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The impact of productive and leisure activities on cognitive health in later life

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THE IMPACT OF PRODUCTIVE AND LEISURE ACTIVITIES ON COGNITIVE HEALTH IN LATER LIFE

by

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DEDICATION

I would like to dedicate this work to my family. Most importantly, this dissertation is for my parents. Without their sacrifice and support, I would not have had the opportunity to study this far. I admire their love for God and passion for serving vulnerable people. Thank you for trusting in me and being the most loving parents that I could ever ask for.

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THE IMPACT OF PRODUCTIVE AND LEISURE ACTIVITIES

ON COGNITIVE HEALTH IN LATER LIFE

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ABSTRACT

Background and Objectives: Cognitive decline in old age brings challenges such as economic and caregiving burden, loss of independence, and other health consequences (Alzheimer's Association, 2018). The productive aging literature has advanced a number of ideas about how to stay healthy in later life (Hooyman & Kiyak, 2018; Morrow-Howell, Gonzales, Matz-Costa, & Greenfield, 2015). However, existing literature has: tended to focus on productive and leisure activities during limited spans of time; not explored how the productive/leisure activity–cognitive health relationship differs by the social determinants of health such as gender or race/ethnicity; and has not considered how these activities are collectively associated with cognition among older adults in the United States. Thus, using longitudinal data from a national cohort of older adults, this dissertation focuses on the following research questions: (1) Are the previous and ongoing cognitive, physical, and social complexities of work associated with cognitive health in later life? (2-a) Are the ongoing cognitive, physical, and social complexities of work and volunteering associated with cognitive health in later life? (2-b) Are the ongoing cognitive, physical, and social complexities of work, volunteering, and leisure activities associated with cognitive health in later life? For each question, the dissertation will explore whether associations vary by key social determinants of health.

Research Design: Using a nationally representative sample of older adults (51+) in the Health and Retirement Study (HRS; 2004–2014), growth curve modeling is applied. The samples for research questions 1, 2-a, and 2-b include the following respondents, respectively: the Early Baby Boomer cohort, the HRS core survey respondents, and the HRS core respondents who provided information on leisure activity in the HRS Consumption and Activities Mail Survey (CAMS).

Contributions: Consistent with the Social Work Grand Challenge of advancing long and productive lives by focusing on cognitive aging, this study provides insight into cognitive aging research, interventions, and policy from a behavioral and social science perspective. Overall, this study adds to the discussion about policies and services to support older adults in maintaining active lifestyles and to promote healthy cognitive aging among older adults in the United States.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Cognitive decline in old age brings challenges such as economic and caregiving burden, loss of independence, and other health consequences (Alzheimer's Association, 2018). Dementia care is costly; the costs for dementia care are expected to increase from between $159 billion and $215 billion in 2010 to between $379 billion and $511 billion by 2040 (Hurd, Martorell, Delavande, Mullen, & Langa, 2013). Moreover, the combined Medicare and Medicaid spending on Alzheimer's was approximately $186 billion in 2018, and this is expected to increase to $750 billion in 2050 (Alzheimer's Association, 2018). Responding to this issue, dementia research funding at the National Institutes of Health (NIH) increased from $338 million in 2011 to $2.3 billion in 2019 (Alzheimer's Impact Movement, 2018). With the growing size of the older adult population (He, Goodkind, & Kowal, 2016), cognitive health issues in older adulthood are of interest to not only individuals and families but to society at large.

Traditionally, cognitive aging research has been conducted by researchers from biomedical science fields, but an increasing number of social scientists have turned their attention to this area. In particular, the productive aging literature has advanced our knowledge of various opportunities to stay healthy and cognitively active in later life (Andel, Finkel, & Pedersen, 2016; Global Council on Brain Health, 2017; Gonzales, Matz-Costa, & Morrow-Howell, 2015; Morrow-Howell, Gonzales, Matz-Costa, & Greenfield, 2015). They have found that productive activities (i.e., paid or unpaid activities that have value at the societal level rather than only at the individual level; Morrow-Howell, Hinterlong, & Sherraden, 2001) and leisure activities (i.e., non-paid and voluntary activities that people engage in during their free time; Burda, Hamermesh, & Weil, 2007; Pressman et al., 2009; Wang, Xu, & Pei, 2012) are associated with cognitive health benefits, because such activities provide a stimulating environment (Andel et al., 2016; Fisher et al., 2014).

To help explain these findings, previous research has relied on the concept of environmental complexity (Andel et al., 2017; Fisher et al., 2014), which suggests that a complex environment produces stimuli requiring greater thinking and decision-making processes, leading to cognitive health benefits. Because labor force participation has increased rapidly among older adults (e.g., increasing from 12.1 percent in 1990 to 16.1 percent in 2010 for adults 65 and older; Kromer & Howard, 2013), work complexity may be an especially important area of focus, given its potential as a form of cognitive engagement that has cognitive health benefits for older adults (Andel et al., 2016).

In addition, and as noted above, the productive aging framework would suggest the importance of considering engagement in other activities such as formal volunteering and leisure activities as ways to increase older adults' exposure to environmental complexity and to promote cognitive health (Proulx, Curl, & Ermer, 2017; Morrow-Howell et al., 2014). Similar to employment, volunteering and leisure activities require utilizing one's cognitive, physical, and social skills (Fissler, Küster, Schlee, & Kolassa, 2013; Karp et al., 2006). The emerging body of research linking productive and leisure activities with better cognitive health suggests the potential for developing innovative health promotion strategies for older adults (Andel et al., 2005; Andel et al., 2016; Fried et al., 2004; Karp et al., 2009; Proulx et al., 2017).

In spite of the promise of engagement in productive and leisure activities to promote cognitive health, important questions remain concerning what aspects of these activities can result in cognitive benefits. The existing literature has: (1) often been based upon European samples, (2) tended to focus on participation in productive and leisure activities during limited spans of time without taking into account continued engagement in such activities, (3) not explored how productive/leisure activity-cognitive health relationship differ by social determinants of health (e.g., gender, race/ethnicity, education level, and parental education level) and (4) not considered how the complexity of productive activity and leisure environments are collectively associated with cognitive health among older adults in the United States. Therefore, this study explores the longitudinal associations of productive and leisure complexities on cognition using the nationally representative study of older adults in the United States and examines the influence of gender, race/ethnicity, education level, and parental education level.

This dissertation uses a nationally-representative sample of older U.S. adults to investigate the following research questions: (1) Are the previous and ongoing cognitive, physical, and social complexities of work associated with cognitive health in later life? (2-a) Are the ongoing cognitive, physical, and social complexities of work and volunteering associated with cognitive health in later life? (2-b) Are the ongoing cognitive, physical, and social complexities of work, volunteering, and leisure activities associated with cognitive health in later life? For each of these questions, analyses will explore moderating effects by gender, race/ethnicity, education, and parental education, to examine whether key associations differ by important social determinants of health.

THEORY AND EVIDENCE

The subsequent section summarizes theoretical frameworks that guide this study: 1) the productive aging framework, 2) the environmental complexity hypothesis, 3) the cognitive reserve hypothesis, and 4) the use-it-or-lose-it hypothesis. This section introduces each theoretical framework followed by a review of previous literature examining the effect of productive/leisure activity on cognitive health outcomes. Cognition is referred to as either cognitive health or cognitive functioning depending on the cited study. Similarly, the complexity of different activities is described using the terms demand or complexity.

Productive aging framework

This study uses productive aging as the guiding framework to explain the impact of activities such as work and volunteering on health. Productive activities are defined as paid or unpaid activities that contribute to society (e.g., economic benefits) rather than activities that only benefit individuals (Bass, Caro, & Chen, 1993; Morrow-Howell et al., 2001). Compared to other frameworks that address dependence in old age (e.g., disengagement theory; Cumming & Henry, 1961 as cited in Hooyman & Kiyak, 2018) or activity at an individual level (e.g., activity or role theory; Cottrell, 1941, Havighurst, 1963, 1968, as cited in Hooyman & Kiyak, 2018), the productive aging framework emphasizes the capacity of older adults to stay productive by virtue of their ongoing contributions to society (Morrow-Howell et al., 2001). This framework provides an opportunity to perceive the aging process in a positive, strengths-based perspective, rather than viewing older adults as dependent people. Moreover, the productive aging framework is closely linked to social determinants of health as it addresses the impact of social structural factors on one's health. Socioeconomic conditions affect opportunities for older adults to participate in and integrate into society, and these relationships vary by gender, race, and class (Estes & Mahakian, 2001). The productive aging framework informs how policies and services can maximize cognitive aging benefits for older adults through various activities so that they can stay independent and engaged.

The productive aging framework underscores the need to examine the association between cognitive health and engagement in work and volunteering. It suggests that these activities foster healthy and enriched environments through more opportunities for using cognitive, psychological, and physical skills (Morrow-Howell, 2010; Lee et al., 2014). For example, Staudinger, Finkelstein, Calvo, and Sivaramakrishnan (2016) suggest that with positive conditions and choices, engaging in the optimal amount of work can not only bring economic benefits but also cognitive, physical, and mental health benefits for individuals. That is, engagement in productive and nonproductive activities provides pathways to improve health for older adults and promotes a society where older adults are recognized for their contributions. Compared to the major productive activities (e.g., work and volunteering), leisure activities and their impact on cognitive health require greater attention.

Environmental complexity hypothesis

The environmental complexity hypothesis (Kohn & Schooler, 1978) suggests that cognitively stimulating experiences contribute to positive cognitive health outcomes. Previous studies revealed that work, education, and leisure activities contribute to positive cognitive health outcomes in mid to later life (Andel et al., 2017; Andel, Silverstein, & Kåreholt, 2014; Schooler & Mulatu, 2001; Schooler, Mulatu, & Oates, 2004). Building on this hypothesis, Kohn and Schooler (1978) defined work complexity as "substantive complexity of work" meaning "the degree to which the work in its very substance requires thought and independent judgment" (p. 30). Schooler (1984) explained that because it is a critical aspect of the environment for adults, work that requires complex thinking and decision-making processes increases their intellectual flexibility across the lifespan. By extension, volunteering and leisure activities also involve tasks that require cognitive, physical, and social skills that contribute to greater environmental complexity (Fried et al., 2004; Matz-Costa, Carr, McNamara, & James, 2016). In a literature review, Anderson and colleagues (2018) suggest that older adults can engage in cognitive, physical, and social activity through volunteering, resulting in reduced risk of dementia and cognitive decline.

The complexity of productive and leisure activities has been measured in different ways. Scholars have classified work complexity into work with people, data, or things (Andel et al., 2005; Andel et al., 2017). Similarly, volunteering and leisure activities have been documented to play complex roles that require cognitive, physical, and social demands (Anderson et al., 2018; Karp et al., 2006). In sum, according to the environmental complexity hypothesis, work, volunteering, and leisure activities require cognitive, physical, and social skills.

Cognitive reserve hypothesis

Given the potential for productive and leisure activities to stimulate cognitive health, an important consideration is when such exposure should occur to have an impact. The cognitive reserve hypothesis emphasizes how mentally stimulating life experiences can positively influence the brain structure over time. Cognitive reserve is described as the brain's ability to be resilient to damage (Ritchie, Bates, Der, Starr, & Deary, 2013; Stern, 2009), and can be explained as “brain structure and function that can promote normal cognitive function even in the presence of extensive age-related neuropathology” (Andel et al., 2017, p. 2).

Thus, the cognitive reserve hypothesis proposes that greater richness of certain life experiences, such as work and education, can result in building greater brain capacity to efficiently perform mental processing or neurological networking (Ritchie et al., 2013; Stern, 2009). Andel et al. (2017) describe cognitive reserve as “cognitive capital” protecting the brain from cognitive aging and damage. Therefore, people with higher cognitive reserve levels will take a longer period of time before becoming cognitively impaired (Tucker-Drob, Johnson, & Jones, 2009). Studies revealed that engagement in socially and mentally engaging activities contribute to enhanced cognitive reserve and improved cognitive functioning (Vance et al., 2008). Certain experiences in midlife (e.g., work, volunteering, and leisure activities) can mitigate cognitive decline in old age (Boots et al., 2015; Finkel, Andel, Gatz, & Pedersen, 2009; Proulx et al., 2017; Stern, 2009).

The cognitive reserve hypothesis is relevant to current research questions as it conceptualizes the importance of accumulated experience in cognitively stimulating activities as a way to promote cognitive health. For example, guided by the cognitive reserve hypothesis, one's main lifetime occupation contributes significantly towards cognitive reserve, protecting cognition in old age (Andel et al., 2005; Andel et al., 2017).

Use-it-or-lose-it hypothesis

In addition to the accumulation of rich and stimulating experiences, the use-it-or-lose-it hypothesis suggests that ongoing engagement may be relevant to older adults' cognitive health. Scholars across scientific fields have used the term "use-it-or-lose-it" to describe how the usage of mental exercise can support maintaining cognitive health (Fisher et al., 2014; Salthouse, 2006; Salthouse, Berish, & Miles, 2002) and was first documented approximately a hundred years ago (e.g., Foster & Taylor, 1920; Jones & Conrad, 1933 as cited in Salthouse, 2006).

This hypothesis suggests that current participation in cognitively stimulating activities relates to maintenance of or changes in cognitive function (Hultsch, Hertzog, Small, & Dixon, 1999). According to the use-it-or-lose-it hypothesis, retirement or other types of disengagement from cognitively stimulating activities, can result in immediate lower levels of cognitive functioning and a steeper rate of decline in cognitive ability (Fisher et al., 2014). The use-it-or-lose-it hypothesis is relevant to the current research questions because it suggests the importance of considering ongoing levels of activity participation in addition to accumulation of cognitive reserve.

Previous studies on work, volunteering, and leisure activities and cognition

The current section reviews relevant evidence on productive and leisure activities in relation to theories on cognition. Engagement in work by older adults has received the most empirical attention. In a study of Swedish older adults, Andel et al. (2005) examined how work complexity relates to dementia or Alzheimer's dementia. Focusing on the complexity of major lifetime occupation, they found that people who were engaged in an occupation that involved greater interaction with people had a lower risk of Alzheimer's dementia (odds ratio = 0.78; 95% confidence interval = 0.63 to 0.98). Similarly, significant associations between main lifetime work complexity with people or data and cognitive functioning were found among Scottish older adults (Smart, Gow, & Deary, 2014). Moreover, significant associations between lifetime work complexity with people or things and dementia were revealed among Canadian older adults (Kröger et al., 2008). The research (Andel et al., 2005; Finkel et al., 2009; Smart et al., 2014) reveals consistent positive associations between work complexity involving cognitive and social demands (i.e., work with data and people) on cognition. However, associations between physical demands of work (i.e., work with things) and cognition were inconsistent (Kröger et al., 2008). Overall, it can be speculated that cognitive and social occupational demands are more critical to cognitive health than physical work demands.

A growing number of studies in other countries show that long-term exposure to complex work is associated with better cognitive health outcomes. Research in the U.S. has been far more limited. Focusing on the occupation people had engaged in for at least 10 years at the time of retirement, Fisher and colleagues (2014) explored how the mental demands of work (i.e., measured using ten items such as such as analyzing data or information from the Occupational Information Network [O*NET]) are related to cognitive functioning (i.e., episodic memory and mental status) using the longitudinal Health and Retirement Study (HRS). They found that greater mental demands of work were not only associated with higher cognitive functioning but also predicted slower cognitive functioning decline after retirement.

Much less research has focused on the cognitive benefits of volunteerism, but similar to research on work complexity, a handful of studies find that engaging in volunteering requires cognitive, physical, and social demands that may have cognitive health benefits. Proulx and colleagues (2017) found that formal volunteering (i.e., volunteering as time-varying variable) was related to better working memory and cognitive processing. Reporting initial findings, Fried et al. (2004) found that the Experience Corps model, where older adults were trained to help children increase their literacy, activities, problem-solving skills, and school attendance, led to multiple positive health outcomes such as better cognitive functioning among the older adults. Unlike previous research on work complexity, data limitations have prevented researchers from exploring volunteering complexity. One exception to this is that Anderson and colleagues (2018) are developing a volunteering complexity measure assessing the cognitive, physical, and social dimensions of volunteering (N. Anderson, personal communication, May 14, 2018). Moreover, studies on volunteering often focus on physical or mental health outcomes (Anderson et al., 2014; Morrow-Howell, Hinterlong, Rozario, & Tang, 2003; Van Willigen, 2000). Therefore, more studies are needed to explore volunteering and cognitive health among older adults (Anderson et al., 2014).

In addition to productive activities (i.e., work and volunteering), research suggests that engagement in leisure activities may improve cognitive health. Leisure activities are defined as "pleasurable activities that individuals engage in voluntarily when they are free from the demands of work or other responsibilities" (Pressman et al., 2009, p. 2) and have often been classified as cognitive (e.g., playing puzzles), physical (e.g., walks), and social activities (e.g., club meetings; Andel et al., 2016; Chang, Wray, & Lin, 2014; Wang, Karp, Winblad, & Fratiglioni, 2002; Verghese et al., 2003). Because leisure is a broad activity including a wide range of actions, previous research has reported mixed associations between leisure activities and cognitive health. Using leisure activities measured at one-time point, Lee et al. (2014) found positive associations between cognitive leisure activities and processing speed, between cognitive leisure activities and verbal ability, and between social leisure activities and memory among older Australians. There were no significant associations between physical leisure activities and cognitive outcomes. Other longitudinal studies found that mentally and socially stimulating activities are associated with cognitive health benefits. For instance, mentally and socially stimulating activities were associated with lower incidences of dementia (Wang et al., 2002). In another study, self-improvement leisure activities and intellectual cultural activities were related to better verbal ability, spatial ability, and speed among men, and with better verbal ability and memory among women (Hassing, 2017). Among Swedish older adults, cognitive leisure activities were associated with verbal skills, processing speed, and memory whereas physical leisure activities were associated with verbal skills and processing speed (Andel et al., 2016). Wayne and colleagues (2014) performed a systematic review and meta-analysis, finding that a type of Chinese martial art called Tai Chi can provide cognitive benefits. They summarized that Tai Chi improves plasticity in the brain, neurophysiological pathways, working memory skills, and executive functioning. Engaging in Tai Chi can also provide social support and reduction in the negative impact of stress, resulting in cognitive benefit. Yet, previous studies have not used prevailing theories such as the environmental complexity hypothesis to inform their study of leisure and cognitive health. Thus, it is important to understand the complexity of leisure activities to identify the pathways of leisure impact on health.

