampling weights, *N* =12,972 with D=57,399

[b] Mean composite memory score ranges from 0 to 100

3.6 References

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CHAPTER 4

THE EFFECT OF HIGHEST LIFETIME BODY MASS INDEX ON COGNITIVE FUNCTION AND DECLINE IN OLDER AGE

4.1 Abstract

Prior research suggests that overweight and obesity as measured by body mass index (BMI) increases the risk of dementia and poor cognitive functioning in older age. Using data from the Health and Retirement Study this study aimed to determine whether highest lifetime BMI is associated with cognitive performance and change in later life, whether this relationship is mediated by vascular-related health problems or BMI in later life, and whether there is effect modification by gender, obesity at baseline, or socioeconomic position (SEP). Highest lifetime BMI was significantly associated with the initial level performance on memory-based cognitive tasks at age 65 in unadjusted models but the relationship was attenuated by later life BMI, diabetes, hypertension, stroke, and smoking status. Education was found to be a confounder of the highest lifetime BMI-cognition relationship but did not modify the effect of highest lifetime BMI on cognitive performance or rate of decline. Highest BMI was associated with more rapid cognitive decline after adjustment for current BMI. The effect of highest lifetime BMI on performance level and rate of change was modified by measures of childhood

SEP, gender, and current obesity. These findings suggest that the association between BMI and cognitive outcomes might not be the same for all groups. Further investigation into the interaction of SEP and adiposity is warranted.

4.2 Introduction

Research into cognitive function in older age reveals that there are multiple determinants of cognitive decline. Aside from age, socioeconomic factors and disease pathology are commonly implicated. Low educational attainment, low occupational status, and other markers of low socioeconomic position (SEP) in adulthood are associated with cognitive decline and greater risk of Alzheimer disease (AD) and dementia. [Brunner 2005; Elias et al., 1997; Evans et al., 1997; Farmer et al., 1995; Holland et al., 1991; Katzman 1993; Koster et al., 2005; Stern et al., 1994] An equally substantial body of work supports the association between vascular risk factors such as diabetes mellitus, hypertension, atherosclerosis, and poor cognitive outcomes. [Breteler 2000; Haan et al., 1999; Singh-Manoux et al., 2003; Whitmer et al., 2005a; Wu et al., 2003]

Recently, evidence suggests that body mass index (BMI) and obesity in middle-age are also associated with cognitive impairment and dementia. Although some research has found that weight loss in later life precedes dementia and that low BMI is associated with dementia cross-sectionally, [Barrett-Connor et al., 1998; Gustafson et al., 2003] prospective evidence has shown that high midlife BMI is a risk factor for poor later-life cognitive outcomes. Compared to those with normal BMI, individuals who were overweight or obese in midlife have a higher risk of AD and vascular dementia (VaD), independent of the presence of cardiovascular disease, diabetes comorbidities,

and stroke. [Kivipelto et al., 2005; Rosengren et al., 2005; Whitmer et al., 2007] Possible mechanisms of the association between obesity and dementia include the harmful effects of hormones, adipocyte secreted proteins, and inflammatory cytokines on the brain. [Whitmer 2007] While previous studies on the association between BMI and cognitive function and dementia usually controlled for the effect of education, none have investigated whether this or other measures of SEP moderate the relationship.

Like cognition, obesity is strongly determined by socioeconomic status such that persons of low socioeconomic status in adulthood are at increased risk for weight gain and the development of overweight and obesity. [Ball et al., 2005; Sobal et al., 1989] Research also suggests that there are lasting effects of childhood socioeconomic disadvantage on weight in adulthood, independent of adult socioeconomic status. Although most studies find stronger associations for adult socioeconomic status, measures of socioeconomic status in early life have been found to be inversely associated with adult obesity and weight change. [Ball et al., 2006; Blane et al., 1996; Brunner et al., 1999] Specifically, population-based studies of women have shown that parental occupation is strongly associated with adult weight, while measures based on maternal education were more predictive of weight change. [Ball et al., 2006; Lahmann et al., 2000]

The enduring connection between markers of SEP and obesity as well as SEP and cognition suggest that the relationship between BMI and cognition might be more pronounced in certain socioeconomic subgroups. The primary goals of this study are (1) to determine whether measures of childhood SEP are associated with highest lifetime BMI, (2) to ascertain whether the effect of BMI on cognition is mediated by vascular-

related health problems and BMI in later life, (3) to evaluate whether gender, obesity at baseline, and measures of SEP in childhood and adulthood modify the association between BMI in midlife and cognition.

4.3 Methods

Study Population and Data

We used data from the Health and Retirement Study (HRS), a population-based, nationally representative, prospective panel study of adults over age 50 funded by the National Institutes of Aging and conducted by the Institute for Social Research at the University of Michigan.

The study sample includes over 20,000 community-dwelling adults with oversamples of African-Americans and Hispanics. A new cohort of respondents is added to the sample every six years to adjust to maintain the steady state design and to account for aging and attrition. Currently, the study is a combination of five cohorts: the AHEAD cohort of persons born between 1890 and 1923; the Children of the Depression Age (CODA) cohort of those born between 1924 and 1930; the original HRS cohort of those born between 1931 and 1941; the War Babies (WB) cohort of those born between 1942 and 1947; and the Early Baby Boomer (EBB) cohort of those born between 1948 and 1953, which was added in 2004. To date, seven waves of data have been collected from the HRS cohort; six waves from the AHEAD cohort; four from the CODA and WB cohorts; and one wave from the EBB cohort.

Interviews are conducted with sampled respondents and their spouses or partners every two years, including those respondents who have entered nursing homes. Interviews were conducted by telephone for most respondents less than 80 years of age

and face-to-face for persons 80 years of age or older and for baseline interviews. Interviews were conducted in both English and Spanish. Additional detail about the design of the HRS is available elsewhere. [Heeringa et al., 1995; Juster et al., 1995]

These analyses were limited to interviews with self respondents and cases with at least one interview with self-reported cognition data. Respondents at least 51 years of age who were not missing on baseline covariates and had at least one interview wave with a valid cognitive test were eligible for inclusion in the analyses. Since HRS did not begin asking questions about early childhood exposures until 1998, and did not ask the highest reported weight until 2004, respondents also had to have been interviewed at least once since 1998 and in 2004 to be included in the analyses. From the eligible sample, one member of each household was randomly selected for inclusion in the analyses to avoid confounding from unmeasured household-level variables (N=10,034).

Assessment of Cognitive Function

Performance on the episodic memory tasks administered at each wave was used as the cognitive functioning measure for these analyses. For the episodic memory tests, respondents are asked to recall a list of 10 common nouns immediately after hearing them (immediate recall) and after approximately five minutes of additional test administration (delayed recall). These tasks were selected because they have been shown to be sensitive measures of cognitive change. [Small et al., 1999] A composite score was calculated using the unweighted average of the immediate and delayed recall tasks and was then normalized to a score range of 0 to 100. Respondents who refused at the beginning of the test were assigned a zero on that portion of the test while respondents who refused during the test were given the score they had obtained up until that point. For most of the

interview waves the 10-noun recall tests were administered; however, the verbal recall tests in the 1992 and 1994 interviews with the original HRS cohort consisted of a list of 20 common nouns rather than 10. The distributions of scores on the 20-item tests are highly skewed with less than 5% scoring more than 10 on either test. Scores from these waves were rescaled so that a score of 10 or above was considered perfect to make these scores comparable to waves using the 10-item lists. This approach has been used in pervious analyses from the HRS. [McArdle et al., 2007]

Measurement of Socioeconomic Position

SEP in childhood was examined using parental educational attainment and father's occupation. Because of differences in question administration over time, parental education was coded as a dichotomous variable indicating whether the parents had ≥ 8 years of education. Father's main occupation was classified as white collar (professionals, managers, salesmen, clerical and service industries) or blue collar (operators, craftsmen, farmers) and unemployed/other. Primary occupation was assigned using the occupation code according to the 1980 US Census guidelines. Respondents who reported they did not live with their father were excluded from the analyses.

Socioeconomic position in adulthood was using respondent's education and household wealth at baseline. Total years of education, reported at baseline, was categorized, as less than 12 years, or 12 or more years. Education was also coded as [Years of education -12] to be approximately centered.