Furthermore, a gap remains between the definition of leisure complexity and its measurement. Schooler and Mulatu (2001) defined "the cognitive complexity of leisure time activities as the degree to which the environmental demands faced in carrying out such activities derive from diverse stimuli and entail making decisions that require taking into account large numbers of relatively ill-defined and apparently contradictory contingencies" (p. 469). Yet, they measure leisure activities in relatively simplistic ways, for instance as the number of books read within the past 6 months or the frequency of visits to fine art institutions, and likely does not fully capture the definition of complex leisure activities. In another study of Swedish older adults, using the baseline leisure activity information, Karp and colleagues (2006) found that higher levels of mental, social, or physical leisure activity demands were associated with reduced risk of dementia. Karp et al. (2006) is noteworthy as being the only study that has calculated a complexity score for the mental, social, and physical aspects of leisure activities based on the Kungsholmen Project of Swedish older adults. The authors developed a complexity score based on their own judgments (e.g., reading literature scored high (3) for mental demands but low (0) for both physical and social demands).

The literature summarized above is broadly consistent in reporting positive associations between engagement in productive or leisure activities and cognitive health. However, the environmental complexity hypothesis suggests that exploring how the cognitive, physical, and social complexity of all work, volunteering, and leisure activities, relate to cognition would deepen our understanding of cognitive aging. Despite the fact that engagement in both productive and leisure activities ought to be associated with cognitive health, only a limited body of research has examined the joint influence.

Previous studies have often explored the unique impact of work, volunteering, and leisure activities on cognition. However, what is the joint impact of these activities on cognition? Among the three activities, which activity is related to cognition? The following paragraph summarizes what joint associations have been explored. Previous research has explored associations between outcomes for older adults and participation in 1) work and volunteering on mental health (Choi & Bohman, 2007), and on physical health and mortality (Luoh & Herzog, 2002), 2) work and caregiving on health and stress (Fredriksen-Goldsen & Scharlach, 2006) and, on self-perception of aging (Quach, 2018), and 3) volunteering and caregiving on mobility problems, mental health problems, and mortality risk (O'Reilly, Rosato, Ferry, Moriarty, & Leavy, 2017). Fewer scholars have focused on the association between multiple activity engagement and cognitive health (Andel et al., 2014; Andel et al., 2016). Driven by the environmental complexity hypothesis, Andel and colleagues (2014) examined how work (i.e., work with data and people) and leisure (i.e., cognitive activities such as reading books, doing hobbies, going to the movies, going to the theatre, attending study circles and social activities such as visited by friends and/or relatives) relate to cognition as measured by the Mini-Mental State Examination (i.e., registration, orientation, the delayed recall, attention/concentration, and visual-spatial ability) among Swedish older adults. They found that midlife complex work and leisure activities were independently associated with better cognition in later life. They also found that participation in cognitive or physical leisure activities compensated for simpler work environments (Andel et al., 2014). Andel et al. (2014) suggested that those with lower midlife work complexity enjoy cognitive health benefits by having opportunities to engage in leisure activities. Another study of Swedish older adults explored longitudinal associations between cognitive health and leisure (i.e., incorporated one measurement occasion) and complex lifetime work (Andel et al., 2016). The Andel et al. (2016) study used data from the Swedish Adoption/Twin Study of Aging (SATSA) that included up to 23 years of follow-up across up to eight waves to explore how leisure activity (i.e., physical activities, social activities, and cognitive activities) compensates for low work complexity when examining the impact on cognitive functioning (i.e., verbal, spatial, memory, and processing speed abilities). Results indicate that cognitively (i.e., reading books and playing puzzles or chess) and physically engaging leisure (i.e., athletics and walks) activities are associated with cognitive health benefits regardless of the level of work complexity.

Social determinants of health (e.g., gender, race/ethnicity, education, and parental education) are also related to the productive/leisure activities-cognition relationship (Andel et al., 2017; Proulx et al., 2017). Yet the literature is inconclusive. Andel and colleagues (2017) found that work complexity and cognition does not differ by gender. On the other hand, in a cross-sectional study, Grzywacz, Segel-Karpas, and Lachman (2016) found that women experienced a positive association between occupational complexity (e.g., identifying complex problems) and cognitive health such as episodic memory and executive functioning, but this was not true for men. Finkel et al. (2009) found that men experienced higher occupational complexity on average compared to women. This may imply that women may be experiencing different levels of cognitive benefits through work. There were fewer studies exploring whether the relationship between productive/leisure activities and cognition varies by gender, race/ethnicity, education, and parental education. For instance, Proulx and colleagues (2017) found that women and people with low educational attainment can experience greater cognitive health benefits through formal volunteering over time. In terms of parental education, Andel and colleagues (2017) found that the work complexity-cognition relationship differed by childhood economic hardship. Although Morrow-Howell and colleagues (2003) examined how age, gender, race, and social integration moderate the relationship between volunteering and range of health outcomes, they did not include cognition as an outcome.

Gaps in the previous literature

Studies about the association between activities and cognitive aging are growing, yet there are several limitations in extant literature. First, despite a growing number of studies based on other countries, greater attention is needed on older adults in the United States. A Swedish sample has often been utilized to explore the work complexity-cognition association (e.g., Andel et al., 2005; Andel et al., 2014; Andel et al., 2016; Finkel et al., 2009; Karp et al., 2006). Scottish older adults (Smart et al., 2014) and Canadian older adults (Kröger et al., 2008) have also been studied. As the economic and cultural situation may differ across countries, focusing on older adults in the United States can provide implications for policy and services that may differ from those derived from European and other data sources.

Second, although the productive aging literature provides empirical evidence on how both work and volunteering can have cognitive health benefits, the way scholars operationalize work and volunteering are often based on duration or intensity, which does not fully capture what aspects of the activities may be particularly benefiting cognition. Consistent with many studies on work complexity (Andel et al., 2005; Andel et al., 2017; Smart et al., 2014), exploring the cognitive, physical, and social complexity of productive and leisure activities provides a more holistic understanding of these activities.

Third, studies have often focused only on older adults' engagement in one or two types of activity instead of exploring multiple activities simultaneously in relation to older adults' health. According to Morrow-Howell (2010), "most studies of co-occurring activities have focused on productive activities, excluding leisure, religious, or social activities. Yet these activities are likely important in the balance that maximizes outcomes for the individual" (p. 464). Putnam et al. (2013) and Morrow-Howell et al. (2014) argue that focusing on a single activity in relation to health provides a limited understanding. Thus, it is unclear how participation in one activity relates to other participation domains. To date, few scholars have examined work complexity in conjunction with volunteering or leisure in the United States, either cross-sectionally or longitudinally.

Fourth, studies on work complexity have often been motivated by both the cognitive reserve and the use-it-or-lose-it hypotheses, yet they have focused solely on lifetime occupation while disregarding the influence of ongoing participation in work (Andel et al., 2005; Fisher et al., 2014). Similarly, past studies have relied solely on one-time leisure activity engagement status (Andel et al., 2017; Lee et al., 2014) or ongoing volunteering engagement (Proulx et al., 2017) but not in conjunction with other activities. Guided by the use-it-or-lose-it hypothesis, ongoing participation in work, volunteering, and leisure activities has implications for cognitive aging but these relationships have been largely unexamined. The current state of knowledge is insufficient for understanding how both cognitive reserve and ongoing participation in these activities influence one's cognition.

Lastly, despite the potential influence of the social determinants of health in the relationship between productive/leisure activities and cognitive health, studies have not examined how gender, race/ethnicity, education, and parental education levels play a role in this relationship among older adults in the United States.

CURRENT STUDY

Given the limitations in the previous work, this study proposes to explore the influence of the cognitive, physical, and social complexity of productive and leisure activities on cognitive health based on a longitudinal dataset of older adults. Figure 1 provides a conceptual overview of the proposed study, and describes antecedents, mediators/moderators, and outcomes. According to Tarawneh and Holtzman (2012), the decline in cognitive domains such as episodic memory and executive functions are the hallmark of cognitive impairment that affects one's social and work life. However, neuropsychological testing is not sensitive enough to detect the early stage of dementia. Thus, it is important to accumulate knowledge and explore how productive/leisure activities are related to not only global cognitive function but also different dimensions of cognition. This study hypothesizes that engagement in these activities can uniquely improve cognitive domains such as episodic memory, working memory, attention/processing speed, and self-rated memory of older adults.

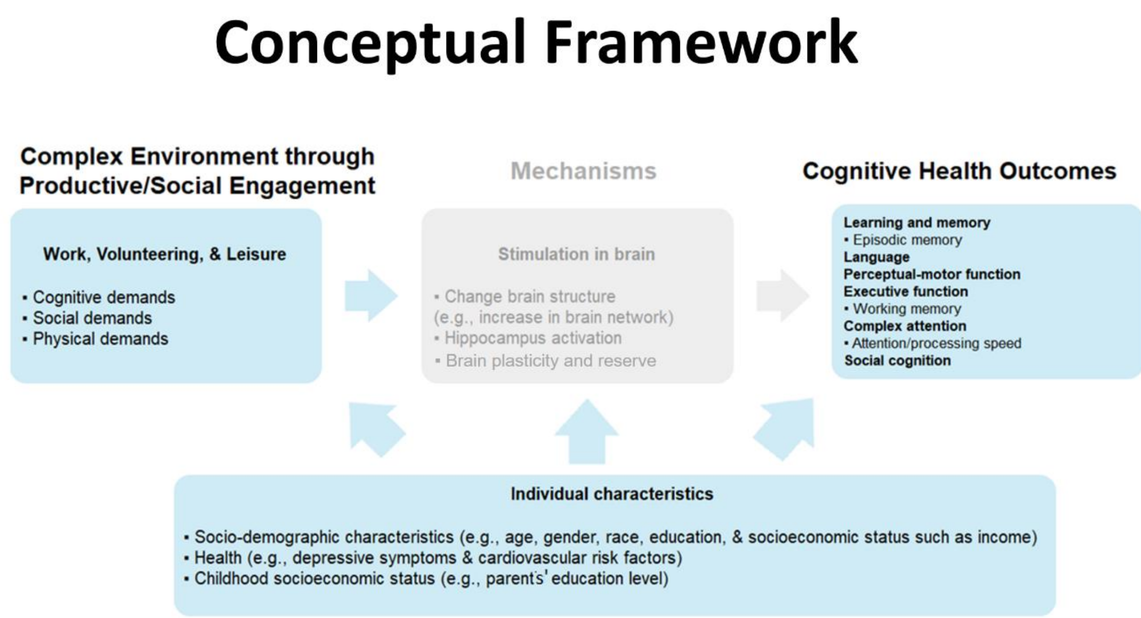

Figure 1. Conceptual framework guided by research on the environmental complexity hypothesis, productive aging, and cognition (Alzheimer's Association, 2018; Andel et al., 2016; Fried et al., 2004; Sachdev et al., 2014). *Notes*: Due to the limited information on all cognitive health domains, this study mainly focuses on episodic memory, working memory, and attention/processing speed (episodic memory and attention/processing are hallmarks of cognitive impairment, Tarawneh & Holtzman, 2012). Self-rated memory was examined in the supplementary analysis.

Research questions

1. Are the previous and ongoing cognitive, physical, and social complexities of work associated with cognitive health in later life?

2-a. Are the ongoing cognitive, physical, and social complexities of work and volunteering associated with cognitive health in later life?

2-b. Are the ongoing cognitive, physical, and social complexities of work, volunteering, and leisure activities associated with cognitive health in later life?

The roles of gender, race/ethnicity, education, and parental education are explored among these relationships.

RESEARCH DESIGN

In the subsequent section, I first introduce the specific data used in this study. I then provide a description of the sample, measurement, and analytic plan for each research question.

Data

The data for the current study comes from three components of the Health and Retirement Study (HRS): 1) the HRS core files, 2) the Research and Development (RAND) HRS data files, and 3) the Consumption and Activities Mail Survey (CAMS). The HRS is a longitudinal, nationally representative, population-based study of older adults aged 51+ years, sponsored by the National Institute on Aging and conducted by the University of Michigan (HRS, 2019a). Beginning in 1992, participants have responded to the HRS core survey every two years, and the sample is replenished every six years.

Most variables come from the RAND HRS data files from the RAND Center for the Study of Aging because variables are harmonized across waves and are imputed if they would otherwise have a high number of missing cases (e.g., household income, cognition) in the raw dataset (Bugliari et al., 2016). Sociodemographic characteristics, health characteristics, and cognitive health were selected from the RAND HRS.

Finally, for research question 2-b, this study used data from the CAMS 2005-2015. The CAMS is a separate survey administered to a randomized subsample of the HRS in odd-numbered years beginning 2001, and it includes rich information on leisure activities. Each year of the CAMS corresponds to the preceding year of the HRS core survey (Hurd & Rohwedder, 2009). In 2005, out of 8,124 questionnaires, a total of 5,815 questionnaires were returned, indicating that 71.6% of the core HRS respondents had matching CAMS survey data.

Methods

Sample

Research question 1 used data from the Early Baby Boomer (EBB) cohort, which was added to the HRS in 2004. Year 2004 was selected as the initial data point (hereafter, wave 1) for research question 1 due to inconsistencies in the measurement of cognition (the dependent variable) before this point, and because information on work history (a key independent variable) was only available for the Early Baby Boomer respondents entering the survey for the first time. Among 2,687 EBB participants born between 1948 and 1953, the current study used an analytic sample size of 1,974 who were not missing information on past employment, who were not missing information on any study covariates, and who were not missing information on the primary independent or dependent variables during the follow-up waves. Data from survey years 2004, 2006, 2008, 2010, 2012, and 2014 were used for the analysis for research question 1.

Models for research question 2-a used data from the 2004 to 2014 HRS survey waves. Inclusion criteria included older adults age 51+ at baseline (2004), who participated in the 2004 core HRS survey, and those who were not missing any data on any study variables at any wave, resulting in an analytic sample size of 15,439.

Finally, for research question 2-b, analyses used data from respondents to the 2004 to 2014 waves of the HRS for whom there was matching information on the corresponding (2005 to 2015) CAMS surveys. The sample was comprised of those older adults age 51+ at baseline (2004), who participated in the CAMS, and those who were not missing data on any variables at any wave, resulting in an analytic sample size of 2,739.

Measures

Research question 1. Are the previous and ongoing cognitive, physical, and social complexities of *work* associated with cognitive health in later life?

Work complexity. Past work complexity information was only obtained from those who entered the survey for the first time in 2004. Current work complexity was measured at every wave from 2004 to 2014. The core survey contains information on respondents' current and recent employment, and information on the unmasked U.S. Census Occupation Code is available via a restricted data access application (HRS, 2019b). Such information is necessary in order to code the complex work environments of HRS respondents (described more fully below). Accordingly, an Agreement for Use of Restricted Data from the HRS was completed.

At each wave, respondents were asked 1) whether they were currently working, 2) whether they were engaged in prior work if they were currently working, and 3) if they were not currently working, whether or not they had ever worked for pay. Respondents who were currently working, were asked: "What sort of work do you do?" and "In what month and year did you start doing this kind of work, including work for previous employers?" People who were not currently working were asked, "Have you ever worked for pay for more than a few months?"; "What sort of work did you do?"; "When did you last work for pay?"; "When did you start working for [that employer/yourself]?"

At wave 1 (2004), EBBs were also asked about their previous work history. HRS respondents who were currently working were asked about their most recent work experience before their current work. Similar to the current work questions, respondents were asked the start and end date for their most recent previous work and the occupation type.

Guided by previous studies (Andel et al., 2015; Andel et al., 2017), the current study followed several steps to measure previous and current work complexity. First, once past and current work occupations were identified, the three-digit Census Occupation Codes were linked to the Standard Occupational Classification (SOC) codes. The SOC codes are used by federal agencies to classify occupational categories based on work tasks, skills, and required training (U.S. Bureau of Labor Statistics, n.d.). Next, the SOC codes were linked to information from the Occupational Information Network (O*NET), which includes updated and rich detail on occupational characteristics (National Center for O*NET Development). O*NET is sponsored by the US Department of Labor and provides standardized information on job characteristics and the importance of occupational skills.[1] Specifically, for each occupation, the O*NET system classifies occupations according to the following domains: abilities, interests, knowledge, skills, work activities, work context, work styles, and work values. Components within some of these domains are further classified with respect to their importance to the job ("importance scores") and the level required in order to do the job ("level scores";

[1] Some SOC codes link to more than one O*NET job code. In these cases, and following Pool and colleagues (2016), the average importance score was assigned across all O*NET occupations that linked to the HRS respondents.

O*NET OnLine, 2019).

In O*NET, importance scores represent how important certain characteristics are to a particular occupation. The level scores indicate the levels of particular characteristics required to perform the work. Level scores are not available for each occupation in O*NET. Therefore, past and ongoing cognitive, physical, and social complexity of employment were calculated using importance scores as described below.

Cognitive complexity of occupations. Based on the previous work of Fisher et al. (2014), cognitive complexity (Cronbach's $\alpha = .93$) was assessed using the 10 O*NET items that describe the work activities involved with mental processes. These were:

1. analyzing data or information;
2. developing objectives and strategies;
3. evaluating information to determine compliance with standards;
4. judging the qualities of things, services, or people;
5. making decisions and solving problems;
6. organizing, planning, and prioritizing work;
7. processing information;
8. scheduling work and activities;
9. thinking creatively; and
10. updating and using relevant knowledge.

Physical and social complexity of occupations. No previous study has used the O*NET classification system to code the physical or social complexity of work. However, this study relied on a procedure similar to the one adopted by Andel et al.

(2005), who used a separate occupational classification system (the Dictionary of Occupational Titles [DOT]) to measure physical and social complexity.

Physical Complexity of Occupations. Physical complexity was measured using the following 9 items in O*NET that describe the "physical abilities" required of jobs: 1) dynamic flexibility; 2) dynamic strength; 3) explosive strength; 4) extent flexibility; 5) gross body coordination; 6) gross body equilibrium; 7) stamina; 8) static strength; and 9) trunk strength. Physical complexity was measured as an average of the importance scores for these nine items (Cronbach's $\alpha = .97$).

Social Complexity of Occupations. Specifically, Andel et al. (2005), used the DOT to classify 'things' and 'work with people,' as proxies for the 'physical complexity' and 'social complexity' of occupations, respectively. Appendix A provides details of which items from the Andel et al. (2005) study are comparable to items from this study. Andel et al. (2005) included the following 9 items to characterize the *work with people* variable: 1) mentoring, 2) negotiating, 3) instructing, 4) supervising, 5) diverting, 6) persuading, 7) speaking-signaling, 8) serving, and 9) taking instructions-helping. To calculate social complexity using the O*NET system, the researcher of this dissertation compared these to available characteristics in O*NET. The items that matched most closely were the six social skills descriptors, including: 1) coordination, 2) instructing, 3) negotiation, 4) persuasion, 5) service orientation, and 6) social perceptiveness to construct social complexity. As with cognitive complexity, the social complexity of jobs was measured by averaging the importance scores of the six items (Cronbach's $\alpha = .93$). Appendix B provides an example of generating the social complexity of occupation.

Table 1 shows an example of the cognitive, physical, and social occupational complexity scores of a social work teacher. Social work teachers are often engaged in decision making and problem solving, resulting in a total average cognitive complexity score of 76.1. Since social work teachers are mostly not engaged in physically demanding work, the physical complexity of the occupation is low (total average physical complexity = 1.44).

Table 1. Example: Calculating the work complexity scores for social work teachers

	Cognitive complexity score	**Physical complexity score**	**Social complexity score**
Work characteristics	Analyzing data or information=79	Dynamic Flexibility=0	Coordination=56
	Developing Objectives and Strategies=70	Dynamic Strength=0	Instructing=91
	Evaluating Information to Determine Compliance with Standards=58	Explosive Strength=0	Negotiation=47
	Judging the Qualities of Things, Services, or People=75	Extent Flexibility=0	Persuasion=50
	Making Decisions and Solving Problems=84	Gross Body Coordination=0	Service Orientation=56
	Organizing, Planning, and Prioritizing Work=78	Gross Body Equilibrium=0	Social Perceptiveness=66
	Processing Information=84	Stamina=0	
	Scheduling Work and Activities=58	Static Strength=0	
	Thinking Creatively=84	Trunk Strength=13	
	Updating and Using Relevant Knowledge=91		
Total average complexity score	761/10=76.1	13/9=1.44	366/6=61

Using this information, the current (cognitive, physical, and social) complexity of work was measured at each wave based on employment at the time of survey. Respondents who were not working at a given wave were coded as 0 for each type of complexity.

In addition, I calculated past work complexity for the ten years prior to the wave 1 (2004) baseline survey, using information on the type and duration of current work, past work and labor force status. The cognitive, physical, and social complexity of work for each year were summed across the 10-year period to generate a measure of "Total Past Work Complexity." For any years between the current and past employment within the 10-year timeframe, and for years where respondents' labor force participation was coded as "retired", "unemployed", "retired", "not in labor force", or "disabled", work complexity for all domains was coded as 0. I focused on the previous 10 years as it was a long enough time to capture the potential impact of cognitive reserve, but not too long that it might unnecessarily increase the risk of losing participants for whom it was not possible to calculate work histories (and who would then be dropped from the study). A previous study (Fisher et al., 2014) also selected a 10-year timeframe to explore the impact of mental work demands and retirement on cognition. People with incomplete current or past work duration or status within the past 10-year from baseline and missing covariates were excluded from the study.

Research question 2-a. Are the ongoing cognitive, physical, and social complexities of work and *volunteering* associated with cognitive health in later life?

Formal volunteering. The HRS does not include past information on volunteering, but at each wave does ask about respondents' current and ongoing engagement in volunteering. At each wave, respondents are asked "Have you spent any time in the past 12 months doing volunteer work for religious, educational, health-related or other charitable organizations?" For respondents who said "yes," they were asked whether the total time doing so amounted to fewer than 50 hours, about 50 hours, 51 to 99 hours, about 100 hours, 100 to 199 hours, about 200 hours, or more than 200 hours. Previous studies have used this information to group people into a low level (0-99 hours) or a high level (100+ hours) of volunteering (Hao, 2008) or 1-99 hours, 100-199 hours, and 200 and more hours (Proulx et al., 2017). In the current study, formal volunteering was divided into: (a) no engagement (zero "0" hours, reference), (b) a moderate level of formal volunteering (1-199 hours annually), and (c) a high level of formal volunteering (200 and more hours annually). Supplemental analyses using alternate versions of this variable produced similar results to those reported below.

Research question 2-b. Are the ongoing cognitive, physical, and social complexities of work, volunteering, and *leisure activities* associated with cognitive health in later life?

Leisure activities. At each wave in the CAMS survey in the year following the HRS core survey, participants were asked how many hours per week or month in the past they were engaged in a number of different leisure activities. In this study, leisure activities were grouped into cognitive, physical, and social leisure activities. To generate a measure that is more comparable to the work complexity score, the current study followed other previous work by Karp et al. (2006) to generate measures of the cognitive, physical, and social complexity of leisure. Karp and colleagues (2006) coded the cognitive, physical, and social complexity of each leisure activity in the Kungsholmen Project according to the following metric: 0=no complexity, 1=low, 2=moderate complexity, and 3=high complexity. They created this coding based on their own evaluation and discussed the procedure as a team to reach consensus. According to their approach, for instance, doing puzzles has a cognitive complexity score of 3, a social complexity score of 0, and a physical complexity score of 0. Lacking an alternative approach to classify leisure activities, this study followed a similar scoring approach[2]: each leisure activity measured in the HRS was evaluated and assigned a complexity score similar to Karp et al. (2006). Accordingly, items were categorized as: 1. Cognitive leisure activities (reading newspapers or magazines; reading books; playing cards or games, or solving puzzles; listening to music; singing or playing a musical instrument; doing arts and craft projects, including kitting, embroidery and painting), 2. Physical leisure activities (walking and participating in sports or other exercise activities), and 3. Social leisure activities (visiting in-person with friends, neighbors, or relatives; attending meetings of clubs or religious groups; attending concerts, movies, or lectures, or visiting museums; physically showing affection for others through hugging, kissing, etc.; praying or meditating; attending religious services).

As a final step, following Karp et al. (2006), at each wave cognitive, physical, and social complexity of leisure scores were assigned by taking the average score across relevant items (refer to Appendix C). Furthermore, the total complexity of leisure activities was calculated by summing the cognitive, physical, and social leisure scores and used in the final models.

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[2] Appendix C provides a summary of which leisure activities from the CAMS survey are selected, and how these compare with the items used in other studies (Andel et al., 2016; Karp et al., 2006; Kaufmann, Montross-Thomas, & Griser, 2018; Lee, Min, & Chi, 2017).

Cognitive health. The key dependent variable for all analyses was cognitive health. At each wave, respondents to the HRS were administered different measures designed to test cognitive functioning in a number of domains: episodic memory, working memory, and attention and processing speed, as well an overall score for total cognitive functioning, and a separate measure for self-rated memory. For all individual cognitive domains as well as for the total cognition score, higher values indicate better cognitive functioning.

Episodic memory measures the ability to consciously use long-term memory (Tulving, 2002), and was measured with two separate tests in the HRS: an immediate word recall test, which asks respondents to immediately recall the 10 nouns that the interviewer read (scored: 0-10); and a delayed recall test, which asks respondents to recall the nouns provided from the immediate recall task with an approximately five-minute time gap in between the immediate recall test and the delayed recall test (scored: 0-10).

According to Cowan (2008), *working memory* includes the ability to recall recent experiences and other processing mechanisms that help one to make use of short-term memory. Working memory was assessed using the Serial 7's test (score: 0-5), which requires participants to subtract 7 from 100 five times in a row.

To measure *attention* and *processing speed*, respondents were asked to count backwards for 10 numbers from the number 20. Respondents were given a score of 2 when their answer was correct on the first try, a score of 1 when the respondent's answer was correct on the second try, and score of 0 when respondents did not provide a correct answer for either attempt.

Episodic memory, working memory, and attention/processing speed were used to generate a total cognition score (scored 0-27), an approach that has have been used in previous work to examine the cognitive health of HRS participants 51+ years of age (Crimmins, Kim, Langa, & Weir, 2011; Fisher, Hassan, Faul, Rodgers, & Weir, 2015; Proulx et al., 2017).

Self-rated memory was assessed given its strong association with cognitive impairment (St John & Montgomery, 2002) and is measured with a Likert scale and reverse-coded to indicate higher scores (1=poor to 5=excellent).

Covariates. All analyses included covariates for a number of potential confounders of the association between the key predictor variables and cognitive health: age (in years), sex (1=female, 0=male), race and ethnicity (1=non-Hispanic White/Caucasian, 2=non-Hispanic Black/African American, 3=other), vascular risk (i.e., hypertension coded as 1=presence, 0=no & diabetes coded as 1=presence, 0=no), log-transformed income, inverse hyperbolic sine (IHS) transformed wealth[3], education level (0 to 17+ years), depressive symptoms during the past 12 months (Center for Epidemiologic Studies Depression [CES-D] scale, 0-8), parents' education level (greater value of mother or father's level of education in years), labor force status (1=full-time work, 2=part-time/partly retired, 3=retired, 4=unemployed/disabled/not in labor force), and marital status (0=married/married, spouse absent/partnered, 1=separated/divorced/separated, never married). Because the primary methodology for

[3] An IHS was used instead of logarithmic transformation, as household wealth included nonpositive values.

this dissertation is growth curve modeling, the continuous variable age was re-centered at age 51 in the analyses, the youngest age for HRS respondents at wave 1 (2004). Recentering helps to improve the interpretation for the age variable in model results.

The inclusion of this set of controls was notable, as previous studies on work complexity have often included only a minimal number of controls such as age, gender, and education (Andel et al., 2005) or even only education and sex (Andel et al., 2016).

ANALYSIS

Univariate and Bivariate Analyses

Univariate analyses were performed to explore the distribution of normality, mean or proportion, variance, and range for all variables (Burdenski, 2000). Skewed variables were transformed as described above. Power analysis reveal that the sample size was sufficient to analyze the research questions. Bivariate analyses were used to explore correlations among age, past work complexity, ongoing work complexity, volunteering, leisure activity, and total cognition. These analyses were used to evaluate the unconditional associations as well as to assess for collinearity among key predictors.

Multivariate Analyses

The primary analytic method for this study is growth curve modeling. Growth curve models allow one to explore associations between key covariates, the initial levels of cognition, and the rate of change in cognition over time (Singer & Willett, 2003). Implementing this approach allows an understanding of how the occupational complexity, volunteering, and leisure complexity affect initial levels of cognitive health and changes in cognitive health over time. This was accomplished by including interactions between a variable for time (for this study, age) and the predictor variables. This approach also made it possible to control for baseline and ongoing differences between subjects (Koerner & Zhang, 2017).

For all analyses described below, growth curve analyses were specified using random intercept and random slope models, which allow for initial cognitive status (the intercept) and the association between time and cognitive health to vary randomly for each person. Time was operationalized as age, which as noted above, was re-centered at 51. Analyses for growth curve models include two types of results, those for fixed effects, which present the associations among key variables, and those for random effects, which describe the variation between and within people over time.

Consistent with best practices (Singer & Willett, 2003), two unconditional growth models – one with no predictors (i.e., the unconditional means model) and one with only the measure for time (recentered age) included (i.e., the unconditional growth model) – were specified for each outcome variable. The unconditional means model informs whether there is significant between- and within-person variation in the outcome to justify the approach, and the unconditional growth model allows the researcher to decide whether there is sufficient within- (over time) and between-person variation in cognition before the model building process (Miller, 2009; Singer & Willett, 2003). Since (as shown below) the unconditional means model and the unconditional growth model found sufficient variability in cognition, subsequent models included covariates, work complexity, volunteering, and leisure activities. With these conditional growth models, "the fixed and random effects are … 'conditioned on' the predictors" (Curran, Obeidat, & Losardo, 2010, p. 5).

An important consideration in growth curve models is whether change in the outcome over time is linear or nonlinear. Thus, this study used the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC; Singer & Willett, 2003) to compare the fit of models that used alternative metrics for time, where smaller AIC and BIC values indicate better model fit. Results from these analyses indicated only marginal improvements in models that included interactions between other predictors and both linear and quadratic terms for age. Thus, the final models presented below opted for a more parsimonious approach by including terms for both age and age squared, but only examining linear interactions between other predictors and age. Finally, for the purpose of interpretation, the major work complexity scores were eventually mean-centered, and (as noted above) age was re-centered at 51.

In response to research question 1 (*Are the previous and ongoing cognitive, physical, and social complexities of work associated with cognitive health in later life?*), controls and measures of past and ongoing work complexity (and their interactions with age) were included as fixed effects in the models.

In response to research question 2-a (*Are the ongoing cognitive, physical, and social complexities of work and volunteering associated with cognitive health in later life?*), to explore the ongoing engagement in work complexity and volunteering in relation to cognition, the second sets of models included work complexity, volunteering, covariates, and their interactions with age as fixed effects. This allowed me to determine how ongoing work complexity and volunteering are associated with changes in cognition over time (growth or decline) and to understand the associations among work complexity, volunteering, and initial cognition status. Lastly, in response to research question 2-b (*Are the ongoing cognitive, physical, and social complexities of work, volunteering, and leisure activities associated with cognitive health in later life?*), the models included work complexity, volunteering, leisure activity, and their interactions with age as fixed effects. The results of this model explore how levels of leisure complexity, in addition to work and volunteering, are associated with initial levels of cognition and changes in cognition over time.

Moderator Analyses

A secondary aim of this dissertation was to explore whether any of the key associations between work complexity, volunteering, or leisure complexity and cognitive health varied across important demographic indicators. All the models described above were re-specified after stratifying by gender (male, female), race/ethnicity (White, not Hispanic, racial/ethnic minority), respondent education (high education [13–17+ years], low education [0–12 years]), and parental education level (high education [13–17+ years], low education [0–12 years]). For simplification, for all stratified models, total cognition score was used as an outcome. All analyses were performed with the *mixed* command in Stata SE version 15 (StataCorp, 2017). The HRS recommends applying sample weights for univariate descriptive analysis, but following previous research (Sonnega, Helppie-McFall, Hudomiet, Willis, & Fisher, 2017), for longitudinal analysis, unweighted data was used for growth curve modeling since the weights are designed for analysis of individual waves.

RESULTS

Research Question 1 Findings

Sample Characteristics

At baseline, the sample participants were 53.11 years of age on average, and the majority of them were White and married/partnered. Approximately 46% of participants were female and the average number of years of education was 13.71. At baseline, 64% of respondents were engaged in full-time work. Participants reported their health conditions as “good” on average and two thirds did not have high blood pressure. Respondents reported relatively high levels of past social complexity of work (M=40) and ongoing cognitive work complexity (M=47), and low levels of past and ongoing physical work complexity (M=14 and 14, respectively; Table 2).

– TABLE 2 HERE –

Table 3 shows correlations among the cognitive functioning, age, and past and ongoing work complexity variables. Higher past cognitive complexity of work was positively associated with higher total cognitive functioning ($p < 0.01$). Similarly, there was a positive association between past social complexity of work and total cognitive functioning ($p < 0.01$). On the other hand, past physical work complexity was associated with lower total cognitive functioning ($p < 0.01$). Importantly, these bivariate associations indicated moderate or strong associations between the cognitive, physical, and social complexity of ongoing work, particularly for cognitive and social complexity (r=0.97, $p < 0.001$). Since these components of ongoing work complexity were highly correlated, the total ongoing complexity variable was used for further analyses.

– TABLE 3 HERE –

Growth Curve Models

Table 4a presents the results of growth curve models exploring the association between past/ongoing work complexity and total cognition. Model 1 presents the unconditional means model. The single random effects term in the unconditional means model is significant, confirming that there is significant variation in total cognition. The unconditional growth model (Model 2) included age and age squared as the sole fixed effects. The unconditional growth model including age and age squared variables showed that age squared term is significantly associated with lower total cognitive decline (β=-0.007, $p < 0.01$). With the age variable included, the AIC and BIC values were smaller, indicating a better model fit. When only the age variable was included, age was negatively associated with baseline total cognition. With the age squared variable included, age was no longer associated with baseline total cognition (Table 4a).

Model 3 included measures for baseline past cognitive, physical, and social complexity of work as well as total ongoing work complexity. First, past cognitive work complexity was not associated with baseline and changes in total cognition. Higher past physical work complexity was associated with lower baseline total cognition (β=-0.063, $p < 0.001$). In other words, a one-unit increase in past physical work complexity was associated with a 0.063 lower total cognition score at baseline. Higher past social complexity of work was associated with higher baseline total cognition (β=0.044, $p < 0.001$) and with significantly slower decreases in total cognition over time (β=0.001, $p < 0.05$). A one-unit increase in past social complexity of work on average resulted in 0.001

points per year slower total cognitive decline. For this Model, the AIC was 48235.47 and BIC was 48342.66, indicating that Model 3 had a better model fit compared to the unconditional means model and the unconditional growth model.