Given that poor health prior to inclusion in the study sample may be associated with lower reported household income at baseline, household wealth was selected as the better measure of adult economic circumstances. Wealth was measured using an assets-

less-debts approach by subtracting debt from the sum of net worth as reported at the baseline interview. Wealth was adjusted for inflation using the Consumer Price Index (CPI) calculated by the Bureau of Labor Statistics and normalized to 1992 dollars. The wealth data were drawn from the RAND HRS data files - version F which includes a summary measures and imputed values for wealth compiled from several HRS questions. [St.Clair et al., 2006] Wealth was dichotomized at the median for use in the analysis.

Body Mass Index

Self-reported height and highest lifetime weight were used to create continuous values for BMI. Highest BMI was centered at the mean (30 kg/m^2) for use in the analyses. Categorical groupings by BMI were also considered to allow for non-linear relationships between BMI and cognition. Current BMI was calculated using the reported weight at every wave and the most recent height. Current BMI was included as a time-varying predictor. Obesity at baseline was classified as being greater than or equal to 30 kg/m^2 at first interview.

Health Conditions and Behaviors

Chronic health conditions that have been identified as correlates for obesity and risk factors for cognitive impairment were selected for inclusion in the analyses. These included self-reported diagnosis of diabetes, hypertension, and stroke or transient ischemic stroke. Because respondents could have developed and reported these conditions at any time during the study, indicators for these conditions were included as time-varying predictors. Because of its relationship with vascular disease, current smoking status was also included as a time-varying predictor.

Covariates

Practice effects - To control for practice effects from repeated administration of cognitive tests, a dummy variable was included in the models to represent prior exposure to the cognitive tests. Respondents were assigned a zero at their baseline wave of cognitive testing and a value of 1 at each subsequent wave. This variable represents the average increase in test score between the baseline and first follow-up interview wave. Previous research has found this approach effectively accounts for the effect of repeated cognitive test administration. [Hultsch et al., 1998]

Race and ethnicity – Respondents were classified into 1 of 3 categories: non-Hispanic white/other, non-Hispanic black, and Hispanic. Respondents who reported both African-American race and Hispanic ethnicity were assigned to the Hispanic group.

Age and Cohort – Age was coded as [Age at interview-65] / 10 to be approximately centered. Thus, the coefficient for age represents the average cognitive performance at age 65 and the average effect on cognitive change with each decade. Similarly, birth cohort was coded as [Birth Year-1930] / 10.

Death and Proxy Status – Two dummy variables were created to help account for differential attrition due to death and loss to follow-up. One variable represented whether the respondent was deceased at the time of last contact with the household. The other represented whether the respondent ever required the use of a proxy during the period of study.

Statistical Methods

Linear models were used to explore the relationship between childhood SEP and education to highest lifetime BMI. We first regressed BMI on childhood SEP variables

independently (Model 1) and then simultaneously (Model 2), controlling for sex, race/ethnicity, and age, to assess the relationship between childhood SEP and highest lifetime BMI. Model 3 added the effect of education and Model 4 added the effect of household wealth (expressed as tertiles). By comparing change in coefficients from Model 2 to Model 3 and from Model 3 to Model 4, we can investigate to what extent the effect of childhood SEP is mediated by adult SEP.

Initially, graphical methods were used to explore patterns of cognitive performance by age. Repeated-measures regression models with random-effects error structure were used to describe the person-specific paths of cognitive decline and to test the effects of covariates on the initial level of cognitive function and rate of change. [Laird et al., 1982] Models were estimated without adjustment for sampling weights using the SAS procedure PROC MIXED (SAS software, Version 9.1: SAS Institute Inc., Cary, NC). This approach accommodates unbalanced data structures, both in terms of number of testing occasions and differences in intervals between assessments, and enables full use of data for all respondents with at least one valid cognitive score. The models were estimated using the full-information maximum likelihood estimation with an unstructured covariance matrix for the random effects and included all data available (N=10,034, D=48,071).

An individual growth model in which change in cognitive score is a linear function of age is represented by the level-1 submodel shown below:

$$COG_{ij} = \pi_{0i} + \pi_{1i} [(AGE_{ij} - 65)/10] + \varepsilon_{ij}$$

where COG_{ij} is the cognition score for person i at time j and AGE_{ij} is the wave-specific age. In this model the intercept (π_{0i}) represents the value of i's cognition score at age 65

years (because age is centered) and the slope term (π_{1i}) is the rate of change in cognitive score per decade. This model assumes that a straight line adequately represents each person's true change over time and that any deviation from linearity observed in the sample data result from random error (ε_{ij}).

The level-2 submodels are shown below:

$$\pi_{0i} = \gamma_{00} + \gamma_{01}\text{VAR} + \zeta_{01}$$

$$\pi_{1i} = \gamma_{10} + \gamma_{11}\text{VAR} + \zeta_{11}$$

These models treat the intercept (π_{0i}) and the slope (π_{1i}) of an individual's growth trajectory as level-2 outcome that may be associated with predictor variables (VAR). Each component also has its own residual (ζ_{01} and ζ_{11}) that allows the level-1 growth parameters to vary across individuals.

To this base model, we then examined the main effect as well as the interaction of highest lifetime BMI with age to test the degree to which it was associated with the absolute difference in cognitive function scores at age 65 as well as to test the effect of BMI on the rate of change in cognitive function. We then reestimated the effects of the BMI on cognitive function and change in a series of models that included terms sex, race/ethnicity, birth cohort, practice effects, and proxy status, education, and current BMI. These models tested the degree to which the effects high BMI earlier in life was associated with cognitive function independent of the respondents' demographics, current BMI, and own educational attainment. Later models assessed whether the relationship between of BMI and cognitive performance and decline was mediated by reported health conditions and health behavior. Finally, to examine whether the effects BMI was

consistent across subgroups categorized by gender, obesity, and SEP, we fit the same series of modes separately by subgroup.

4.4 Results

Data on highest lifetime BMI and all covariates was available on 12,617 individuals with 10,034 respondents selected for inclusion in the final analytic sample (4,405 men and 5,629 women). Characteristics of the sample by gender, obesity at baseline, and SEP are shown in Table 4.1. On average, respondents were age 61 years and had a mean score of 56 points (SD 20.64) out of a possible 100 points at their initial interview. The average number of interview waves was 4.79.

Mean memory score at baseline was significantly different across all subgroups with the exception of obesity-defined groups. Mean highest lifetime BMI did not differ by sex or maternal education. However, a higher lifetime BMI was significantly associated with higher current BMI, with having less than 12 years of education, lower than median wealth in adulthood, and fathers with less than 8 years of education or who were unemployed or had a blue collar occupation during the respondent's childhood. For respondents for whom age at highest weight was available, most reported the age at which they were their highest weight between their 4^{th} and 6^{th} decades, and usually at least 10 years prior to their initial participation in the HRS (data not shown).

All childhood SEP variables were significant predictors of highest lifetime BMI (Table 4.2). Higher paternal education and white collar occupation were associated with lower maximum lifetime BMI while higher maternal education was associated with a higher lifetime BMI in the simultaneously adjusted model. Adjustment for respondents' education and wealth attenuated the effect of paternal education and occupation by 24

and 26%, respectively. However, adjustment by these factors increased the magnitude of the association with maternal education.

Results from models assessing the impact of highest lifetime BMI on cognitive function are summarized in Table 4.3. Model 1 presents the unadjusted effects of BMI. In this model, BMI was significantly associated with the level of cognitive performance at age 65 (the intercept) but not with cognitive change. The relationships persisted even after adjusting for demographics and education. However, after the effects of sex, race/ethnicity, birth cohort, and practice effects were taken into consideration, the effect of BMI on cognitive performance was reduced by approximately 50%, although still significant. The effect of BMI was further attenuated by the inclusion of education in the model.

Adjusting for current BMI further attenuated the effect of highest lifetime BMI on initial cognitive performance. This adjustment also resulted in a significant effect of both highest BMI and current BMI on cognitive change, although in different directions. Higher lifetime BMI was associated with a significant decline in cognitive score whereas higher current BMI was protective against decline.

Adjusting for health conditions (diabetes, hypertension, and stroke) additionally weakened the effect of highest BMI on initial performance but did not affect the relationship between highest BMI and cognitive change. The final model (Model 6) added smoking status and included all covariates. In the fully adjusted model, highest BMI was not associated with initial performance at age 65 but remained significantly associated with cognitive decline.

Table 4.4 presents the results from the same models above stratified by gender. Higher lifetime BMI was associated with a reduction in initial score for both men and women in the unadjusted models and the models adjusted for demographics. Adjusting for education attenuated the effect of BMI on cognitive performance for both groups and more so for men. There were differential results once current BMI was added to the model. For men, adjusting for current BMI resulted in a significant association between highest lifetime BMI and cognitive decline, whereas the association was not significant among women (Model 4). Although there was also an inverse relationship between highest lifetime BMI and cognitive change for women, it was not significant. Further adjustment by health conditions and smoking status did not diminish the effect size for of highest lifetime BMI on cognitive decline for men.