Model 4 (Table 4a), a fully conditional model that included all main predictors as well as controls found that past cognitive work complexity was not associated with baseline total cognition and changes in total cognition[4]. Higher past physical work complexity was associated with lower baseline total cognition (β=-0.025, $p < 0.001$) and higher past social complexity of work was associated with higher baseline total cognition (β=0.016, $p < 0.01$). None of the measures of ongoing or past work complexity were associated with the rate of change over time in total cognition. Age squared term was negatively associated with total cognition (β=-0.005, $p < 0.05$), and racial/ethnic minority status was associated with lower baseline total cognition (non-Hispanic Black: β=-1.756, $p < 0.001$; Hispanic: β=-1.018, $p < 0.001$; non-Hispanic others: β=-1.357, $p < 0.01$; Appendix D). Higher income was associated with slower total cognitive decline (β=0.011, $p < 0.05$), and higher wealth was associated with higher baseline total cognition (β=0.027, $p < 0.05$; Appendix D). As predicted, higher depressive symptoms were associated with lower baseline total cognition (β=-0.076, $p < 0.05$), and better self-rated health was associated with higher baseline total cognition (β=0.185, $p < 0.01$; Full results for controls are included in Appendix D).

Table 4b presents the results for fully conditional models examining individual

[4] Based on the preliminary analyses, controls for cardiovascular factors were not significantly associated with cognitive health outcomes across models. Thus, cardiovascular factors were excluded in the conditional multivariate models for research question 1.

cognitive domains including all ongoing and past predictors for work complexity as well as all controls. Similar to the other models, past cognitive work complexity was not significantly associated with any of the cognitive health domains. Higher past physical work complexity predicted lower baseline episodic memory (Table 4b Model 5: β=-0.018, $p < 0.001$), lower baseline working memory (Table 4b Model 6: β=-0.008, $p < 0.01$), and steeper declines over time in self-rated memory (Table 4b Model 8: β=-0.001, $p < 0.01$). Past social complexity of work predicted higher baseline episodic memory (Table 4b Model 5: β=0.014, $p < 0.01$), slower declines in working memory (Table 4b Model 6: β=0.001, $p < 0.01$), and higher baseline levels of self-rated memory (Table 4b Model 8: β=0.004, $p < 0.05$).

Figure 2 presents the results for stratified models examining associations between past and ongoing work complexity and cognitive outcomes; they were based on the fully conditional model (Table 4a, Model 4). For parsimony, the Figures present only coefficients associated with the initial level of total cognition, because key variables were not significantly associated with changes in total cognition over time (full results are available in Appendix E). Overall, stratified results were similar to the full model results: past cognitive work complexity was not associated with total cognition, past physical work complexity was negatively associated with total cognition, and there were cognitive benefits of socially complex work. For example, among men, past physical work complexity was associated with lower levels of baseline total cognition (β=-0.023, $p < 0.01$), whereas past social complexity of work was associated with higher levels of baseline total cognition (β=0.022, $p < 0.01$). An interesting exception was for models stratified by parental education, where among those with highly educated parents, none of these measures of past work complexity were significantly associated with baseline total cognition.

– TABLES 4a, 4b HERE –

– FIGURE 2 HERE –

Research Question 2-a Findings

Sample Characteristics

Table 5 shows descriptive statistics for research question 2-a. The mean age was approximately 65 (SD=0.18), with 82.45% being non-Hispanic White and 56.44% being female. More than one-quarter of the sample were moderately engaged in volunteering, and 7.57% were engaged in high levels of volunteering.

– TABLE 5 HERE –

Table 6 shows correlations among the age, work complexity, volunteering, and cognitive functioning variables. At the bivariate level, cognitive and social ongoing work complexity and volunteering were positively correlated with total cognition (Table 6: all significant at $p < 0.01$). It appears that higher volunteer engagement was more strongly associated with total cognition (r=0.22) than was work complexity: cognitive complexity of ongoing work was positively associated with total cognition (r=0.03), physical complexity of ongoing work had a weakly negative but not significant association with total cognition (r=-0.001), and social complexity of ongoing work was positively associated with total cognition (r=0.03). Due to the high correlations among the ongoing work complexity variables, total ongoing work complexity was used for further analyses.

– TABLE 6 HERE –

Growth Curve Models

Table 7a presents the association between ongoing work complexity and volunteering in relation to total cognition. As with analyses for research question 1, the unconditional means model (Model 1) and unconditional growth model (Model 2) indicate that there is sufficient variation to proceed with more complex analyses. Thus, Model 3 estimates how age, work complexity, and volunteering are associated with both the initial level of total cognition and its change over time. In this uncontrolled model, both moderate and high levels of volunteering were associated with healthier initial total cognition (moderate level volunteering: $\beta=0.266$, $p < 0.001$; high level volunteering: $\beta=0.374$, $p < 0.01$) and slower total cognitive decline over time (moderate level volunteering: $\beta=0.019$, $p < 0.001$; high level volunteering: $\beta=0.032$, $p < 0.001$), compared to not being engaged in volunteering. In other words, total cognitive health was higher among volunteers at baseline and the decline in cognition over time was less severe among volunteers. Comparing moderate levels of volunteering versus high levels of volunteering, volunteers engaged in high levels of volunteering had almost 1.5 times slower decline rates compared to volunteers engaged in moderate levels of volunteering.

Model 4 includes control variables[5]. Both moderate levels and high levels of volunteering were associated to slower total cognitive decline ($\beta=0.021$, $p < 0.001$ for moderate levels and $\beta=0.033$, $p < 0.001$ for high levels), though neither were still

[5] As with research question 1, preliminary analyses revealed that cardiovascular factors, except high blood pressure, were not significantly associated with cognition at the multivariate level across models. Therefore, among the cardiovascular factors, only high blood pressure was included.

significantly associated with the initial level of total cognition. As shown in the full results (Appendix F), racial/ethnic minority status (Black: β=-2.082, $p < 0.001$; Hispanic: β=-0.856, $p < 0.001$; non-Hispanic other: β=-1.637, $p < 0.001$) and being disengaged from the labor force (retired: β=-0.283, $p < 0.01$; not engaged in work: β=-0.329, $p < 0.01$) were associated with lower baseline total cognition.

Table 7b presents results for the specific domains of cognitive health and for self-rated memory. Overall, results for the specific domains of cognitive health were comparable to those for the total cognition score in that both moderate levels and high levels of volunteering were associated with slower decline in episodic memory (Table 7b Model 5: β=0.016, $p < 0.001$ for moderate levels and β=0.022, $p < 0.001$ for high levels), working memory (Table 7b Model 6: β=0.006, $p < 0.001$ for moderate levels and β=0.011, $p < 0.001$ for high levels), and attention/speed (Table 7b Model 7: β=0.001, p < 0.05 for moderate levels and β=0.002, $p < 0.05$ for high levels). In addition, moderate levels of volunteering were associated with higher baseline self-rated memory (Table 7b Model 8: β=0.045, $p < 0.01$). However, high levels of volunteering were not significantly associated with baseline and changes in self-rated memory.

Figure 3 presents subgroup differences in the associations between volunteering and rate of change in total cognition. Associations between ongoing work complexity and total baseline cognition, and between volunteering and total baseline cognition are not included in Figure 3 as these results were not statistically significant. As in the main model, stratified models consistently found the protective effect of volunteering across different subgroups: moderate and high levels of volunteering predicted a slower cognitive decline rate (Figure 3).

– TABLES 7a, 7b HERE –

– FIGURE 3 HERE –

Research Question 2-b Findings

Sample Characteristics

The sample consisted of 2,739 HRS 2004 respondents aged 51+ whose responses could be matched to CAMS surveys and for whom information on study variables was not missing (Table 8). The mean age was about 65 (SD=0.29) years. Most people were non-Hispanic White (83.97%) and there were more women (58.67%) than men. On average, people had 12.97 years (SD=0.06) of education.

– TABLE 8 HERE –

Focusing on leisure activities, at the bivariate level, total ongoing work complexity, volunteering, and cognitive, physical, and social leisure activities were correlated with total cognitive functioning ($p < 0.01$; Table 9). Based on strong correlations among ongoing work complexity variables and leisure variables, (indicating the possibility of multicollinearity), the total ongoing work complexity score and leisure score, combining all cognitive, physical, and social scores, were used for further analyses.

– TABLE 9 HERE –

Growth Curve Models

Table 10a presents the results from the models that examined associations between ongoing work complexity, volunteering, and leisure activities and total cognition. The unconditional means model and the unconditional growth model provided evidence that there is sufficient variation in total cognition, supporting the rationale for the additional model building process.

In Table 10a, Model 3 presents uncontrolled estimates of associations between the key predictor variables and total cognition. Results indicate that total leisure activity was associated with higher baseline cognition (β=0.012, $p < 0.10$) and slower declines in total cognition over time (β=0.001, $p < 0.01$).[6] Neither total work complexity nor volunteerism were associated with either the initial level of total cognition or change in cognition over time. This pattern of results was largely replicated in the fully conditional model, reported in Model 4[7].

Next, Table 10b presents the associations between work complexity/volunteering/leisure and specific cognitive domains. Total leisure activity was associated with less steep decline in working memory (Table 10b Model 6: β=0.0004, $p < 0.01$) and attention/speed (Table 10b Model 7: β=0.0001, $p < 0.10$ refer to Appendix H).

Figure 4 presents subgroup differences in the associations between volunteering/leisure activities and change in total cognition over time. Ongoing complexity of work was not associated with cognition and was omitted from the figure. Full results are available in Appendix I. Among men, moderate levels of volunteering

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[6] Because different leisure type variables were highly correlated with each other, in supplemental models (reported in Appendix H Model 9-11), the study also examined cognitive leisure, physical leisure, and social leisure individually.

[7] As in earlier analyses, cardiovascular factors were excluded as the variables were not significantly related to total cognitive functioning.

were associated with slower total cognitive decline (β=0.027, $p < 0.05$) whereas for women, total leisure was associated with a slower total cognitive decline rate (β=0.001, $p < 0.05$). Racial and ethnic minorities experienced slower total cognitive decline when they were engaged in higher levels of volunteering (β=0.089, $p < 0.05$), whereas among Whites, total leisure activity was associated with slower cognitive decline (β=0.001, $p < 0.05$). Interestingly, among respondents with a lower education level, total leisure activity predicted slower total cognitive decline (β=0.001, $p < 0.05$; Figure 4). On the other hand, among respondents with a higher education level, it was moderate (β=0.027, $p < 0.01$) and high levels of volunteering (β=0.031, $p < 0.10$) that predicted slower total cognitive decline (Figure 4). A similar pattern was observed when the model was stratified by parental education level: total leisure activity predicted slower total cognitive decline among respondents with a lower parental education level (β=0.001, $p < 0.01$). Among respondents with a higher parental education level, high levels of volunteering were associated with slower total cognitive decline (β=0.065, $p < 0.05$; Figure 4).

– TABLES 10a, 10b HERE –

– FIGURE 4 HERE –

DISCUSSION

Concerns about cognitive impairment in later life have focused attention on understanding various non-genetic interventions with an emphasis on social activities and their association with cognitive health. Given the differing complexities of productive and leisure activities, this study attempted to explore the impact of productive/leisure activity complexities on the longitudinal trajectories of cognition among older adults in the United States over a 10-year period. This study found that work complexity and leisure complexity were associated with both the initial status of and the rate of change in cognition. It also found that volunteering is associated with positive cognitive aging regardless of one's gender, race/ethnicity, education, and parental education levels.

Building upon the productive aging framework (Bass et al., 1993; Fried et al., 2004; Morrow-Howell et al., 2001) and the environmental complexity hypothesis (Kohn & Schooler, 1978), this study stressed the importance of understanding the potential associations between engaging in complex activities and cognition of older adults. By and large, the current study's findings support the conclusions of the productive aging framework and the environmental complexity hypothesis. That is, the complexities of various activities were associated with cognition. However, unlike previous studies, the current study expands the way we have been thinking about environmental complexity. Previous studies found the positive impact of cognitively stimulating activities on cognitive health, but the current study further suggests the importance of physical and social complexity.

Bivariate results are consistent with previous studies that found a significant impact of cognitively stimulating occupations on total cognitions in later life (Andel et al., 2017; Fisher et al., 2014). The positive associations between cognitive occupational complexity and cognition at the bivariate level were consistent with the previous studies (Andel et al., 2017; Fisher et al., 2014). At a multivariate level, past cognitive work complexity was marginally associated with slower decline in self-rated memory. Past physical work complexity was negatively associated with baseline total cognition whereas past social complexity of work was positively associated with baseline total cognition. Specifically, past social complexity of work predicted a slower decline in working memory. These findings are different than those reported in earlier studies, which found a positive association between cognitively stimulating work and cognition (Andel et al., 2005; Fisher et al., 2014), whereas the current study did not find a significant pattern of positive association between past work complexity and cognition. Results reported here may be different from the previous studies, because these earlier studies only explored the impact of cognitively stimulating work on cognition (Andel et al., 2017; Fisher et al., 2014). In fact, in multivariate models, when cognitive, physical, and social complexity of work were all included as predictors, cognitive work complexity was no longer significantly associated with cognitive health for research question 1. This unexpected result might be explained by the fact that other studies have not included physical and social complexity of work in addition to cognitive work complexity (Fisher et al., 2014), and often used retirement as a pivot point to understand cognitive changes (Andel et al., 2015; Fisher et al., 2014).

The divergence between previous work and the findings of this dissertation with respect to older adults' engagement in cognitively complex work suggests the importance of focusing on other dimensions of work, such as reducing the burden of physically demanding work, in order to improve cognitive health in old age. Further, it indicates the importance of future research to understand the relationships among different types of work complexity. Either way, the concept of "complexity" in the previous literature (Kohn & Schooler, 1978; Schooler, 1984) may not be broad and holistic enough to capture different dimensions of work.

Consistent with the previous studies (Fried et al., 2004; Proulx et al., 2017), volunteering had positive cognitive health benefits. Results from research question 2-a revealed that volunteering was beneficial over time regardless of one's gender, race/ethnicity, education, and parental education level. In research question 2-b using a different sample, volunteering was beneficial only among those with higher educational attainment or higher parental education. However, due to the limitations of the data, the types of volunteering are unknown. People with higher education may be involved in complex volunteering activities, for instance mentoring and taking leadership roles, which require abilities such as problem-solving and decision-making. Thus, engaging in activity that is novel facilitates positive plastic change (Fissler et al. 2013), and intellectually challenging volunteering can result in cognitive health benefits (Anderson et al., 2014; Guiney & Machado, 2017). On the other hand, people with a lower education level may be engaged in simpler volunteering activities such as serving meals in soup kitchens and cleaning up communities, thus resulting in a less cognitively stimulating environment. The findings align well with Guiney and Machado (2017)'s suggestion to explore and understand the different types of volunteering and their impact on health. Thus, providing volunteering programs such as Experience Corps for older adults may slow their cognitive decline.

Research question 2-a demonstrated that volunteering reduced the cognitive decline rate. Thus, increasing volunteering opportunities that provide social interaction, complex thinking, and a healthy amount of physical movement are important. In particular, this study found that both moderate and high levels of volunteering engagement predicted a slower decline in episodic memory and working memory. People who may not have cognitively stimulating work can use volunteering as an alternative approach to increase plasticity.

Findings from research question 2-b provided evidence that leisure activity is uniquely associated with slower cognitive decline, indicating cognitively protective effects. These findings are consistent with the previous study from the Kungsholmen Project focusing on the Swedish older adult sample where Karp and colleagues (2006) found the unique impact of cognitive, physical, and social leisure on reduced risk of dementia. In terms of the leisure activity variable, similar to Karp et al. (2006), the present study’s leisure measurements were also highly correlated. This may imply that there needs to be a more sophisticated approach to categorizing leisure activities, as each activity may share similar characteristics. For instance, although current and previous studies assigned a score of "3" for cognitive leisure activity, playing a game such as Monopoly versus Jenga may require different cognitive skills. Monopoly requires greater information processing, decision making, problem solving, and creative thinking.

Despite the small effect size for leisure activities, cognitive, physical, and social leisure activities provide unique cognitive benefits. Cognitively stimulating leisure may activate neural connections, increase the ability to restore disconnected synapses, and connect alternative neural pathways to maximize cognitive function (Fissler, Küster, Schlee, & Kolassa, 2013; Stern & Munn, 2010; Swaab, 1991). Next, both human observational studies and animal studies have provided evidence that physical activity improves neurogenesis throughout the lifespan by positively affecting executive control functions, anterior cingulate cortex (i.e., part of the brain that is connected with multiple brain areas) and reduce disease risk that may affect cognition (Hillman, Erickson, & Kramer, 2008; Kramer, & Erickson, 2007). Thus, physical leisure activity may have a similar effect on older adults' brain. Lastly, social leisure activities may affect cognition by providing an opportunity for social interaction (Fu, Li, & Mao, 2018). Even when people suffer from cognitive impairment, social integration can provide better coping strategies eventually resulting in decreased oxidative stress and slower progression of atherosclerosis (Obisesan & Gillum, 2009).

This study underscores the importance of understanding the effects of other leisure activities in addition to productive activities. Productive activities are typically defined as including work, volunteering, and caregiving (Bass et al., 1993; Morrow-Howell et al., 2001). Expanding the predictors of cognitive aging to include both productive and other activities can provide more options to effectively develop cognitive impairment intervention strategies.

Moreover, moderator analyses (described in Figure 4) suggest that engaging in leisure activities was associated with better cognitive outcomes for older adults with lower education or lower parental education. This suggests the potential of the utilization of leisure activities to improve cognitive aging among people who may have lower academic attainment due to financial difficulty or lack of social support. Thus, engaging in complex leisure activities may buffer the impact of lower educational attainment. Despite the lack of resources and support for older adults of color to engage in productive activities (Gonzales et al., 2015), when comparing work, volunteering, and leisure activities, it was found that volunteering slowed cognitive decline over time. Policies and programs should be developed to not only provide opportunities for older adults of color to engage in volunteering activities but to also provide necessary means such as transportation.