The results stratified by obesity at baseline are presented in Tables 4.5. In the model adjusted for demographics, highest lifetime BMI was associated with lower cognitive score at age 65 in both the obese and non-obese groups. However, adjustment by education and later life health status reduced this association indicating that these factors fully mediate the effect of highest lifetime BMI on cognitive performance level across BMI groups. In contrast, the effect of highest lifetime BMI was inversely and significantly associated with cognitive decline among obese respondents only. In the fully adjusted model, the effect was equal to -0.156 points per BMI unit per decade.

Table 4.6 presents the results from the models estimated separately for subgroups classified by parental education and father's occupation. There was a significant difference in the effect of highest lifetime BMI by parental education and occupation, although the pattern was not consistent. Maternal education seemed to be robust modifier

of the highest lifetime BMI-cognition relationship while groups categorized by paternal education were nearly identical. In unadjusted models, those whose mothers completed 8 or more years of education experienced nearly double the reduction in cognitive score than those whose mothers had fewer than 8 years of education. However, adjustment for demographics and respondents' own education, and health status attenuated the effect. As seen in the total sample, in models adjusted by current BMI, highest lifetime BMI was associated with more rapid decline although among the higher maternal education group only.

Father's occupation also modified the relationship between highest lifetime BMI and cognition. In the unadjusted models, respondents whose fathers held white collar jobs experienced a 27% larger reduction in absolute cognitive score points than those whose fathers had blue collar occupations. Adjustment for demographic confounders reduced the size and relative difference in this effect. In contrast to pattern seen with parental education, the effect of highest BMI on cognitive change was seen in the lower SEP group. Respondents whose father's held blue collar jobs or who were unemployed experienced more deleterious effects from highest lifetime BMI than those with fathers who worked white collar jobs.

Although education appears to be a significant confounder of the highest lifetime BMI-cognition relationship, the effect of highest BMI on cognition did not by differ by education or by wealth although there was a trend toward greater negative effects on performance level and slope among the lower education group and the higher wealth group (results not shown).

4.5 Discussion

The HRS provided an opportunity to study the effect of highest lifetime BMI on trajectories of cognitive functioning in older age. This paper presents several key findings. First, highest lifetime BMI was negatively associated with memory-based cognitive performance although this effect was significantly mediated by BMI in later life and vascular-related health conditions. Adjustment for education also attenuated the effect of highest BMI on cognitive performance suggesting that it is an important confounder of this relationship. However, the effect of highest lifetime BMI, as well as the strength of the mediating factors, differed by subgroup. Maternal education, father's occupation, gender, and current BMI are effect modifiers of the association between highest lifetime BMI and cognitive performance in later life.

Secondly, while highest BMI was not associated with cognitive decline in unadjusted models, it was significantly and inversely related to cognitive decline in models adjusted for current BMI. This relationship was also modified by childhood SEP, gender, and current obesity. In contrast, current BMI was protective against decline even after adjustment for vascular health conditions and smoking status.

The role of overweight and obesity as risk factors for poor cognitive performance and decline in older age has not been well explored despite the substantial literature relating dementia with vascular conditions, many of which are associated with obesity. Only recently have studies begun to consider overweight as a separate risk factor for cognitive outcomes and none to date have specifically examined the differential effects by socioeconomic status.

In this sample, highest lifetime BMI was associated with poor cognitive function but was attenuated by current BMI, health conditions, and smoking status suggesting that the effect of lifetime BMI operates through its association with vascular disease and negative health behaviors. But stratification by measures of SEP revealed that the effect of lifetime BMI is modified by maternal measures of childhood SEP. Specifically, SEP as defined by father's occupation and maternal education were effect modifiers of the effect of highest lifetime BMI on cognitive performance in later life although the effect of highest BMI was more pronounced in the higher SEP group defined by maternal education but the lower SEP group as defined by father's occupation. Education is associated with both BMI and cognition and adjustment for education in the model of cognitive performance regressed on highest BMI reduced the size of the coefficient for BMI categories by over 50% in most groups. However, stratifying by education (< 12 yrs, 12+ yrs) revealed that education was not a modifier of the effect of highest lifetime BMI on cognitive performance. The effect of highest BMI was also not modified by household wealth. It should also be noted that there were several significant differences in composition of the SEP subgroups, especially by race and ethnicity. However, when the analyses were rerun excluding Hispanics and non-Hispanic blacks, the difference in the effect of highest lifetime BMI between BMI groups were more disparate among whites only.

Gender was also found to modify the association between highest lifetime BMI and cognitive performance. In models adjusted for current BMI, higher lifetime BMI was associated with faster decline among men only. Sex differences may in part be due

to a biological disparity relating to differences in body fat distribution or differences in cumulative hormone (e.g. estrogen) exposure.

The results by gender are similar to results from previous studies. In a prospective study of a community-based sample, Elias et al. found that obesity was related to cognitive performance, including a memory-delayed recall task, in men but not women. [Elias et al., 2005] Adjustment for age, education, occupation, native English language, health behaviors, cholesterol, diabetes, and hypertension, attenuated the associations between obesity and cognition for men, but completed negated the associations in women. However, in the Elias et al. study, BMI was measured concurrently with cognition and not earlier in life. In contrast with the present study, other studies have found a stronger relationship between body mass index in midlife and cognitive outcomes among women. An 18-year prospective study on body mass and dementia found that overweight and obesity was related to the development of AD in women later in life but not in men. [Gustafson et al., 2003] Another study found that obesity in middle age, measured by body mass index and skinfold thickness, increased the risk of dementia independently of comorbid conditions. [Whitmer et al., 2005b] While the relationship was found among both men and women, the risk was highest among obese women. However, this study did not adjust for current weight when examining the association between midlife BMI and cognitive outcomes.

Although the present analyses did not specifically consider BMI at mid life as a risk factor for poor cognitive performance, the results are in line with several studies that examined the association between middle-age BMI and cognitive outcomes. Previous studies have shown that body mass index in midlife is strongly predictive of dementia

and vascular dementia, as well as the risk of Alzheimer disease. [Gustafson et al., 2003; Whitmer et al., 2005b; Whitmer et al., 2007]

The difference in results from studies using current or midlife BMI as a risk factor for poor cognitive performance as well as the significant mediation and modifying effect of current BMI found in this study, underscores the importance of considering a lifecourse approach when investigating exposures that may not manifest until much later in life. This is especially true in studies of older adults as metabolic and physiological changes that precede the onset of disease in later life may mask or confound the true association of risk factors with outcomes. A lifecourse approach is also significant with regard to studies of body weight and composition. Adipose tissue is an ever-present lifetime exposure that begins in early life, possibly in utero, and its influence is likely relevant at all ages and stages of brain development and decline.

Measures of childhood SEP were associated with highest adult weight, as has been found in previous studies. [Brunner et al., 1999] Specifically, BMI was inversely associated with early life SEP independent of education and adult SEP. This finding suggests that socially patterned accumulation of health capital and obesity risk begins in childhood and continues, according to socioeconomic position, during adulthood. Additionally, the relationship of SEP as a moderating variable has also been found with other health outcomes. Socioeconomic status was shown to moderate the association between a measure of generalized atherosclerosis and cognition in stroke-free middle-aged individuals. [Singh-Manoux et al., 2007] The association between the measure of atherosclerosis and 6 different measures of cognitive function, including verbal memory,

inductive reasoning, fluency, and a measure of global cognitive status, was restricted to the group with low occupation-based socioeconomic status.

Some limitations of the current study should be noted. Although the measures of cognitive performance are a strength of this study in that their repeated administration allows for the examination of longitudinal change, the HRS cognitive measures are limited in their dimensionality compared to the more extensive batteries used in clinical studies. However, this is a limitation that is not uncommon to other large-scale surveys. In this study we focused exclusively on the use of the immediate and delayed recall items but the debate about the specificity of cognitive impairment, meaning which domains are the important hallmarks of dementia, merits repeating these analyses using the other cognitive measures such as the Serial 7's to asses working memory, and the Telephone Interview for Cognitive Status (TICS) to assess general intelligence.

A further limitation to this study is the use of retrospective reports on early-life circumstances and self-reported health conditions. Recall of childhood health and family financial situation in childhood may be influenced by circumstances of adult health and socioeconomic status. However, it is unlikely this would lead to a systematic bias. Relying on self-report of health conditions is not as reliable as clinical or laboratory-based indicators of disease. Respondents with undiagnosed conditions, which may be more likely in lower SES groups with less access to health care, would result in misclassification bias. Although, a bias of this sort would likely lead to an overestimate of the association between highest lifetime BMI and cognition and it is unlikely that it would produce the pattern of results observed here where the relationship with highest lifetime BMI was stronger among higher SES groups. Stronger associations between

disease conditions and cognitive function and decline might have been found if better measures of vascular disease had been used. In addition, more sensitive and specific measures may result in greater attenuation of the effect of highest lifetime BMI on cognition.

Similarly, the use of self-reported height and highest weight in the calculation of BMI is not the ideal method characterizing body weight and composition. Although BMI is the most common measure of adiposity in population-based studies, other measures such as waist-to-hip ratio and waist circumference are better measures of central adiposity and are likely more sensitive indicators of disease risk. This is especially salient in studies of aging as the ratio of fat-free mass to height starts to decrease in middle age, notably among women. [Barlett et al., 1991] Future studies should consider using multiple measures of adiposity as possible correlates of disease. Additionally, more work should be done to establish associations using biomarker data, such as the concentration of adipocyte hormones in the blood. [Gustafson 2006]

Selective survival and attrition may also have influenced the results to some extent as those of lower SEP and with lower cognitive performance are more likely to be lost to follow-up than cognitively intact persons or persons with less disadvantage. Aside from biases relating to low socioeconomic position and poor cognitive function, it is likely that poor health also affected loss to follow-up and conversion to proxy. By controlling for use of proxy status and demographic and health characteristics closely associated with proxy we attempted to adjust for this effect. In addition, the analytic methods used here, specifically the maximum likelihood method for fitting the random

effects model, incorporates information from all observed data which helps to make full use of the available data.

Lastly, there are some limitations of the methods that were used to model the trajectories of cognitive change. The growth-curve approach used in these analyses did not incorporate sampling weights in the estimation of the models. The inability to adjust using sampling weights with the SAS PROC MIXED procedure makes the models more sensitive to model misspecification. There is a risk of this if either the sampling is informative (i.e. related to the outcome even after conditioning on covariates) or if the functional form of model is misspecified and has a quadratic rather than linear trend.

Despite these limitations, this study contributes to the growing body of evidence linking obesity to cognitive impairment and adds that lifecourse SEP is an important risk factor in the development of overweight and obesity and subsequent cognitive status. Furthermore, the association between midlife or highest lifetime BMI might not be the same for all groups so subgroup analyses and further investigation into the interaction of SEP and adiposity is warranted. Specifically, current BMI is a significant mediator and effect modifier of the effect of earlier life BMI on cognition.

Table 4.1. Descriptive Statistics of Respondents over Age 50 by Sex, Obesity at Baseline, and SEP

		Sex			Obesity at Baseline		
	Total (n=10,034)	**Men (n=4,405)**	**Women (n=5,629)**	**p value**	**BMI < 30 kg/m2 (n= 7645)**	**BMI ≥ 30 kg/m2 (n= 2389)**	**p value**
Mean age, yrs (SD)	61.04 (9.14)	59.83 (8.55)	61.98 (9.47)	<.0001	61.65 (9.37)	59.09 (8.07)	<.0001
Mean memory score at baseline[b], (SD)	56.00 (20.64)	53.94 (19.83)	57.62 (21.11)	<.0001	56.15 (20.84)	55.54 (19.98)	0.1950
Mean birth year, yr (SD)	1932.25 (10.81)	1936.28 (10.34)	1933.37 (11.00)	<.0001	1933.87 (10.90)	1937.15 (10.14)	<.0001
Highest Reported BMI, (kg/m^2) (SD)	29.94 (6.32)	30.07 (5.38)	29.84 (6.97)	0.0530	27.61 (4.11)	37.39 (6.41)	<.0001
BMI category, (kg/m2) (% distribution)							
< 22	5.00	2.02	7.34	<.0001	6.54	0.08	<.0001
22-24.9	14.58	10.72	17.61	<.0001	19.08	0.17	<.0001
25-29.9	38.58	44.11	34.25	<.0001	49.90	2.34	<.0001
30-24.9	25.74	29.28	22.97	<.0001	21.21	40.27	<.0001
35+	16.10	13.87	17.84	<.0001	3.27	57.14	<.0001
Female (%)	56.10	---	---		55.29	58.69	0.0035
Race / Ethnicity (% distribution)							
Non-Hispanic White / Other	79.76	81.29	78.56	0.0007	82.04	72.46	<.0001
Non-Hispanic Black	12.25	10.51	13.61	<.0001	10.24	18.67	<.0001
Hispanic	7.99	8.20	7.83	0.5084	7.72	8.87	0.0688
Childhood SEP							
Mother's Education ≥ 8 yrs (%)	73.88	77.00	71.43	<.0001	74.48	71.95	0.0142
Father's Education ≥ 8 yrs (%)	67.99	70.53	66.00	<.0001	69.01	64.71	<.0001
Father White Collar Job (%)	20.54	20.70	20.41	0.7197	22.39	14.61	<.0001
Education, yrs (SD)	12.59 (3.18)	12.87 (3.35)	12.38 (3.02)	<.0001	12.70 (3.17)	12.26 (3.19)	<.0001
Education category (% distribution)							
Incomplete high school	21.79	20.66	22.67	0.0155	20.69	25.28	<.0001
Complete high school	33.74	29.58	36.99	<.0001	33.56	34.28	0.5172
Some college	21.34	20.52	21.98	0.0778	21.23	21.68	0.6370
College graduate	11.07	13.62	9.08	<.0001	11.59	9.42	0.0032
Post college	12.07	15.62	9.29	<.0001	12.92	9.33	<.0001
Current BMI, (kg/m2) (SD)	27.19 (5.04)	27.45 (4.33)	26.99 (5.53)	<.0001	25.04 (2.84)	34.10 (4.27)	<.0001
Health Conditions[c] (%)							
Diabetes	19.43	20.16	18.87	0.1045	14.40	35.54	<.0001
Hypertentsion	59.20	56.39	61.40	<.0001	55.23	71.91	<.0001
Stroke / TIA	9.36	9.04	9.61	0.3257	9.30	9.54	0.7213
Current Smoker[c] (%)	21.29	23.54	19.52	<.0001	22.92	16.07	<.0001
Mean household wealth, 1992 $ (SD)	237,895.29 (494,214.25)	279,888.69 (610,438.73)	205,033.16 (375,985.80)	<.0001	256805.44 (515297.33)	177381.23 (414020.22)	<.0001
Mean number of waves tested, (SD)	4.79 (2.17)	4.54 (2.26)	4.99 (2.07)	<.0001	4.86 (2.12)	4.55 (2.29)	
Ever required a proxy interview (%)	11.30	15.35	8.14	<.0001	11.41	10.97	0.5540

[a]Mean and standard deviation are presented for continuous variables; percentage is presented for categorical variables. Estimates are unweighted.

[b]Mean composite memory score ranges from 0 to 100

[c]Ever reported condition or beahvior during study period

Table 4.1. (Cont.) Descriptive Statistics of Respondents over Age 50 by Sex, Obesity at Baseline, and SEP