However, it is important to note that the coefficient size for leisure was small. Although the association between leisure and total cognition was significant, due to the small effect size, interpretation for leisure-related interventions needs more evaluation. Leisure can be an important area to explore, yet its effectiveness on cognitive aging needs longer observations.

It is important to note that this study utilized a different sample to answer each research question. Research question 1 explored the impact of both past and current work complexity on cognition using an Early Baby Boomer sample. Research question 2-a, and question 2-b utilized the total ongoing work complexity unlike research question 1 where specific past work complexity and total ongoing work complexity were examined together. To explore this relationship the overall HRS sample was used for research question 2-a, and CAMS sample was used to answer research question 2-b.

To the best of my knowledge, the present study is the first to examine whether different dimensions (i.e., cognitive, physical, and social complexity) of productive and leisure activities influence cognition over time for older adults with HRS data in the United States. Previous studies by Fried et al. (2004) and Anderson et al. (2014) suggested that cognitive, physical, and social volunteering activities improve physiological and psychological health outcomes. However, the studies are limited in their scope as far as incorporating all cognitive, physical, and social dimensions of various activities and their impact on cognition. It is important to also note that these studies were based on primary data analysis.

Limitations. There are several limitations of the present study to note. First, this study was not able to measure the complexity of volunteering due to limited information in the HRS, despite the fact that previous studies suggest that there are complex dimensions to volunteering (Carlson et al., 2009; Fried et al., 2004). Incorporating the complexity of volunteering in future research would expand understanding about how additional dimensions of volunteering can impact cognition.

Second, it is important to note that HRS recommends matching each wave of the HRS dataset with the next year's CAMS files. This means that information on leisure was not collected at strictly the same time as information on work and volunteering.

Third, the study was not able to not explore the causal relationship between the major variables, and results reported here may be biased. For example, it is possible that people with better cognition may also be more likely to engage in the various productive and leisure activities explored here. Future studies could utilize a structural equation modeling (SEM) approach, propensity score analysis, or experimental study design to explore the causal relationship. Moreover, evaluating the results from SEM would improve the understanding of the causal relationship (Bollen & Pearl, 2013).

Fourth, although the current study expanded the domains of work complexity using O*NET, there is no consistent and validated approach to measuring domains of the complexity of work, volunteering, and leisure activities. It would be important for future studies to perform various factor analysis and measurement validation to provide valid and reliable measures of environmental complexity.

As discussed briefly above, another limitation is that this study utilized different samples for each research question, making it challenging to provide a conclusion for all three research questions. One way to address this issue is to examine the three research questions with the same sample. However, to increase the sample sizes, this study had to draw samples from different sub-datasets that contained the major interest predictors such as work complexity (HRS occupational census codes), volunteering (HRS core dataset), and leisure activities (i.e., CAMS dataset). Nonetheless, by connecting three research questions under the overarching theme of exploring productive and leisure activities and cognitive aging, this study provides preliminary empirical evidence to understand environmental complexity and cognition.

Lastly, in the HRS, people who were not currently working were asked about their last job experience, but any work held before their last occupation was not recorded in the dataset. Thus, there may have been other previous jobs that could have meaningfully contributed to respondent's environmental complexity, resulting in variations in cognitive health outcomes. The second or the third most recent jobs may have had a more significant impact on cognitive reserve, yet due to this data limitation, this possibility could not be explored.

Implications. Despite the limitations, there are at least initial practice, policy, and research implications that can be drawn from this study's findings. Workers engaged in physically demanding work are important professionals that contribute to societal needs and resources. Thus, to protect their cognitive health, workplaces can offer additional alternative activities where they can develop and enhance social interactions and cognitive stimulation. This can be done by companies providing therapy sessions to relieve physical burdens, social interaction workshops, and cognitively stimulating training opportunities. In fact, workers with low work complexity can still enjoy cognitive health benefits by incorporating novelty at work (Oltmanns et al., 2017). This can be done by regularly introducing new work tasks for employees.

Currently, there are programs such as the Total Worker Health initiative. The National Institute for Occupational Safety and Health (NIOSH) provides a "Total Worker Health" (TWH) approach that highlights eliminating adverse and hazardous work environments to promote the health and well-being of workers (Lee et al., 2016). NIOSH suggests improvements such as redesigning work to reduce repetitive movement, evaluating workers' age profiles and needs to provide self-management strategies, developing policies that guarantee flexibility of the work, active communication between supervisors and workers to identify stressful working conditions, and educating opportunities such as Employee Assistance Programs (Lee et al., 2016). Yet, these systems do not account for the longer and accumulated impact that workers may experience from physically demanding work. Based on this study's finding, these strategies should start from an earlier stage to protect the brain. Perhaps occupation specific workplace safety networks can protect workers who experience physical burdens. Sonnega et al. (2017) found that both low physical mobility and jobs that require high physical effort were related to earlier retirement. As retirement was associated with steeper declines in verbal memory prior to retirement (Xue et al., 2018), it would be important to start TWH programs before retirement.

Supporting older adults with different life experiences can be done by increasing motivation for volunteering and by providing means such as transportation to make intellectually challenging volunteering opportunities more accessible. Diversifying volunteering options through updates to the Serve America Act of 2009 (Corporation for National and Community Service, n.d.) could open more doors for diverse older adults to consider volunteering as a way to not only stay physically active but also cognitively healthy.

One of the primary social work core values is social justice. Collectively, this dissertation's findings offer insight on how social workers can provide support and resources to adults who may have a higher risk for cognitive impairment. It is known that variations in age, gender, race/ethnicity, and education result in different types of resources and opportunities to connect with society and stay actively engaged (Gonzales et al., 2015). The study results identified that people who are engaged in physically demanding jobs may experience lower cognitive functioning. Similar to the findings from the present study, negative associations between physically demanding work and education have been observed in the previous study (Johnson, Mermin, & Resseger, 2011). Thus, promoting healthy working conditions for blue collar jobs and ensuring diverse leisure options for older adults with lower education levels may promote social justice by supporting healthy cognitive aging (National Association of Social Workers, n.d.). One of the relevant current programs includes the Senior Community Service Employment Program (SCSEP) supporting low-income older adults to engage in work (Mikelson, 2017). Considering how to provide cognitively and socially stimulating work, but less physically demanding tasks may promote healthy cognitive aging.

This study contributes to the Grand Challenges for Social Work (Grand Challenges for Social Work, n.d.; Morrow-Howell, Gonzales, Matz-Costa, James, & Putnam, 2018) by specifically examining how major social determinants of health including gender, race/ethnicity, education, and parental education, influence the association between productive/leisure activity and cognitive health. This is relevant to the following social work grand challenges: 1) Close the health gap, 2) Advance long and productive lives, 3) Eradicate social isolation, 4) Reduce extreme economic inequality, and 5) Achieve equal opportunity and justice. Addressing the diverse life experiences of older adults can improve their well-being and strengthen opportunities to support them to experience healthy cognitive aging through a productive aging lens.

CONCLUSION

In conclusion, this study advances knowledge and state-of-the-art science to examine the associations of occupational complexity, volunteering, and leisure complexity with cognitive health in later life. This dissertation demonstrates that occupations are complex and shape cognition in mid- and later-life. Past physical complexity accelerates cognitive decline in later life. Additionally, volunteering and leisure activities may delay cognitive decline. The findings enrich the environmental complexity hypothesis (Kohn & Schooler, 1978) by providing the initial empirical evidence to re-conceptualize complex environments.

Social work and geriatric practitioners can apply the findings from this study to utilize productive and leisure activities as cognitive aging interventions for older adults. The existing productive aging literature provides rich data on the positive impact of various activities such as volunteering. Yet, little is known about how different dimensions of productive and leisure activities may change the cognition of diverse older adults. Health care practitioners working with older adults can ask questions such as: What elements of occupations enhance working memory, executive functioning, attention, and subjective memory? What levels of complexity of occupations, volunteering, and leisure activities are too demanding? Anderson and colleagues (2018) argue that an appropriate dosage of volunteering results in better cognitive health outcomes. They found that when the volunteering is too intense or too challenging, it may no longer have a cognitively beneficial impact. Understanding the right amount of activity engagement is important. For instance, the current study suggests that jobs that are too physically demanding may have a harmful effect on one's brain. Thus, understanding meaningful engagement for appropriate levels of cognitive, physical, and social stimulation through engagement may look different based on socioeconomic status (Gonzales et al., 2015). Social work practitioners and health care professionals working with older adults can identify different levels of engagement and complexity for activities in order to implement effective cognitive impairment intervention strategies. Various types of work complexity, volunteering, and leisure activities can potentially be used for cognitive aging interventions and research.

In the United States, people spend approximately 8 to 12 hours per day at work (Caban-Martinez et al., 2007). Therefore, workplace and activity engagement in daily life is important to understand one’s health and well-being. The health conditions of employees are highly stratified by the occupation type and available resources (Clougherty, Souza, & Cullen, 2010; Schreurs, Van Emmerik, De Cuyper, Notelaers, & De Witte, 2011). In addition to the type of work, contextual factors at the workplace, social determinants of health, and person-environment fit can determine how older workers and volunteers can stay active in a cognitively stimulating environment. Overall, the present study's findings provide insight that types of occupation stratify cognitive health outcomes and social determinants of health may influence the opportunity to engage in volunteering/leisure in old age. Addressing unequal environmental complexity at work from earlier life may function as a way to slow cognitive decline. Yet, a society focused on productivity may not pay sufficient attention to improving conditions for workers. To fully understand cognitive aging, greater attention must be paid to understand the complexity of productive and leisure activities.

Table 2. Descriptive statistics with complex survey weights for research question 1 variables from year 2004 (n=1,974)

Variable name	Mean (SD) or %	Range
Independent variables		
Past cognitive complexity of work (theoretical range 0–100)	35.82 (0.82)	0–82.4
Past physical complexity of work	14.10 (0.38)	0–60.89
Past social complexity of work	40.38 (0.67)	0–74.17
Total past complexity of work	90.36 (1.69)	0–173.29
Ongoing cognitive complexity of work	47.25(0.77)	0–82.4
Ongoing physical complexity of work	14.11 (0.38)	0–60.89
Ongoing social complexity of work	40.46 (0.67)	0–74.17
Total ongoing complexity of work	101.81 (1.54)	0–183.54
Dependent variable		
Cognitive functioning (theoretical range 0–27)	16.77 (0.14)	2–27
Episodic memory (word recall)	10.87 (0.11)	0–20
Working memory (serial's 7)	3.99 (0.04)	0–5
Attention/processing speed (backward counting)	1.92 (0.01)	0–2
Self-rated memory	3.43 (0.03)	1–5
Covariates		
Age (in years)	53.11 (0.05)	51–56
Centered age (used in the models)	2.11 (0.05)	0–5
Gender (female=1)	45.61%	
Race/ethnicity		
Non-Hispanic Black	10.45%	0–1
Hispanic	8.39%	0–1
Non-Hispanic White	76.83%	0–1
Non-Hispanic others	4.32%	0–1
Education (in years)	13.71 (0.14)	0–17
Income	97391.63 (4649.65)	0–2250000
Wealth	402058.5 (32241.15)	-2245500–2.05e+07
Parental education level (in years)	11.60 (0.18)	0–17
Labor force status		

Engaged in work (full-time)	64.34%	0–1
Engaged in work (part-time/partly retired)	12.26%	0–1
Fully retired	8.94%	0–1
Not engaged in work (unemployed/disabled/not in labor force)	14.47%	0–1
Marital status		
Married/partnered	70.15%	0–1
Separated/divorced/widowed/never married	29.85%	0–1
Depressive symptoms	1.52 (0.06)	0–8
High blood pressure (yes=1)	32.64%	0–1
Diabetes (yes=1)	10.72%	0–1
Heart conditions (yes=1)	9.44%	0–1
Self-rated health (higher score=better health)	3.40 (0.04)	1–5

Notes: transformed income and wealth are used in the analytic models.

Table 3. Correlational matrix for the major study variables for research question 1 (n=9,374)

	1	2	3	4	5	6	7	8
1. Age	1							
2. Cognitive complexity of past work	-0.020	1						
3. Physical complexity of past work	-0.003	0.2368**	1					
4. Social complexity of past work	-0.012	0.6060**	0.3875**	1				
5. Cognitive complexity of ongoing work	-0.2229**	0.4162**	0.1832**	0.5984**	1			
6. Physical complexity of ongoing work	-0.1590**	0.1583**	0.6228**	0.2279**	0.4919**	1		
7. Social complexity of ongoing work	-0.2201**	0.4009**	0.1692**	0.6196**	0.9658**	0.4816**	1	
8. Total cognition	-0.0598**	0.1711**	-0.0678**	0.2589**	0.2576**	-0.0073	0.2529**	1

*p<0.05, **p<0.01

Table 4a. Results from linear growth models of the associations between work complexity and total cognition, HRS, 2004-2014 (n=9,374)

	Model 1		Model 2		Model 3		Model 4	
	Unconditional means model		Unconditional growth model		Model with major predictors		Past and ongoing work complexity	
Age			0.035 (0.028)		0.032 (0.029)		-0.117 (0.083)	
Age squared			-0.007** (0.002)		-0.006** (0.002)		-0.005* (0.002)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	16.373*** (0.078)		16.502*** (0.109)		16.559*** (0.110)		11.583*** (0.654)	
Past cognitive work complexity					0.005 (0.004)	-0.0004 (0.0003)	0.003 (0.003)	-0.0004 (0.0004)
Past physical work complexity					-0.063*** (0.006)	0.001 (0.001)	-0.025*** (0.006)	0.001 (0.001)
Past social work complexity					0.044*** (0.005)	0.001* (0.001)	0.016** (0.005)	0.0006 (0.001)
Total ongoing work complexity					0.002 (0.002)		-0.003 (0.005)	-0.00002 (0.001)
Random Effects								
Time			0.008* (0.004)		0.007* (0.004)		0.005* (0.004)	
Intercept	10.149* (0.377)		8.977* (0.506)		7.433* (0.454)		5.144* (0.380)	
Covariance			0.065 (0.039)		0.048 (0.037)		0.027 (0.035)	
Residual	6.842*(0.112)		6.698* (0.123)		6.704* (0.123)		6.700* (0.123)	
Goodness of Fit								
Df	3		7		15		43	
AIC	48619.59		48549.31		48235.47		47676.67	
BIC	48641.03		48599.33		48342.66		47983.93	

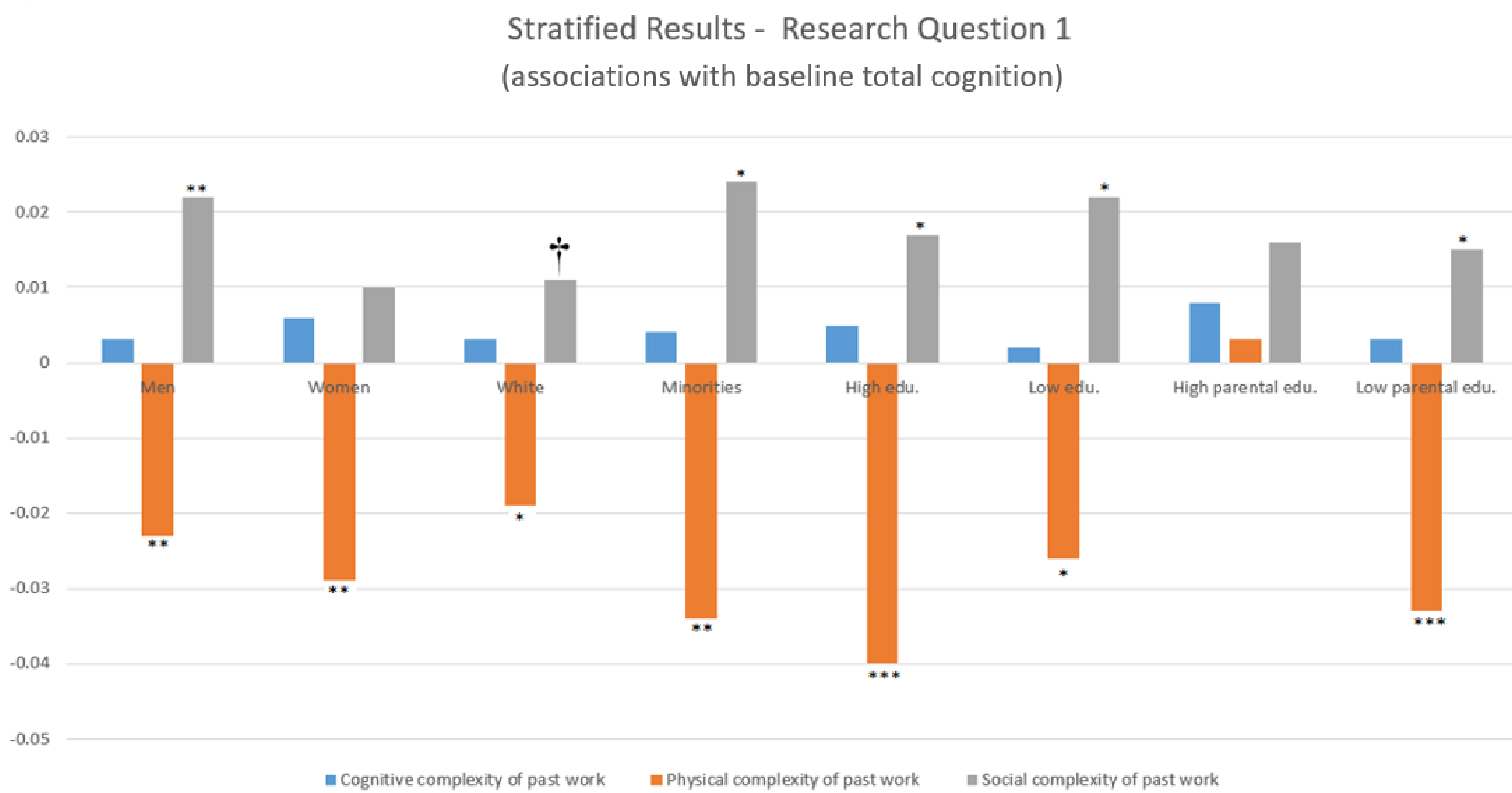
***p<.001; **p<.01; *p<.05; †p<.10; Models 4 include all controls.

Table 4b. Results from linear growth models of the associations between work complexity and cognitive domains, HRS, 2004-2014 (n=9,374)

	Model 5		Model 6		Model 7		Model 8	
	Episodic memory		Working memory		Attention/ Processing speed		Self-rated memory	
Age	-0.060 (0.072)		-0.066* (0.031)		0.002 (0.012)		-0.027 (0.021)	
Age squared	-0.004* (0.002)		-0.0002 (0.001)		-0.0002 (0.0003)		0.001 (0.001)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	7.340*** (0.558)		2.684*** (0.251)		1.683*** (0.083)		2.330*** (0.175)	
Past cognitive work complexity	0.003 (0.003)	-0.0003 (0.0003)	0.0002 (0.001)	-0.0001 (0.0001)	0.0001 (0.0004)	-0.00004 (0.0001)	-0.0005 (0.001)	0.0002† (0.0001)
Past physical work complexity	-0.018*** (0.005)	0.001 (0.001)	-0.008** (0.002)	0.0003 (0.0003)	0.001 (0.001)	-0.0002 (0.0001)	-0.001 (0.002)	-0.001** (0.0002)
Past social work complexity	0.014** (0.005)	-0.0001 (0.001)	0.001 (0.002)	0.001** (0.0002)	0.0001 (0.001)	0.0001 (0.0001)	0.004* (0.001)	-0.0002 (0.0001)
Total ongoing work complexity	-0.003 (0.004)	0.0001 (0.001)	0.0003 (0.002)	-0.0001 (0.0002)	-0.001 (0.001)	0.0001 (0.001)	0.00003 (0.0002)	0.00003 (0.0002)
Random Effects								
Time	0.001* (0.004)		0.001* (0.001)		0.0005* (0.0001)		0.002* (0.0003)	
Intercept	2.726* (0.273)		0.932* (0.059)		0.026* (0.0051)		0.525 (0.030)	
Covariance	0.032 (0.029)		-0.003 (0.005)		-0.001* (0.001)		-0.018* (0.003)	
Residual	5.381* (0.101)		0.892* (0.016)		0.142* (0.003)		0.372* (0.007)	
Goodness of Fit								
Df	46		43		43		43	
AIC	45014.5		29180.48		9885.499		21203.97	
BIC	45343.2		29487.74		10192.76		21511.23	

***p<.001; **p<.01; *p<.05; †p<.10; Models 5-8 include all controls.

Figure 2. Stratified results – research question 1



***p<.001; **p<.01; *p<.05; †p<.10

Table 5. Descriptive statistics with complex survey weights for research question 2-a variables from year 2004 (n=15,439)

Variable name	Mean (SD) or %	Range
Independent variables		
Ongoing cognitive complexity of work	17.29 (0.40)	0–82.4
Ongoing physical complexity of work	5.22 (0.15)	0–60.89
Ongoing social complexity of work	14.98 (0.36)	0–74.17
Formal volunteering		
Not engaged (reference)	63.95%	0–1
1–199 hours (moderate levels of volunteering)	28.48%	0–1
200+ hours (high levels of volunteering)	7.57%	0–1
Dependent variable		
Cognitive functioning	15.85 (0.06)	0–27
Episodic memory (word recall)	10.19 (0.05)	0–20
Working memory (serial's 7)	3.74 (0.02)	0–5
Attention/processing speed (backward counting)	1.91 (0.004)	0–2
Self-rated memory	3.10 (0.01)	1–5
Covariates		
Age (in years)	64.62 (0.18)	51–102
Gender (female=1)	56.44%	
Race/ethnicity		
Non-Hispanic Black	8.42%	0–1
Hispanic	6.57%	0–1
Non-Hispanic White	82.45%	0–1
Non-Hispanic others	2.55%	0–1
Education (in years)	12.95 (0.07)	0–17
Income	70024.84 (1673.03)	0–3540242
Wealth	451447.1 (16993.38)	2245500–3.64e+07
Parental education level (in years)	10.50 (0.07)	0–17
Labor force status		
Engaged in work (full-time)	31.74%	0–1
Partly retired/part-time	13.49%	0–1
Fully retired	41.81%	0–1
Not engaged in work (unemployed/disabled/not in labor force)	12.96%	0–1
Marital status		
Married/partnered	66.23%	0–1
Separated/divorced/widowed/never married	33.77%	0–1
Depressive symptoms	1.43 (0.03)	0–8
High blood pressure (yes=1)	47.31%	0–1
Diabetes (yes=1)	15.26%	0–1
Heart conditions (yes=1)	19.58%	0–1
Self-rated health	3.25 (0.02)	1–5

Table 6. Correlational matrix for the major study variables for research question 2-a (n=73,136)

	1	2	3	4	5	6
1. Age	1					
2. Cognitive complexity of ongoing work	-0.0844**	1				
3. Physical complexity of ongoing work	-0.0943**	0.5624**	1			
4. Social complexity of ongoing work	-0.1000**	0.9904**	0.5331**	1		
5. Volunteering	-0.3627**	0.0427**	0.0171**	0.049**	1	
6. Cognitive functioning	-0.0715**	0.0264**	-0.0009	0.029**	0.2225**	1

*p<0.05, **p<0.01

Table 7a. Results from linear growth models of the associations between work complexity, volunteering, and total cognition, HRS, 2004-2014 (n=73,136)

	Model 1		Model 2		Model 3	
	Unconditional means model		Unconditional growth model		Model with major predictors	
Age			0.041*** (0.006)		0.021** (0.007)	
Age squared			-0.006*** (0.0002)		-0.006*** (0.0002)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	14.564*** (0.032)		16.710*** (0.066)		16.656*** (0.071)	
Total ongoing work complexity					0.0003 (0.0003)	-0.00004** (0.00001)
Volunteering						
Moderate					0.266*** (0.068)	0.019*** (0.003)
High					0.374** (0.122)	0.032*** (0.006)
Random Effects						
Time			0.006* (0.001)		0.006* (0.001)	
Intercept	14.398* (0.186)		10.114* (0.383)		9.965* (0.382)	
Covariance			-0.027 (0.018)		-0.034* (0.018)	
Residual	7.512* (0.045)		6.660* (0.042)		6.673* (0.042)	
Goodness of Fit						
Df	3		7		13	
AIC	390741.7		381497		380955.2	
BIC	390769.3		381561.4		381074.8	

***p<.001; **p<.01; *p<.05; †p<.10

Table 7a. Continued (n=73,136)

	Model 4	
	Model with major predictors and covariates	
Age	0.017 (0.018)	
Age squared	-0.005*** (0.0002)	
Independent Variables	Initial level	Change over time
Intercept	9.326*** (0.326)	
Total ongoing work complexity	-0.001† (0.0003)	-0.0002 (0.00001)
Volunteering		
Moderate	-0.031 (0.067)	0.021*** (0.003)
High	0.011 (0.120)	0.033*** (0.006)
Random Effects		
Time	0.007* (0.001)	
Intercept	5.970* (0.275)	
Covariance	-0.058* (0.014)	
Residual	6.677* (0.042)	
Goodness of Fit		
Df	51	
AIC	374057.4	
BIC	374526.6	

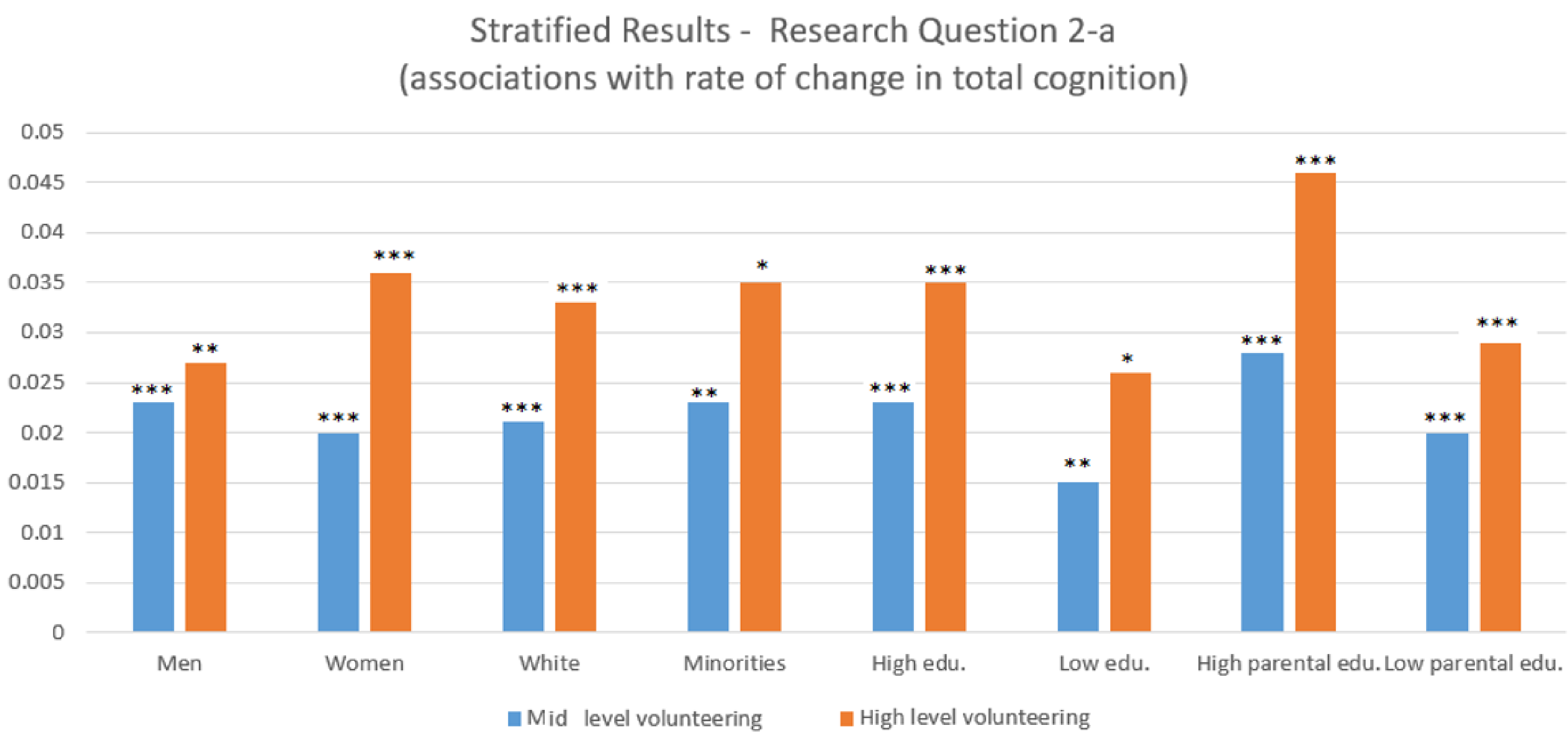
***p<.001; **p<.01; *p<.05; †p<.10; Models 4 include all controls.

Table 7b. Continued (n=73,136)

	Model 5		Model 6		Model 7		Model 8	
	Episodic memory		Working memory		Attention/ Processing speed		Self-rated memory	
Age	0.022 (0.014)		-0.013† (0.007)		-0.001 (0.002)		-0.004 (0.004)	
Age squared	-0.004*** (0.0002)		-0.001*** (0.0001)		-0.0003*** (0.00003)		0.0003*** (0.00005)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	5.7572** (0.266)		1.927*** (0.129)		1.742*** (0.041)		1.844*** (0.079)	
Total ongoing work complexity	-0.0004 (0.0003)	-6.23e-06 (0.00001)	-0.0001 (0.0001)	-5.78e-06 (5.67e-06)	-0.0001† (0.0001)	-7.68e-07 (2.33e-06)	0.0003** (0.0001)	
Volunteering								
Moderate	-0.015 (0.057)	0.016*** (0.003)	-0.004 (0.026)	0.006*** (0.001)	-0.007 (0.009)	0.001* (0.0005)	0.045** (0.016)	-0.001 (0.001)
High	0.106 (0.101)	0.022*** (0.005)	-0.059 (0.047)	0.011*** (0.002)	-0.017 (0.017)	0.002* (0.001)	0.043 (0.028)	0.001 (0.001)
Random Effects								
Time	0.002* (0.0004)		0.0007* (0.001)		0.0002* (0.00001)			0.001* (0.00004)
Intercept	3.004* (0.163)		1.051* (0.046)		0.029* (0.003)			0.492* (0.018)
Covariance	-0.006 (0.009)		-0.006* (0.002)		-0.001* (0.0002)			-0.009* (0.001)
Residual	5.111* (0.031)		0.998* (0.006)		0.175* (0.001)			0.359 (0.002)
Goodness of Fit								
Df	43		43		43			43
AIC	349219.5		236620.4		92508.32			160925
BIC	349615.1		237016		92903.92			161320.7

***p<.001; **p<.01; *p<.05; †p<.10; Models 5-8 include all controls.

Figure 3. Stratified results – research question 2-a



***p<.001; **p<.01; *p<.05; †p<.10

Table 8. Descriptive statistics with complex survey weights for research question 2-b variables from year 2004 (n=2,739)

Variable name	Mean (SD) or %	Range
Independent variables		
Total ongoing work complexity (sum of centered complexity)	-56.56 (1.31)	-90.93–82.36
Formal volunteering		
Not engaged (reference)	62.65%	0–1
1–199 hours	29.75%	0–1
200+ hours	7.60%	0–1
Cognitive leisure	16.87 (0.14)	0–30
Physical leisure	6.72 (0.06)	0–12
Social leisure	11.38 (0.11)	0–22
Total leisure	34.97 (0.29)	0–64
Dependent variable		
Cognitive functioning	15.94 (0.09)	0–27
Episodic memory (word recall)	10.23 (0.07)	0–20
Working memory (serial's 7)	3.79 (0.04)	0–5
Attention/processing speed (backward counting)	1.91 (0.01)	0–2
Self-rated memory	3.12 (0.02)	1–5
Covariates		
Age (in years)	65.05 (0.29)	51–97
Centered age (used in the models)	14.05 (0.29)	0–46
Gender (female=1)	58.67%	0–1
Race/ethnicity		
Non-Hispanic Black	8.52%	0–1
Hispanic	5.32%	0–1
Non-Hispanic White	83.97%	0–1
Non-Hispanic others	2.19%	0–1
Education (in years)	12.97 (0.06)	0–17
Log-transformed income	10.39 (0.04)	0–14.30
Income	61230.3 (1898.96)	0–1624344
Wealth	388657.4 (20029.02)	-1999200–2.60e+07

Parental education level (in years)	10.55 (0.08)	0–17
Labor force status		
Engaged in work (full-time)	29.96%	0–1
Partly retired/part-time	13.35%	0–1
Fully retired	44.74%	0–1
Not engaged in work (unemployed/disabled/not in labor force)	11.95%	0–1
Marital status		
Married/partnered	52.28%	0–1
Separated/divorced/widowed/never married	47.72%	0–1
Depressive symptoms	1.42 (0.04)	0–8
High blood pressure (yes=1)	47.31%	0–1
Diabetes (yes=1)	14.96%	0–1
Heart conditions (yes=1)	17.56%	0–1
Self-rated health	3.25 (0.03)	1–5

Table 9. Correlational matrix for the major study variables for research question 2-b (n=12,430)

	1	2	3	4	5	6	7	8	9
1. Age	1								
2. Cognitive complexity of ongoing work	-0.0669**	1							
3. Physical complexity of ongoing work	-0.0721**	0.5652**	1						
4. Social complexity of ongoing work	-0.0826**	0.9906**	0.5368**	1					
5. Volunteering	-0.0226*	0.0179*	-0.0086	0.0209*	1				
6. Cognitive leisure	-0.0447**	-0.0028	-0.0370**	0.0001	0.3595**	1			
7. Physical leisure	-0.0620**	0.0031	-0.0228*	0.0042	0.2904**	0.7366**	1		
8. Social leisure	-0.0080	-0.0070	-0.0335**	-0.0052	0.3875**	0.8952**	0.7921**	1	
9. Cognitive functioning	-0.3476**	0.0268**	-0.0032	0.0337**	0.1774**	0.2419**	0.1758**	0.1891	1

*p<0.05, **p<0.01

Table 10a. Results from linear growth models of the associations between work complexity, volunteering, leisure activities and total cognition, HRS, 2004-2014 (n=12,430)

	Model 1		Model 2		Model 3	
	Unconditional means model		Unconditional growth model		Model with major predictors	
Age			-0.019 (0.015)		-0.039* (0.019)	
Age squared			-0.005*** (0.0004)		-0.004*** (0.0004)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	15.123*** (0.066)		17.101*** (0.158)		16.694 *** (0.283)	
Total ongoing work complexity					6.67e-06 (0.001)	
Volunteering						
Moderate					0.171 (0.166)	0.012 (0.008)
High					0.426 (0.283)	0.016 (0.013)
Total leisure complexity					0.012† (0.007)	0.001** (0.0003)
Random Effects						
Time			0.006* (0.002)		0.005* (0.002)	
Intercept	11.846* (0.358)		10.199* (0.894)		9.797* (0.878)	
Covariance			-0.076 (0.042)		-0.079 (0.041)	
Residual	6.765* (0.100)		6.137* (0.096)		6.180* (0.096)	
Goodness of Fit						
Df	3		7		15	
AIC	65340.51		64019.92		63859.39	
BIC	65362.79		64071.91		63970.81	