	Mother's Education			Father's Education			Father's Occupation		
	< 8 yrs (n=2,621)	8+ yrs (n=7,413)	p value	< 8 yrs (n=3,212)	8+ yrs (n=6,822)	p value	Blue Collar / Unemp (n=7,973)	White Collar (n=2,061)	p value
Mean age, yrs (SD)	63.66 (10.02)	60.11 (8.62)	<.0001	63.28 (9.71)	59.98 (8.67)	<.0001	60.77 (9.08)	62.08 (9.33)	<.0001
Mean memory score at baseline[b], (SD)	49.02 (21.02)	58.47 (19.93)	<.0001	50.24 (20.83)	58.72 (19.98)	<.0001	54.75 (20.46)	60.84 (20.61)	<.0001
Mean birth year, yr (SD)	1931.27 (11.17)	1935.84 (10.43)	<.0001	1931.84 (10.95)	1935.97 (10.49)	<.0001	1935.27 (11.07)	1932.26 (9.38)	<.0001
Highest Reported BMI, (kg/m^2) (SD)	30.06 (6.21)	29.90 (6.36)	0.2474	30.36 (6.45)	29.74 (6.25)	<.0001	30.22 (6.42)	28.86 (5.80)	<.0001
BMI category, (kg/m2) (% distribution)									
< 22	4.43	5.21	0.1148	3.89	5.53	0.0005	4.62	6.50	0.0005
22-24.9	13.81	14.85	0.1944	13.20	15.23	0.0072	13.57	18.49	<.0001
25-29.9	38.61	38.57	0.9684	38.20	38.76	0.5932	38.10	40.42	0.0544
30-24.9	26.67	25.41	0.2068	27.18	25.07	0.0239	26.41	23.14	0.0025
35+	16.48	15.96	0.5305	17.53	15.42	0.0074	17.30	11.45	<.0001
Female (%)	61.35	54.24	<.0001	59.59	54.46	<.0001	56.19	55.75	0.7197
Race / Ethnicity (% distribution)									
Non-Hispanic White / Other	60.43	86.59	<.0001	64.07	87.14	<.0001	76.65	91.8	<.0001
Non-Hispanic Black	17.78	10.29	<.0001	18.46	9.32	<.0001	14.56	3.30	<.0001
Hispanic	21.79	3.12	<.0001	17.47	3.53	<.0001	8.79	4.90	<.0001
Childhood SEP									
Mother's Education ≥ 8 yrs (%)	---	---		34.78	92.29	<.0001	70.44	87.19	<.0001
Father's Education ≥ 8 yrs (%)	20.07	84.93	<.0001	---	---		63.19	86.56	<.0001
Father White Collar Job (%)	10.07	24.24	<.0001	8.62	26.15	<.0001	---	---	
Education, yrs (SD)	10.52 (3.78)	13.33 (2.56)	<.0001	10.88 (3.62)	13.40 (2.58)	<.0001	12.20 (3.20)	14.12 (2.59)	<.0001
Education category (% distribution)									
Incomplete high school	46.36	13.10	<.0001	41.31	12.59	<.0001	25.39	7.86	<.0001
Complete high school	30.56	34.86	<.0001	33.13	34.02	0.3756	35.98	25.04	<.0001
Some college	13.20	24.21	<.0001	14.98	24.33	<.0001	20.26	25.52	<.0001
College graduate	4.92	13.25	<.0001	5.20	13.84	<.0001	9.12	18.63	<.0001
Post college	4.96	14.58	<.0001	5.39	15.22	<.0001	9.26	22.95	<.0001
Current BMI, (kg/m2) (SD)	27.69 (5.03)	27.20 (4.91)	0.0006	27.65 (5.14)	26.98 (4.92)	<.0001	27.46 (5.14)	26.15 (4.47)	<.0001
Health Conditions[c] (%)									
Diabetes	24.30	17.71	<.0001	24.84	16.89	<.0001	20.27	16.21	<.0001
Hypertentsion	66.54	56.60	<.0001	65.78	56.10	<.0001	59.43	58.32	0.3632
Stroke / TIA	12.09	8.39	<.0001	12.08	8.08	<.0001	9.19	10.00	0.2653
Current Smoker[c] (%)	20.60	21.53	0.3190	21.17	21.34	0.8442	22.11	18.10	<.0001
Mean household wealth, 1992 $ (SD)	138,224.44 (311,265.47)	273,135.72 (540,014.05)	<.0001	148,694.63 (320,865.22)	279,893.61 (552,527.53)	<.0001	212,090.62 (469,825.51)	337,720.92 (568,161.16)	<.0001
Mean number of waves tested, (SD)	4.97 (2.01)	4.73 (2.22)	<.0001	4.92 (2.03)	4.73 (2.23)	<.0001	4.61 (2.27)	5.51 (1.51)	<.0001
Ever required a proxy interview (%)	16.60	9.43	<.0001	15.72	9.22	<.0001	11.59	10.19	0.0736

[a]Mean and standard deviation are presented for continuous variables; percentage is presented for categorical variables. Estimates are unweighted.

[b]Mean composite memory score ranges from 0 to 100

[c]Ever reported condition or beahvior during study period

Table 4.1. (Cont.) Descriptive Statistics of Respondents over Age 50 by Sex, Obesity at Baseline, and SEP

	Education			Household Wealth		
	< 12 yrs (n=2,186)	12+ yrs (n=7,848)	p value	< $107,169 (n=5,017)	≥ $107,170 (n=5,017)	p value
Mean age, yrs (SD)	63.57 (9.83)	60.33 (8.82)	<.0001	60.64 (9.26)	61.44 (9.00)	<.0001
Mean memory score at baseline[b], (SD)	44.80 (20.61)	59.12 (19.54)	<.0001	52.72 (21.19)	59.28 (19.54)	<.0001
Mean birth year, yr (SD)	1931.10 (10.53)	1935.64 (10.68)	<.0001	1935.00 (10.98)	1934.29 (10.63)	<.0001
Highest Reported BMI, (kg/m^2) (SD)	30.55 (6.44)	29.77 (6.28)	<.0001	30.77 (6.87)	29.12 (5.59)	<.0001
BMI category, (kg/m2) (% distribution)						
< 22	3.80	5.34	0.0034	4.74	5.26	0.2338
22-24.9	12.53	15.15	0.0022	12.70	16.46	<.0001
25-29.9	36.37	39.19	0.0163	35.02	42.14	<.0001
30-24.9	28.73	24.91	0.0003	27.05	24.44	0.0028
35+	18.57	15.41	0.0004	20.49	11.70	<.0001
Female (%)	58.37	55.47	0.0155	59.30	52.90	<.0001
Race / Ethnicity (% distribution)						
Non-Hispanic White / Other	59.56	85.38	<.0001	68.15	91.37	<.0001
Non-Hispanic Black	19.3	10.28	<.0001	19.69	4.8	<.0001
Hispanic	21.13	4.33	<.0001	12.16	3.83	<.0001
Childhood SEP						
Mother's Education ≥ 8 yrs (%)	44.42	82.08	<.0001	65.42	82.34	<.0001
Father's Education ≥ 8 yrs (%)	39.30	75.98	<.0001	58.84	77.14	<.0001
Father White Collar Job (%)	7.41	24.20	<.0001	14.93	26.15	<.0001
Education, yrs (SD)	8.13 (2.69)	13.84 (1.95)	<.0001	11.57 (3.37)	13.61 (2.60)	<.0001
Education category (% distribution)						
Incomplete high school	100.00			33.35	10.23	<.0001
Complete high school		43.13		34.04	33.43	0.5128
Some college		27.28		19.69	22.98	<.0001
College graduate		14.16		6.06	16.09	<.0001
Post college		15.43		6.86	17.28	<.0001
Current BMI, (kg/m2) (SD)	27.74 (5.11)	27.04 (5.01)	<.0001	27.80 (5.44)	26.58 (5.00)	<.0001
Health Conditions[c] (%)						
Diabetes	27.40	17.21	<.0001	23.68	15.19	<.0001
Hypertentsion	68.07	56.73	<.0001	63.36	55.03	<.0001
Stroke / TIA	13.04	8.33	<.0001	11.40	7.32	<.0001
Current Smoker[c] (%)	26.30	19.89	<.0001	26.79	15.79	<.0001
Mean household wealth, 1992 $ (SD)	95,273.43 (277,883.15)	277,621.51 (532,487.67)	<.0001	36,309.67 (81,412.77)	439,480.92 (632,950.52)	<.0001
Mean number of waves tested, (SD)	4.97 (1.98)	4.74 (2.21)	<.0001	4.74 (2.19)	4.84 (2.14)	0.0127
Ever required a proxy interview (%)	21.09	8.58	<.0001	12.92	9.69	<.0001

[a]Mean and standard deviation are presented for continuous variables; percentage is presented for categorical variables. Estimates are unweighted.

[b]Mean composite memory score ranges from 0 to 100

[c]Ever reported condition or beahvior during study period

Table 4.2. Ordinary Least Squares Regression Coefficients of Highest Lifetime BMI (N=10,034)

	Model 1: Independent Effect of Childhood SEP			Model 2: All Childhood SEP Variables			Model 3: Adding Educaiton			Model 4: Adding Wealth		
	Coefficient	*SE*	*p value*	Coefficient	*SE*	*p value*	Coefficient	*SE*	*p value*	Coefficient	*SE*	*p value*
Childhood SEP												
Mother's Education ≥ 8 yrs (%)	-0.354	0.153	0.247	0.278	0.183	0.128	0.453	0.185	0.014	0.494	0.184	0.007
Father's Education ≥ 8 yrs (%)	-0.874	0.142	<.0001	-0.849	0.171	<.0001	-0.721	0.172	<.0001	-0.645	0.171	0.000
Father White Collar Job (%)	-1.110	0.155	<.0001	-0.973	0.157	<.0001	-0.788	0.160	<.0001	-0.718	0.159	<.0001

[a]All models adjusted for age, sex, and race/ethnicity

Table 4.3. Repeated Multivariate Analysis[a] of Change in Cognitive Function – Effect of Highest Lifetime BMI and Current BMI

	Model 1: Highest BMI Unadjusted		Model 2: Adding Retest, Proxy Status, and Demographics[b]		Model 3: Adding Education		Model 4: Adding Current BMI		Model 5: Adding Diabetes, Hypertentsion, and Stroke		Model 6: Adding Current Smoking	
	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*	Coefficient	*SE*
Fixed Effects												
Initial Status												
Intercept at Age 65	53.0539	0.1433	53.9638	0.2870	52.1999	0.2765	52.5622	0.9172	53.2656	0.9197	53.3550	0.9310
Main Effects												
Highest BMI[c]	-0.2338	0.0228	-0.1222	0.0209	-0.0526	0.0195	-0.0412	0.0291	-0.0032	0.0295	-0.00366	0.02951
Current BMI							-0.0154	0.0319	-0.0224	0.0319	-0.0241	0.0321
Rate of Change												
Age (slope per decade)	-9.1432	0.1209	-14.2193	0.2492	-14.1183	0.2473	-17.0708	0.8646	-16.9587	0.8701	-16.7487	0.8784
Highest BMI	0.0117	0.0197	0.0216	0.0187	0.0198	0.0181	-0.05518	0.0272	-0.0572	0.0274	-0.0568	0.0274
Current BMI							0.1112	0.0311	0.1145	0.0312	0.1102	0.0313
Random Effects												
Variances												
Between Individuals												
In initial status	139.1500	2.9928	148.2100	4.9307	126.5800	4.6133	126.4500	4.6295	126.1100	4.6234	126.0500	4.6219
In rate of change	24.4311	2.1642	12.6766	1.7953	11.9928	1.6848	12.1171	1.6898	12.0799	1.6821	12.0316	1.6812
Retest variance			63.3393	4.2099	62.0096	4.1742	62.5003	4.2009	62.2167	4.1951	62.0734	4.1933
Within-person												
Residual errors	170.4800	1.3015	158.1700	1.3294	158.2800	1.3285	158.1700	1.3333	158.1200	1.3327	158.1300	1.3327
Total Variance	334.0611		382.3959		358.8624		359.2374		358.5266		358.2850	
Goodness of Fit												
-2LL	399976.8		397160.1		395757.4		393057.5		392956.6		392951.4	
AIC	399992.8		397202.1		395803.4		393107.5		393018.6		393017.4	
BIC	400050.5		397353.6		395969.3		393287.9		393242.3		393255.5	

[a] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=10,034 with D=48,071; shaded cells are not significant at $p < 0.05$

[b] Demographics include: sex, race/ethnicity (Non-Hispanic white, Non-Hispanic black, Hispanic) and cohort

[c] Highest BMI is centered at 30 kg/m^2

Table 4.4. Effect of Highest Reported BMI[a] on Cognitive Function by Sex[b]

	Sex					
	Men			Women		
	Coefficient	*SE*	p value	Coefficient	*SE*	p value
Model 1						
Initial Status	-0.141	0.039	0.0003	-0.276	0.027	<.0001
Rate of Change	-0.065	0.035	0.0656	0.062	0.024	0.0084
Model 2						
Initial Status	-0.084	0.037	0.0243	-0.146	0.026	<.0001
Rate of Change	-0.035	0.034	0.3068	0.046	0.023	0.0441
Model 3						
Initial Status	-0.014	0.034	0.6718	-0.070	0.024	0.0043
Rate of Change	-0.026	0.033	0.4185	0.041	0.022	0.0653
Model 4						
Initial Status	-0.037	0.051	0.4682	-0.041	0.036	0.2517
Rate of Change	-0.106	0.049	0.0309	-0.032	0.033	0.3303
Model 5						
Initial Status	0.006	0.052	0.9071	-0.006	0.036	0.8747
Rate of Change	-0.113	0.049	0.0223	-0.032	0.033	0.3420
Model 6						
Initial Status	0.009	0.052	0.8696	-0.008	0.036	0.8306
Rate of Change	-0.113	0.049	0.0217	-0.030	0.033	0.3619

[a] Highest BMI is centered at 30 kg/m^2

[b] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=10,034 with D=48,071; shaded cells are not significant at $p < 0.05$

*Model 1 is unadjusted; Model 2 is adjusted for retest, proxy status, and demographics [race/ethnicity (Non-Hispanic white, Non-Hispanic black, Hispanic) and cohort]; Model 3 is adjusted for retest, proxy status, demographics, and years of education; Model 4 is adjusted for retest, proxy status, demographics, years of education, and current BMI; Model 5 is adjusted for retest, proxy status, demographics, years of education, current BMI, and health conditions (diabetes, hypertension, and stroke); Model 6 is adjusted for retest, proxy status, demographics, years of education, current BMI, health conditions, and smoking status.

Table 4.5. Effect of Highest Reported BMI[a] on Cognitive Function by Obesity at Baseline[b]

	Obesity					
	BMI < 30 kg/m^2			BMI ≥ 30 kg/m^2		
	Coefficient	*SE*	p value	Coefficient	*SE*	p value
Model 1						
Initial Status	-0.292	0.040	<.0001	-0.083	0.047	0.0758
Rate of Change	0.009	0.032	0.7897	-0.078	0.043	0.0683
Model 2						
Initial Status	-0.130	0.036	0.0003	-0.102	0.043	0.0186
Rate of Change	0.038	0.030	0.2052	-0.071	0.040	0.0771
Model 3						
Initial Status	-0.055	0.034	0.1051	-0.059	0.041	0.1443
Rate of Change	0.033	0.029	0.2569	-0.066	0.039	0.0891
Model 4						
Initial Status	-0.040	0.042	0.3366	-0.064	0.048	0.1854
Rate of Change	-0.011	0.036	0.7622	-0.144	0.047	0.0024
Model 5						
Initial Status	-0.003	0.042	0.9424	-0.034	0.048	0.4819
Rate of Change	-0.007	0.036	0.8448	-0.156	0.048	0.0010
Model 6						
Initial Status	-0.003	0.042	0.9448	-0.036	0.048	0.4603
Rate of Change	-0.006	0.036	0.8596	-0.156	0.048	0.0010

[a] Highest BMI is centered at 30 kg/m^2

[b] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=10,034 with D=48,071; shaded cells are not significant at $p < 0.05$

*Model 1 is unadjusted; Model 2 is adjusted for retest, proxy status, and demographics [sex, race/ethnicity (Non-Hispanic white, Non-Hispanic black, Hispanic) and cohort]; Model 3 is adjusted for retest, proxy status, demographics, and years of education; Model 4 is adjusted for retest, proxy status, demographics, years of education, and current BMI; Model 5 is adjusted for retest, proxy status, demographics, years of education, current BMI, and health conditions (diabetes, hypertension, and stroke); Model 6 is adjusted for retest, proxy status, demographics, years of education, current BMI, health conditions, and smoking status.