***p<.001; **p<.01; *p<.05; †p<.10

Table 10a. Continued (n=12,430)

	Model 4	
Age	0.007 (0.044)	
Age squared	-0.004*** (0.0004)	
	Initial level	Change over time
Independent Variables		
Intercept	9.587*** (0.811)	
Total ongoing work complexity	-0.001 (0.001)	-2.67e-06 (0.00004)
Volunteering		
Moderate	-0.042 (0.163)	0.012 (0.008)
High	0.120 (0.277)	0.015 (0.013)
Total leisure	0.001 (0.007)	0.001** (0.0003)
Random Effects		
Time	0.006* (0.002)	
Intercept	6.091* (0.644)	
Covariance	-0.072* (0.033)	
Residual	6.141* (0.095)	
Goodness of Fit		
Df	43	
AIC	62820.34	
BIC	63139.74	

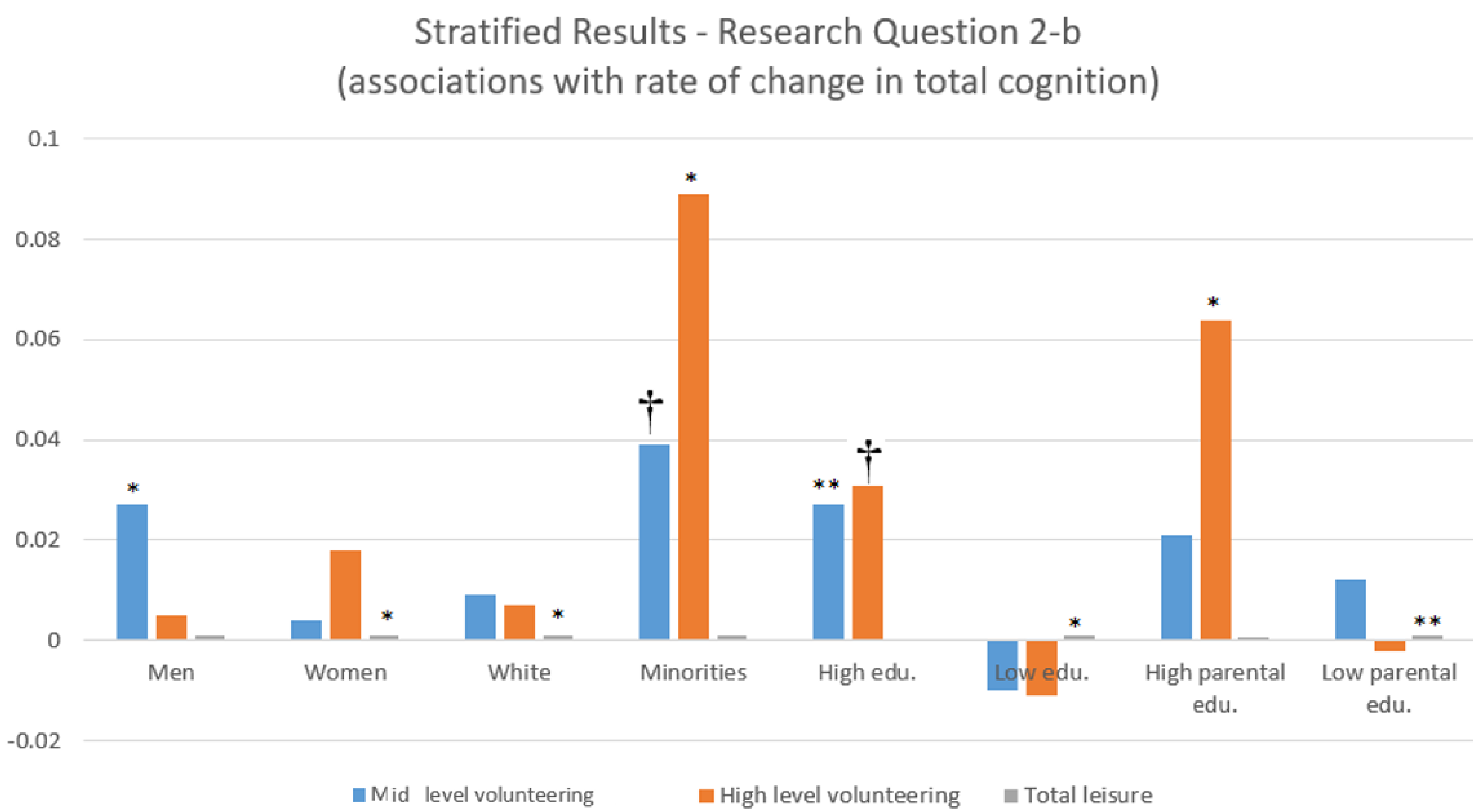
***p<.001; **p<.01; *p<.05; †p<.10; Models 4 include all controls.

Table 10b. Continued (Total leisure and cognitive domains; n=12,430)

	Model 5		Model 6		Model 7		Model 8	
	Episodic memory		Working memory		Attention/ Processing speed		Self-rated memory	
Age	0.013 (0.037)		-0.006 (0.017)		0.007 (0.006)		0.007 (0.010)	
Age squared	-0.003*** (0.0004)		-0.001*** (0.0002)		-0.0002*** (0.0001)		0.0004*** (0.0001)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	5.885*** (0.680)		1.761*** (0.316)		1.681*** (0.097)		1.540*** (0.195)	
Total ongoing work complexity	-0.001 (0.001)	2.77e-06 (0.00003)	0.0001 (0.003)	-8.13e-06 (0.00001)	-0.0001 (0.0001)	1.61e-06 (5.39e-06)	0.0003 (0.0002)	-0.00001 (8.23e-06)
Volunteering								
Moderate	-0.037 (0.140)	0.009 (0.007)	0.005 (0.063)	0.003 (0.003)	0.009 (0.022)	-0.0005 (0.001)	0.097* (0.038)	-0.004* (0.002)
High	0.104 (0.239)	0.009 (0.011)	-0.006 (0.107)	0.007 (0.005)	0.011 (0.037)	0.0005 (0.002)	0.006 (0.065)	0.001 (0.003)
Total leisure activity	-0.001 (0.001)	0.0003 (0.0003)	-0.004 (0.003)	0.0004** (0.0001)	-0.001 (0.001)	0.0001† (0.00004)	0.003 (0.002)	
Random Effects								
Time	0.003* (0.001)		0.0005* (0.0003)		0.0001*(0.00002)		0.0005* (0.0001)	
Intercept	3.477* (0.405)		0.879* (0.105)		0.022* (0.006)		0.465* (0.040)	
Covariance	-0.040 (0.021)		-0.002 (0.005)		-0.001 (0.0004)		-0.009 (0.002)	
Residual	4.870*(0.074)		0.920* (0.014)		0.149* (0.002)		0.322* (0.005)	
Goodness of Fit								
Df	43		43		43		43	
AIC	58969.16		39562.57		13593.77		26611.53	
BIC	59288.56		39881.97		13913.17		26930.93	

***p<.001; **p<.01; *p<.05; †p<.10; Models 5-8 include all controls.

Figure 4. Stratified results – research question 2-b



***p<.001; **p<.01; *p<.05; †p<.10

APPENDIX

Appendix A. Cognitive, physical, and social complexity of occupation

	Original work complexity measure in DOT (Andel et al. 2005)	O*NET work complexity (current study)
Cognitive demands (in DOT term "work with data" is used)	1) Synthesizing 2) Coordinating 3) Analyzing 4) Compiling 5) Computing 6) Copying 7) Comparing	1) Analyzing data or information 2) Developing objectives and strategies 3) Evaluating information to determine compliance with standards 4) Judging the qualities of things, services, or people 5) Making decisions and solving problems 6) Organizing, planning, and prioritizing work 7) Processing information 8) Scheduling work and activities 9) Thinking creatively 10) Updating and using relevant knowledge
Social demands (in DOT term "work with people" is used)	1) Mentoring 2) Negotiating 3) Instructing 4) Supervising 5) Diverting 6) Persuading 7) Speaking-signaling 8) Serving 9) Taking Instructions-Helping	1) Coordination 2) Instructing 3) Negotiation 4) Persuasion 5) Service orientation 6) Social perceptiveness
Physical demands (in DOT term "work with thing" is used)	1) Setting Up 2) Precision working 3) Operating-Controlling 4) Driving-operating	1) Dynamic flexibility 2) Dynamic strength 3) Explosive strength 4) Extent flexibility

	5) Manipulating 6) Tending 7) Feeding-offbearing 8) Handling	5) Gross body coordination 6) Gross body equilibrium 7) Stamina 8) Static strength 9) Trunk strength

Notes: Current study utilizes work characteristics based on HRS and O*NET. DOT items are provided for comparison.

Appendix B. Example of generating social complexity of work

The following six items were used to generate the social complexity of work.
Skills — Social Skills: Developed capacities used to work with people to achieve goals

Coordination — Adjusting actions in relation to others' actions.
Instructing — Teaching others how to do something.
Negotiation — Bringing others together and trying to reconcile differences.
Persuasion — Persuading others to change their minds or behavior.
Service Orientation — Actively looking for ways to help people.
Social Perceptiveness — Being aware of others' reactions and understanding why they react as they do.

Source: https://www.onetonline.org/find/descriptor/browse/Skills/2.B.1/

Detail scores

Skills — Coordination: 72 + 69 + 69 + 66 + 63 + 60/6 = 399/6 = 66.5
Skills — Instructing: 60 + 60 + 56 + 56 + 56 + 50/6 = 338/6 = 56.33 (detailed example below)

60	11-3051.06 Hydroelectric Production Managers
60	11-3051.01 Quality Control Systems Managers
56	11-3051.03 Biofuels Production Managers
56	11-3051.02 Geothermal Production Managers
56	11-3051.00 Industrial Production Managers
50	11-3051.04 Biomass Power Plant Managers

Skills — Negotiation: 56 + 53 + 53 + 50 + 50 + 50 /6 = 312/6 = 52
Skills — Persuasion: 60 + 56 + 56 + 56 + 53 + 50/6 = 331/6 = 55.17
Skills — Service Orientation: 60 + 56 + 47 + 47 + 47 + 41/6 = 298/6 = 49.67
Skills — Social Perceptiveness: 63 + 63 + 60 + 56 + 56 +53/6 = 351/6 = 58.5

Average social complexity: 66.5 + 56.33 + 52 + 55.17 + 49.67 + 58.5 = 338.17/6 = 56.36

Sources:
https://www.onetonline.org/find/descriptor/result/2.B.1.b?a=1
https://www.onetonline.org/find/descriptor/result/2.B.1.e?a=1
https://www.onetonline.org/find/descriptor/result/2.B.1.d?a=1
https://www.onetonline.org/find/descriptor/result/2.B.1.c?a=1
https://www.onetonline.org/find/descriptor/result/2.B.1.f?a=1
https://www.onetonline.org/find/descriptor/result/2.B.1.a?a=1

Appendix C. Types of leisure activities in HRS CAMS and other studies

	Current study	**Karp et al. (2006)**	**Andel et al. (2016)**	**Kaufmann et al. (2018)**	**Lee et al. (2017)**
Data source	HRS CAMS		The Swedish Adoption/Twin Study of Aging (SATSA).	HRS CAMS	HRS CAMS
Total number of items	Selected fourteen items	Twenty-nine items	Eight items	Sixteen items	Eighteen items
Scale	0 = none; 1 = low; 2 = moderate; 3 = high	0 = none; 1 = low; 2 = moderate; 3 = high	Summative score	Summative score	Summative score
Cognitive	▪ Reading newspapers or magazines=3 ▪ Reading books=3 ▪ Playing cards or games, or solving puzzles=3 ▪ Listening to music=2 ▪ Singing or playing a musical instrument=2 ▪ Doing arts and craft projects, including kitting, embroidery and painting=2 ▪ Visiting in-person with friends, neighbors, or relatives=2 ▪ Attending meetings of clubs or religious groups=2 ▪ Attending concerts, movies, or lectures, or visiting museums=3	▪ Reading literature=3 ▪ Handcraft=2 ▪ Doing crossword puzzles=3 ▪ Political or cultural interests=3 ▪ Playing cards or chess=3 ▪ Visiting the summerhouse=2 ▪ Attending courses=3 ▪ Watching TV=2 ▪ Going to theatres or concerts=3 ▪ Doing sport=1 ▪ Going to exhibitions or museums=3 ▪ Meeting friends, participating in groups=2 ▪ Walking=1 ▪ Listening to radio=2 ▪ Travelling=3 ▪ Gardening and flowers=2 ▪ Painting, drawing, photo=3 ▪ Engaging in family or charity=2	**Three items:** ▪ Reading books. ▪ Playing puzzles. ▪ Playing chess.	**Four items:** ▪ Playing cards or games, or solving puzzles. ▪ Attending concerts, movies, or lectures, or visiting museums. ▪ Singing or playing a musical instrument. ▪ Doing arts and crafts projects, including knitting, embroidery, or painting.	**Six items:** ▪ Reading newspapers or magazines. ▪ Reading books. ▪ Listening to music. ▪ Singing or playing a musical instrument. ▪ Playing cards or games or solving puzzles. ▪ Doing arts and craft projects, including kitting, embroidery and painting.

	▪ Physically showing affection for others through hugging, kissing, etc.=2 ▪ Praying or meditating=2 ▪ Attending religious services=2 ▪ Walking=1 ▪ Participating in sports or other exercise activities=1	▪ Doing outdoor activities=2 ▪ Collecting stamps or other items=3 ▪ Cooking food=2 ▪ Writing=3 ▪ Housekeeping=1 ▪ Attending church activities=2 ▪ Playing music=2 ▪ Doing solitaire=2 ▪ Following the stock market=3 ▪ Playing bingo=2 ▪ Singing=2 ▪ No activity at all=0			
Social	▪ Reading newspapers or magazines=0 ▪ Reading books=0 ▪ Playing cards or games, or solving puzzles=3 ▪ Listening to music=0 ▪ Singing or playing a musical instrument=2 ▪ Doing arts and craft projects, including kitting, embroidery and painting=1 ▪ Visiting in-person with friends, neighbors, or relatives=3 ▪ Attending meetings of clubs or religious groups=3 ▪ Attending concerts, movies, or lectures, or visiting museums=1	▪ Reading literature=0 ▪ Handcraft=1 ▪ Doing crossword puzzles=0 ▪ Political or cultural interests=3 ▪ Playing cards or chess=3 ▪ Visiting the summerhouse=2 ▪ Attending courses=2 ▪ Watching TV=0 ▪ Going to theatres or concerts=2 ▪ Doing sport=2 ▪ Going to exhibitions or museums=1 ▪ Meeting friends, participating in groups=3 ▪ Walking=1 ▪ Listening to radio=0 ▪ Travelling=2 ▪ Gardening and flowers=1 ▪ Painting, drawing, photo=0 ▪ Engaging in family or charity=3	**Three items:** ▪ Club meetings. ▪ Church activities. ▪ Courses.	**Six items:** ▪ Visiting in-person with friends, neighbors, or relatives. ▪ Communicating by telephone, letters, e-mail, Facebook, Skype, or other media with friends, neighbors, or relatives. ▪ Caring for pets. ▪ Physically showing affection for others through hugging, kissing, etc. ▪ Helping friends, neighbors, or	**Eight items:** ▪ Visiting in person with friends, neighbors or relatives. ▪ Communicating by telephone, letters or email with friends, neighbors or relatives. ▪ Helping non-co-residing friends, neighbors or relatives who did not pay for help. ▪ Doing volunteer work. ▪ Attending meetings of clubs or religious groups.

	▪ Physically showing affection for others through hugging, kissing, etc.=3 ▪ Praying or meditating=0 ▪ Attending religious services=3 ▪ Walking=1 ▪ Participating in sports or other exercise activities=2	▪ Doing outdoor activities=2 ▪ Collecting stamps or other items=0 ▪ Cooking food=1 ▪ Writing=1 ▪ Housekeeping=0 ▪ Attending church activities=3 ▪ Playing music=2 ▪ Doing solitaire=0 ▪ Following the stock market=0 ▪ Playing bingo=3 ▪ Singing=2 ▪ No activity at all=0		relatives who did not live with you and did not pay you for the help. ▪ Doing volunteer work for religious, educational, health-related, or other charitable organizations.	▪ Physically showing affection for others through hugging, kissing, etc. ▪ Attending concerts, movies or lectures, or visiting museums. ▪ Dining or eating outside the home (not related to business or work).
Physical	▪ Reading newspapers or magazines=0 ▪ Reading books=0 ▪ Playing cards or games, or solving puzzles=0 ▪ Listening to music=0 ▪ Singing or playing a musical instrument=0 ▪ Doing arts and craft projects, including kitting, embroidery and painting=1 ▪ Visiting in-person with friends, neighbors, or relatives=1 ▪ Attending meetings of clubs or religious groups=1 ▪ Attending concerts, movies, or lectures, or visiting museums=1	▪ Reading literature=0 ▪ Handcraft=1 ▪ Doing crossword puzzles=0 ▪ Political or cultural interests=1 ▪ Playing cards or chess=0 ▪ Visiting the summerhouse=2 ▪ Attending courses=1 ▪ Watching TV=0 ▪ Going to theatres or concerts=1 ▪ Doing sport=3 ▪ Going to exhibitions or museums=1 ▪ Meeting friends, participating in groups=1 ▪ Walking=3 ▪ Listening to radio=0 ▪ Travelling=2 ▪ Gardening and flowers=2 ▪ Painting, drawing, photo=0 ▪ Engaging in family or charity=2	**Two items:** ▪ Walks. ▪ Athletics.	**Four items:** ▪ Sleeping and napping (including at night). ▪ Walking. ▪ Participating in sports or other exercise activities. ▪ Treating or managing an existing medical condition of your own.	**Two items:** ▪ Walking. ▪ Participating in sports or other exercise activities.