Table 4.6. Effect of Highest Reported BMI[a] on Cognitive Function by Measures of Childhood SEP[b]

	Mother's Education						Father's Education						Father's Occupation					
	< 8 yrs			8+ yrs			< 8 yrs			8+ yrs			Blue Collar / Unemployed			White Collar		
	Coefficient	*SE*	p value	Coefficient	*SE*	p value	Coefficient	*SE*	p value	Coefficient	*SE*	p value	Coefficient	*SE*	p value	Coefficient	*SE*	p value
Model 1																		
Initial Status	-0.126	0.049	0.0105	-0.254	0.026	<.0001	-0.168	0.042	<.0001	-0.234	0.027	<.0001	-0.192	0.025	<.0001	-0.245	0.050	<.0001
Rate of Change	-0.005	0.037	0.8992	0.003	0.024	0.8964	0.015	0.033	0.6595	-0.001	0.025	0.9768	-0.002	0.022	0.9318	0.048	0.045	0.2916
Model 2																		
Initial Status	-0.049	0.045	0.2760	-0.135	0.024	<.0001	-0.080	0.038	0.0363	-0.117	0.025	<.0001	-0.101	0.023	<.0001	-0.134	0.047	0.0041
Rate of Change	0.008	0.035	0.8290	0.017	0.023	0.4372	0.016	0.032	0.6095	0.018	0.024	0.4427	0.019	0.021	0.3631	0.040	0.043	0.3473
Model 3																		
Initial Status	0.001	0.041	0.9757	-0.069	0.023	0.0026	-0.058	0.035	0.0974	-0.042	0.024	0.0834	-0.050	0.022	0.0216	-0.065	0.045	0.1469
Rate of Change	0.008	0.034	0.8208	0.018	0.022	0.4071	0.019	0.030	0.5271	0.021	0.023	0.3569	0.014	0.020	0.4783	0.043	0.042	0.3156
Model 4																		
Initial Status	-0.004	0.059	0.9497	-0.059	0.034	0.0813	-0.088	0.052	0.0903	-0.019	0.036	0.5970	-0.036	0.032	0.2727	-0.081	0.067	0.2265
Rate of Change	-0.006	0.050	0.9067	-0.091	0.033	0.0062	-0.016	0.046	0.7292	-0.077	0.035	0.0271	-0.072	0.031	0.0186	0.006	0.060	0.9271
Model 5																		
Initial Status	0.054	0.060	0.3649	-0.027	0.034	0.4402	-0.033	0.053	0.5339	0.014	0.037	0.7075	0.002	0.033	0.9488	-0.048	0.068	0.4859
Rate of Change	-0.030	0.051	0.5573	-0.084	0.033	0.0116	-0.037	0.046	0.4241	-0.068	0.035	0.0540	-0.074	0.031	0.0168	0.004	0.061	0.9459
Model 6																		
Initial Status	0.057	0.060	0.3464	-0.027	0.034	0.4252	-0.033	0.053	0.5242	0.013	0.037	0.7147	0.002	0.033	0.9549	-0.049	0.068	0.4700
Rate of Change	-0.030	0.051	0.5491	-0.084	0.033	0.0117	-0.036	0.046	0.4306	-0.067	0.035	0.0550	-0.073	0.031	0.0172	0.005	0.061	0.9366

[a] Highest BMI is centered at 30 kg/m^2

[b] Models fit with SAS 9.1 Proc Mixed without sampling weights using N=10,034 with D=48,071; shaded cells are not significant at $p < 0.05$

*Model 1 is unadjusted; Model 2 is adjusted for retest, proxy status, and demographics [sex, race/ethnicity (Non-Hispanic white, Non-Hispanic black, Hispanic) and cohort]; Model 3 is adjusted for retest, proxy status, demographics, and years of education; Model 4 is adjusted for retest, proxy status, demographics, years of education, and current BMI; Model 5 is adjusted for retest, proxy status, demographics, years of education, current BMI, and health conditions (diabetes, hypertension, and stroke); Model 6 is adjusted for retest, proxy status, demographics, years of education, current BMI, health conditions, and smoking status.

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CHAPTER 5

CONCLUSION

5.1 Summary of Findings

This dissertation examined the role of socioeconomic position (SEP) as a predictor of cognitive function and change among older adults. Specifically, SEP was examined as a potential mediator of the effect of education on late life cognitive function, as an effect with potential origins in early childhood, and as a moderator of the relationship between adiposity and cognition. The focus of this research was to apply a lifecourse approach to the conceptualization and modeling of the social and economic determinants of cognitive performance, and in doing so, attempt to further understand the relationship between disadvantage at different life stages and cognitive health in adulthood.

Specific Aim 1 – Education, adult socioeconomic position, and cognition

(1) To examine the effect of education and other measures of socioeconomic position on cognitive performance and decline, (2) to determine to what extent the effect of education is mediated by socioeconomic status in adulthood, and (3) determine whether these relationships are modified by birth cohort, gender, and race/ethnicity.

In the first paper we hypothesized that higher levels of education, through both direct and indirect pathways mediated by income, wealth, and occupational status in adulthood, would be associated with better cognitive performance and protective against cognitive decline. In addition, we expected these effects to vary significantly across demographic subgroups. Similar to several earlier studies, the results presented here suggest that education has a significant and lasting effect on memory-based cognitive performance later in life. [Cagney et al., 2002; Evans et al., 1993; Stern et al., 1994; Stern et al., 1999] Years of educational attainment were positively related to higher scores at age 65, with each year of education adding an additional 2 percentage points. In addition, having a high school degreed conferred additional benefit net of years of education. However, while contributing a higher baseline level of performance in complex verbal memory tasks, education was actually associated with faster decline over time.

Income, wealth, and lifetime occupation were also associated with cognitive function and only slightly attenuated the effect of education. This suggests that educational attainment has a strong direct effect on cognition independent of its correlation with higher SEP in adulthood. Of these other measures of SEP, occupation had the largest impact on improved cognitive performance at age 65 and like education, also contributed toward a more rapid decline with increasing age.

The association between education and cognition was similar for whites and blacks and for men and women, both independently and adjusted for other measures of SEP. However, there was a differential effect of education across ethnicity and birth cohort. Education did not confer the same benefit for Hispanics as for whites and blacks,

with Hispanics experiencing a 40% smaller return for each year of education. In addition, more recently born cohorts had lower cognitive performance scores at age 65 than older cohorts but declined less rapidly. There was also a significant interaction between birth cohort and education that persisted after adjustment for SEP factors. Each year of education provided less advantage to younger cohorts.

Specific Aim 2 - Early life socioeconomic position, social mobility, and cognition

(1) To determine whether there is a direct effect of childhood SEP on cognitive performance later in life or whether it is mediated entirely through education and measures of SEP in adulthood, (2) to evaluate whether there are gender or cohort differences in the effects of childhood SEP and education on cognitive performance and decline, and (3) to determine whether accumulation of socioeconomic disadvantage and social mobility from childhood to adulthood affect cognitive function.

Measures of childhood SEP, including both parents' education, father's occupation, childhood SES, and childhood health were related to the absolute level of performance on memory-related cognitive tasks at age 65. Father's education and childhood health were both inversely associated with cognitive change. However, in models adjusted for all measures of childhood SEP simultaneously, only father's education remained predictive of cognitive change and childhood SES no longer remained a significant effect on cognitive function at age 65.

Measures of adult SEP mediated the relationship between childhood SEP and cognitive performance in older age. Respondents' education, occupation, and household income and wealth, all mediated the effect of childhood SEP on cognitive function and

cognitive change. Of these measures, education was the strongest attenuator of the effects of childhood SEP suggesting that education mediates the association of early life SEP with cognitive-related outcome more than later-life material resources or social class. However, several measures of childhood SEP including maternal education, childhood SES, father's occupation, and childhood health, had a lasting effect on memory test performance net of the downstream effects of education and adult SEP. This provides additional evidence that early life circumstances are important influences in shaping adult cognitive health. These results do not support the hypothesis that advantageous conditions in early life are associated with less rapid decline in cognitive function in older age. There was no association between early life SEP measures and cognitive change after adjustment for education and adult SEP.

There was no evidence to suggest that gender interacts with childhood SEP to affect adult cognitive functioning; however, differences between cohorts were observed. Respondents from later born cohorts appeared but experienced a slightly greater advantage from better childhood health.

This study found that social mobility was a significant predictor of cognitive functioning in adulthood. Respondents in the stable high group, high SEP throughout childhood and adulthood, obtained the best cognitive performance at age 65, while those in the stable low group performed the worst on the memory tasks. Respondents with low status in childhood who experienced upward mobility through education and above median SEP in adulthood had better cognitive performance at age 65 than respondents with a similar childhood background and less upward mobility. A reverse pattern was observed for who experienced downward mobility. Those who benefited from a

advantage in childhood and then experienced downward mobility into lower education and occupation, income, or wealth groups in adulthood, had worse cognitive performance at age 65 than every other group with the exception of those who were in lowest group though all life stages. In contrast, change appears to be inversely related to social mobility with the stable high and more upwardly mobile groups experiencing faster decline with age than those in the stable low or downwardly mobile groups. Consistent results were found regardless of whether household income, wealth, or occupation was used as the adult SEP measure.

Specific Aim 3 - Body mass index, lifecourse socioeconomic position, and cognition

(1) To determine whether measures of childhood SEP are associated with highest lifetime BMI, (2) to ascertain whether the effect of BMI on cognition is mediated by vascular-related health problems and BMI in later life, (3) to evaluate whether gender, obesity at baseline, and measures of SEP in childhood and adulthood modify the association between BMI in midlife and cognition.

Childhood SEP was a significant predictor of highest lifetime BMI. Higher paternal education and white collar occupation were associated with lower BMI while higher maternal education was associated with a higher BMI. Adjustment for respondents' education and wealth attenuated the effect of paternal education and occupation by approximately 25%. However, adjustment by these factors increased the magnitude of the association of BMI with maternal education.

Highest lifetime BMI was negatively associated with memory-based cognitive performance although this effect was significantly mediated by current BMI and

vascular-related health conditions. Adjustment for education also attenuated the effect of highest BMI on cognitive performance suggesting that it is an important confounder of this relationship. However, the effect of highest BMI, as well as the strength of the mediating factors, differed by subgroup. Maternal education, father's occupation, gender, and current BMI are effect modifiers of the association between highest lifetime BMI and cognitive performance in later life.

Highest BMI was not associated with cognitive decline in unadjusted models but was significantly and inversely related to cognitive decline in models adjusted for current BMI. This relationship was also modified by childhood SEP, gender, and current obesity. However, highest lifetime BMI did not contribute to or ameliorate the large age-related decline in cognitive performance. In contrast, current BMI was protective against decline even after adjustment for vascular health conditions and smoking status.

5.2 Limitations and Recommendations for Future Research

Measurement Error

Measurement of childhood SEP - Measures of childhood SEP were obtained from retrospective reports of parental education and occupation and other early-life circumstances. Recall of childhood health and family financial situation in childhood may be influenced by circumstances of adult health and socioeconomic status. A recent study comparing the effect of self-reported recalled measures of socioeconomic conditions in early life with more objective historical records from health records found that objective measures had a stronger association with mortality and other health outcomes suggesting that the measures used in these analyses may have lead to an

underestimate of the effect of childhood SEP on cognition. [Kauhanen et al., 2006] Better measures of childhood SEP, ones that are more specific and potentially related to deprivation in early life, would help to elucidate the pathways that link socioeconomic position at each lifecourse stage with cognitive function in adulthood. Similarly, measures of early-life cognitive performance, such as IQ upon completion of high school, would also help to disentangle the causal and selection-based explanations of the association between childhood SEP and cognition

Measurement of education and adult SEP - The use of self-reported education level, income, wealth, and occupation data is subject to recall bias since the quality of self-reported information may vary by cognitive performance. In addition to validating or obtaining some of the SEP data from an objective source, future research would benefit from the use of more specific measures of SEP, especially with regard to the measure of education. After adjustment for education and other measures of SEP, significant differences in cognitive performance and rate change remained by gender, race/ethnicity, and cohort. These differences may in part reflect differences in the quality of education. Additional research should explore other measures that better address the meaning of education in populations in which quality is variable and confounded by demographic factors. Including other measures of education quality, such as literacy, may help to deconstruct the various components of education that may contribute to cognitive reserve or are related to innate ability. [Manly et al., 2003] Additional education-related measures may also help to explain the residual heterogeneity in cognitive performance even after education level is factored into the predictive models.

Cognitive performance - The cognitive performance measure used in these analyses was a composite measure of performance on two memory-based recall tasks. Although these tasks were selected because they have been shown to be sensitive measures of cognitive change, they measure only one domain of cognitive performance. [Small et al., 1999] The type of test used to measure cognitive performance is important since not all domains decline at the same rate. Future research should repeat these analyses using the other measures of cognitive performance available in the HRS including, working memory/fluid intelligence (Serial 7's) and general mental status (the Telephone Interview for Cognitive Performance).

Measurement of health conditions and body mass index - Relying on self-report of health conditions is not as reliable as using clinical or laboratory-based indicators of disease. Future research should consider supplementing these reports with biomarker data, such as fasting glucose, hemoglobin A1c, and C-reactive protein, to validate self-reported disease status and indicate disease among undiagnosed persons. Similarly, the use of self-reported height and highest weight in the calculation of BMI is not the ideal measure of adiposity. Measures such as waist-to-hip ratio and waist circumference are better physical measures of central adiposity. Future research should also incorporate measures of bioactive hormonal compounds that are secreted by adipose tissue, such as leptin and sex hormone binding globulin (SHBG), as additional measures of adiposity-related health status. [Gustafson 2006; Gustafson et al., 2007] In addition, as cohorts age it will be possible to track secular changes in obesity with changes in the prevalence do cognitive outcomes which will provide a better understanding of the temporal associations across early, mid, and late life. [Gustafson 2006]

Model Estimation

There are some limitations of the methods that were used in these analyses to model the trajectories of cognitive change. The growth-curve approach used here did not incorporate sampling weights in the estimation of the models. The inability to adjust using sampling weights with the SAS PROC MIXED procedure makes the models more sensitive to model misspecification. This could occur if either the sampling is informative (i.e. related to the outcome even after conditioning on covariates) or if the functional form of model is misspecified and has a quadratic rather than linear trend. These analyses should be repeated using a statistical package such as HLM or Mplus that can utilize survey weights in the estimation of this type of model.

Attrition and Generalizability

Another important limitation of this research is the potential effect of attrition on the sample that varies somewhat across waves. Although the HRS attempts to interview through use of a proxy when needed, inclusion in the analyses necessitates respondents to personally complete to cognitive section of the survey. Since 2000, HRS has collected self-reported cognition data on those who are interviewed by proxy but not all respondents who are unwilling or unable to be interviewed are represented by proxy. Some respondents are lost to follow-up, refusal, and death between interview waves. Many reasons for attrition are related to education and cognitive impairment; those who are more cognitively impaired or have less education are also less likely to participate in the study. Attrition due to cognitive impairment may bias the sample toward a more cognitively intact group and away from seeing an effect of lower education on faster rates of decline if one existed if this group of respondents had a higher mortality risk. We have

attempted to minimize the confounding effects of attrition by controlling for demographic characteristics related to the selection bias, use of a proxy informant at any time during the study period, and death status at last contact, but it is difficult to completely account for the potential differential selection due to attrition and mortality. Thus, these results may not be generalizable to older adults with moderate to severe cognitive impairment who never completed the cognitive portion of the interview at any wave.

Disentangling Age and Cohort Effects

This research has attempted to examine some of the cohort effects that may be confounded with age effects in cross-sectional studies and the data suggest there might be important differences in the effect of SEP on cognition by birth cohort. However, because of the limited overlap of the cohorts observed in the HRS, it is not possible to come to definite conclusions about the potential moderating effect of birth cohort on the relationship between SEP and cognition until additional waves of data are collected. As more data become available, further investigation into the effect of birth cohort is warranted.

5.3 Major Contributions

This dissertation research applied both a lifecourse approach to investigating the relationship between measures of SEP in childhood and adulthood to memory-based cognitive function in older age and employed an analytic method that fully utilized the longitudinal nature of the data to characterize the trajectories of change over time. Because the relationship between risk factors and outcomes spans a longer amount of time for older adults, there is a greater potential for skewing of the temporal association

between cause and effect. As a result, there is a greater need to take a lifecourse approach in research on again and to consider the role of risk factors prior to the onset of older age. In this light, it might be more apt to think of age-related cognitive impairment and decline as a disease of a lifetime rather than as a late-life disease. [Gustafson 2006]

These results add to previous research on SEP and cognitive function and change that have used cross-sectional data or longitudinal data with limited age or geographic representativeness. The large and nationally representative sample of the HRS provides greater geographic representation than prior epidemiologic studies of cognitive change and dementia, and greater generalizability to populations that might not normally be represented in clinical-based samples. Because this research focuses on the effects of SEP on cognitive health, it is especially important that there was sufficient social and economic-related variability in these data. Additionally, the use of growth curve modeling takes advantage of the longitudinal nature of the data and allowed us to make full use of data for all eligible subjects.

This research further supports prior work documenting the lasting impact of education on cognition. The effect of education was robust to adjusting for later life SEP factors indicating that it conferred an additional benefit on cognitive performance level aside from the effect on SEP in adulthood. Consistent with much of the previous research on the effects of childhood SEP on cognition in older age, these results suggest that cognitive performance in adulthood may have origins early in life and that upward social mobility may ameliorate the effects of childhood disadvantage. Additionally, this research also provides a first step toward an examination of the effects of both age and cohort on change in cognitive functioning and the effect of birth cohort on the

relationship between SEP and cognition. Lastly, this study contributes to the growing body of evidence linking obesity to cognitive impairment and adds that lifecourse SEP may be an important risk factor in the development of overweight and obesity and subsequent cognitive status. The research also suggests that gender, lifecourse SEP, and current BMI are important effect modifiers of the relationship between highest lifetime BMI and cognitive performance.

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