	▪ Physically showing affection for others through hugging, kissing, etc.=1 ▪ Praying or meditating=0 ▪ Attending religious services=1 ▪ Walking=3 ▪ Participating in sports or other exercise activities=3	▪ Doing outdoor activities=3 ▪ Collecting stamps or other items=0 ▪ Cooking food=1 ▪ Writing=0 ▪ Housekeeping=2 ▪ Attending church activities=1 ▪ Playing music=1 ▪ Doing solitaire=0 ▪ Following the stock market=0 ▪ Playing bingo=1 ▪ Singing=1 ▪ No activity at all=0			
Religious				**Two items:** ▪ Praying or meditating. ▪ Attending religious services.	**Two items:** ▪ Praying or meditating. ▪ Attending religious services.

Notes: Current study compared with other studies to generate the complexity score for leisure activities. Scores are mostly following the research by Karp et al. (2006). Since leisure complexity score on "physically showing affection for others through hugging, kissing, etc." and "praying or meditating" was not available, I compared the complexity scores across studies and provided an appropriate value.

Appendix D. Full results of research question 1 (Table 4a Model 4 & Table 4b Model 5-Model 8)

Table 4a. Results from linear growth models of the associations between work complexity and total cognition, HRS, 2004-2014 (n=9,374)

	Model 4	
Independent Variables		
Age	-0.117 (0.083)	
Age squared	-0.005* (0.002)	
	Initial level	Change over time
Intercept	11.583*** (0.654)	
Past cognitive work complexity	0.003 (0.003)	-0.0004 (0.0004)
Past physical work complexity	-0.025*** (0.006)	0.001 (0.001)
Past social work complexity	0.016** (0.005)	0.0006 (0.001)
Total ongoing work complexity	-0.003 (0.005)	-0.00002 (0.001)
Gender (female=1)	0.541** (0.163)	0.018 (0.018)
Race/ethnicity (reference=Non-Hispanic White)		
Non-Hispanic Black	-1.756*** (0.227)	-0.023 (0.024)
Hispanic	-1.018*** (0.275)	0.046 (0.030)
Non-Hispanic others	-1.357** (0.410)	0.011 (0.044)
Education (in years)	0.346*** (0.034)	-0.0002 (0.004)
Parental education level (in years)	0.037 (0.026)	0.003 (0.003)
Log-transformed income	-0.041 (0.039)	0.011* (0.005)
Wealth	0.027* (0.011)	-0.002† (0.001)
Labor force status (reference=full-time)		
Engaged in work (part-time/partly retired)	0.064 (0.203)	-0.021 (0.027)
Retired	-0.418 (0.610)	-0.026 (0.085)
Not engaged in work (unemployed/disabled/not in labor force)	-0.485 (0.597)	-0.002 (0.085)
Marital status (reference=married/partnered)		

Separated/divorced/widowed/never married	-0.187 (0.167)	-0.007 (0.020)
Depressive symptoms	-0.076* (0.034)	-0.004 (0.004)
Self-rated health	0.185** (0.069)	0.008 (0.009)
Random Effects		
Time	0.005* (0.004)	
Intercept	5.144* (0.380)	
Covariance	0.027 (0.035)	
Residual	6.700* (0.123)	
Goodness of Fit		
Df	43	
AIC	47676.67	
BIC	47983.93	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix D (continued). Full results of research question 1 (Table 4a Model 4 & Table 4b Model 5-Model 8)
Table 4b. Results from linear growth models of the associations between work complexity and cognitive domains, HRS, 2004-2014 (n=9,374)

	Model 5		Model 6		Model 7		Model 8	
Independent Variables	Episodic memory		Working memory		Attention/ Processing speed		Self-rated memory	
Intercept	7.209*** (0.561)		2.684*** (0.251)		1.683*** (0.083)		2.330*** (0.175)	
Age	-0.065 (0.073)		-0.066* (0.031)		0.002 (0.012)		-0.027 (0.021)	
Age squared	-0.005* (0.002)		-0.0002 (0.001)		-0.0002 (0.0003)		0.001 (0.001)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Past cognitive work complexity	0.003 (0.003)	-0.0003 (0.0003)	0.0002 (0.001)	-0.0001 (0.0001)	0.0001 (0.0004)	-0.00004 (0.0001)	-0.0005 (0.001)	0.0002† (0.0001)
Past physical work complexity	-0.018** (0.005)	0.001 (0.001)	-0.008** (0.002)	0.0003 (0.0003)	0.001 (0.001)	-0.0002 (0.0001)	-0.001 (0.002)	-0.001** (0.0002)
Past social work complexity	0.014** (0.005)	-0.0001 (0.001)	0.001 (0.002)	0.001** (0.0002)	0.0001 (0.001)	0.0001 (0.0001)	0.004* (0.001)	-0.0002 (0.0001)
Total ongoing work complexity	-0.002 (0.004)	0.0001 (0.001)	0.0003 (0.002)	-0.0001 (0.0002)	-0.001 (0.001)	0.0001 (0.001)	0.00003 (0.0002)	0.00003 (0.0002)
Gender (female=1)	0.847*** (0.134)	0.013 (0.016)	-0.292** (0.064)	0.002 (0.007)	-0.009 (0.019)	0.001 (0.003)	-0.020 (0.045)	-0.007 (0.005)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-0.967*** (0.187)	0.004 (0.021)	-0.713*** (0.089)	-0.023* (0.009)	-0.025 (0.026)	-0.005 (0.004)	-0.076 (0.063)	0.001 (0.006)
Hispanic	-0.553* (0.227)	0.042 (0.026)	-0.507*** (0.108)	0.011 (0.011)	-0.004 (0.032)	-0.002 (0.004)	-0.032 (0.076)	0.0003 (0.008)

Non-Hispanic others	-0.935** (0.338)	0.017 (0.039)	-0.353* (0.161)	0.0004 (0.016)	-0.023 (0.048)	-0.011 (0.007)	-0.128 (0.114)	0.011 (0.012)
Education (in years)	0.208*** (0.028)	-0.0004 (0.003)	0.120*** (0.013)	0.001 (0.001)	0.014*** (0.004)	-0.0003 (0.001)	0.057*** (0.009)	-0.002† (0.001)
Parental education level (in years)	0.057** (0.022)	-0.001 (0.002)	-0.018† (0.010)	0.003** (0.001)	-0.004 (0.003)	0.001* (0.0004)	0.001 (0.007)	0.0003 (0.001)
Log-transformed income	-0.043 (0.034)	0.009* (0.005)	-0.006 (0.014)	0.003 (0.002)	0.013* (0.005)	-0.001 (0.001)	-0.007 (0.010)	0.0004 (0.001)
Wealth	0.022* (0.009)	-0.002† (0.001)	0.005 (0.004)	-0.00002 (0.0005)	0.001 (0.001)	-0.0001 (0.0002)	0.004 (0.003)	-0.0004 (0.0003)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	0.196 (0.177)	-0.029 (0.024)	-0.130† (0.076)	0.012 (0.010)	0.0001 (0.028)	-0.003 (0.004)	-0.045 (0.052)	0.006 (0.007)
Retired	-0.260 (0.529)	-0.013 (0.075)	-0.056 (0.229)	-0.014 (0.032)	-0.084 (0.082)	0.003 (0.012)	-0.048 (0.159)	0.004 (0.022)
Not engaged in work (unemployed/ disabled/not in labor force)	-0.256 (0.518)	-0.001 (0.075)	-0.155 (0.224)	-0.0002 (0.032)	-0.083 (0.081)	0.003 (0.012)	0.033 (0.155)	-0.0004 (0.022)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/never married	-0.201 (0.143)	0.003 (0.018)	-0.029 (0.064)	-0.006 (0.007)	0.047* (0.021)	-0.006* (0.003)	0.060 (0.045)	-0.005 (0.005)
Depressive symptoms	-0.052† (0.030)	-0.004 (0.004)	-0.021† (0.013)	-0.0004 (0.002)	-0.012* (0.005)	0.001 (0.001)	-0.062*** (0.009)	0.003** (0.001)
Self-rated health	0.126* (0.061)	0.011 (0.008)	0.071** (0.026)	-0.004 (0.003)	-0.004 (0.009)	0.001 (0.001)	0.157*** (0.018)	0.001 (0.002)
Random Effects								
Time	-		0.001* (0.001)		0.0005* (0.0001)		0.002* (0.0003)	
Intercept	0.004* (0.002)		0.932* (0.059)		0.026* (0.0051)		0.525 (0.030)	
Covariance	2.978* (0.159)		-0.003 (0.005)		-0.001* (0.001)		-0.018* (0.003)	

Residual	5.339* (0.091)		0.892* (0.016)		0.142* (0.003)		0.372* (0.007)	
Goodness of Fit								
Df	42		43		43		43	
AIC	45013.46		29180.48		9885.499		21203.97	
BIC	45313.58		29487.74		10192.76		21511.23	

***p<.001; **p<.01; *p<.05; †p<.10

Notes: In Stata, Model 5 used the *mixed* command without additional *cov(un)* command.

Appendix E. Full results of stratified models of research question 1 (Figure 2)

Table 4c. Stratified results from linear growth models of the associations between work complexity and cognitive domains, HRS, 2004-2014 (n=9,374)

	Model 9		Model 10		Model 11		Model 12	
Independent Variables	Male		Female		White		Minorities	
Intercept	11.419*** (0.915)		12.451*** (0.920)		10.541*** (0.972)		11.359*** (0.895)	
Age	-0.086 (0.115)		-0.159 (0.117)		-0.080 (0.117)		-0.090 (0.123)	
Age squared	-0.005 (0.003)		-0.006* (0.003)		-0.007** (0.002)		-0.002 (0.004)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Past cognitive work complexity	0.003 (0.004)	-0.003 (0.0004)	0.006 (0.005)	-0.001 (0.001)	0.003 (0.004)	-0.0001 (0.0004)	0.004 (0.007)	-0.001 (0.001)
Past physical work complexity	-0.023** (0.008)	0.001 (0.001)	-0.029** (0.010)	0.0004 (0.001)	-0.019* (0.008)	0.001 (0.001)	-0.034** (0.012)	0.001 (0.001)
Past social work complexity	0.022** (0.008)	-0.00004 (0.001)	0.010 (0.008)	0.001 (0.001)	0.011† (0.006)	0.001 (0.001)	0.024* (0.011)	0.0002 (0.001)
Total ongoing work complexity	-0.005 (0.006)	0.0001 (0.001)	-0.003 (0.006)	-0.00001 (0.001)	-0.005 (0.005)	0.0002 (0.001)	0.001 (0.008)	-0.001 (0.001)
Gender (female=1)	-	-	-	-	0.794*** (0.190)	0.017 (0.020)	0.063 (0.310)	0.021 (0.034)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-1.004** (0.335)	-0.050 (0.035)	-2.296*** (0.310)	-0.006 (0.033)	-	-	-	-
Hispanic	-0.854* (0.395)	0.053 (0.042)	-1.167** (0.383)	0.044 (0.041)	-	-	-	-
Non-Hispanic others	-1.120* (0.559)	0.058 (0.058)	-1.554* (0.560)	-0.045 (0.065)	-	-	-	-
Education (in years)	0.323*** (0.047)	0.001 (0.005)	0.378*** (0.050)	-0.001 (0.005)	0.428*** (0.050)	-0.003 (0.005)	0.272*** (0.049)	0.001 (0.005)

Parental education level (in years)	0.055 (0.037)	0.004 (0.004)	0.019 (0.037)	0.002 (0.004)	0.049 (0.036)	0.001 (0.004)	0.015 (0.038)	0.002 (0.004)
Log-transformed income	-0.045 (0.056)	0.010 (0.007)	-0.048 (0.055)	0.013† (0.007)	-0.080 (0.060)	0.014† (0.008)	-0.007 (0.054)	0.008 (0.007)
Wealth	0.020 (0.015)	-0.001 (0.002)	0.034* (0.015)	-0.004† (0.002)	0.017 (0.014)	-0.001 (0.002)	0.036* (0.017)	-0.003 (0.002)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	-0.015 (0.328)	-0.037 (0.041)	0.127 (0.264)	-0.008 (0.036)	-0.029 (0.237)	-0.011 (0.031)	0.173 (0.384)	-0.030 (0.052)
Retired	-0.871 (0.877)	-0.002 (0.121)	-0.152 (0.853)	-0.036 (0.120)	-0.829 (0.723)	0.032 (0.098)	0.236 (1.125)	-0.139 (0.166)
Not engaged in work (unemployed/disabled/not in labor force)	-0.919 (0.879)	0.018 (0.124)	-0.377 (0.825)	0.009 (0.119)	-1.111 (0.717)	0.091 (0.100)	0.389 (1.089)	-0.144 (0.164)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/never married	0.189 (0.246)	-0.060* (0.029)	-0.390† (0.232)	0.028 (0.028)	-0.270 (0.204)	0.004 (0.024)	-0.116 (0.293)	-0.034 (0.035)
Depressive symptoms	-0.107* (0.054)	-0.002 (0.007)	-0.067 (0.045)	-0.003 (0.006)	-0.036 (0.043)	-0.008 (0.006)	-0.126* (0.057)	0.001 (0.007)
Self-rated health	0.285** (0.096)	-0.006 (0.012)	0.042 (0.100)	0.025† (0.013)	0.262** (0.082)	-0.002 (0.011)	0.077 (0.129)	0.019 (0.017)
Random Effects								
Time	0.001* (0.006)		0.008* (0.007)		0.001		0.014* (0.009)	
Intercept	4.867* (0.506)		5.279* (0.568)		4.486		6..336* (0.790)	
Covariance	0.026 (0.046)		0.039 (0.053)		0.057		-0.017 (0.073)	
Residual	6.220* (0.164)		7.133* (0.183)		6.139		7.792* (0.248)	
Goodness of Fit								
Df	41		41		33		37	
AIC	22900.93		24791.26		31053.99		16601.61	
BIC	23164.4		25056.86		31276.27		16825.68	

***p<.001; **p<.01; *p<.05; †p<.10. Notes: In Stata, Model 11 did not indicate the standard error values for the random effects.

Appendix E (continued). Full results of stratified models of research question 1 (Figure 2)

Table 4d. Stratified results from linear growth models of the associations between work complexity and cognitive domains, HRS, 2004-2014 (n=9,374)

	Model 9		Model 10		Model 11		Model 12	
Independent Variables	Low edu.		High edu.		Low parental edu.		High parental edu.	
Intercept	14.467*** (0.880)		16.885*** (0.904)		12.113*** (0.718)		12.365*** (1.616)	
Age	-0.048 (0.120)		-0.196† (0.116)		-0.089 (0.092)		-0.315 (0.194)	
Age squared	-0.004 (0.003)		-0.006* (0.003)		-0.004† (0.002)		-0.006 (0.004)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Past cognitive work complexity	0.002 (0.007)	0.0002 (0.001)	0.005 (0.004)	-0.001 (0.0004)	0.003 (0.004)	-0.001 (0.0004)	0.008 (0.005)	-0.0004 (0.001)
Past physical work complexity	-0.026* (0.011)	-0.0004 (0.001)	-0.040*** (0.008)	0.002† (0.001)	-0.033*** (0.007)	0.001 (0.001)	0.003 (0.013)	0.001 (0.001)
Past social work complexity	0.022* (0.010)	0.001 (0.001)	0.017* (0.007)	0.0005 (0.001)	0.015* (0.006)	0.001 (0.001)	0.016 (0.010)	-9.23e-06 (0.001)
Total ongoing work complexity	-0.013† (0.008)	0.005 (0.001)	0.005 (0.006)	-0.0005 (0.001)	-0.007 (0.005)	-0.00001 (0.001)	0.010 (0.009)	-0.001 (0.001)
Gender (female=1)	0.456 (0.284)	0.017 (0.030)	0.561** (0.201)	0.019 (0.022)	0.338† (0.194)	0.043* (0.021)	0.940** (0.291)	-0.033 (0.033)
Race/ethnicity (reference= Non-Hispanic White)								
Non-Hispanic Black	-1.623*** (0.374)	-0.030 (0.039)	-1.858*** (0.291)	-0.021 (0.031)	-1.560*** (0.252)	-0.059* (0.026)	-2.693*** (0.489)	0.125* (0.056)
Hispanic	-1.399** (0.426)	0.026 (0.046)	-1.450*** (0.377)	0.062 (0.040)	-1.071*** (0.282)	0.027 (0.030)	-1.416* (0.620)	0.052 (0.069)
Non-Hispanic others	-1.833** (0.693)	-0.005 (0.076)		0.020 (0.053)	-1.707*** (0.483)	0.003 (0.053)	-0.196 (0.746)	-0.002 (0.079)
Education (in years)	-	-	-	-	0.337*** (0.036)	0.003 (0.004)	0.357*** (0.083)	0.004 (0.009)

Parental education level (in years)	0.109** (0.040)	0.002 (0.004)	0.054 (0.033)	0.003 (0.004)	-	-	-	-
Log-transformed income	0.026 (0.051)	0.005 (0.007)	-0.100 (0.061)	0.018* (0.008)	-0.019 (0.043)	0.007 (0.006)	-0.133 (0.092)	0.025* (0.012)
Wealth	0.018 (0.017)	-0.002 (0.002)	0.035* (0.014)	-0.003 (0.002)	0.033** (0.012)	-0.003* (0.002)	0.003 (0.024)	0.002 (0.003)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	-0.309 (0.345)	0.029 (0.046)	0.315 (0.251)	-0.050 (0.033)	-0.045 (0.246)	-0.020 (0.032)	0.382 (0.359)	-0.018 (0.047)
Retired	-2.018* (1.009)	0.076 (0.148)	1.068 (0.778)	-0.119 (0.105)	-1.013 (0.702)	-0.001 (0.099)	1.551 (1.240)	-0.158 (0.169)
Not engaged in work (unemployed/disabled/not in labor force)	-1.680† (0.986)	0.023 (0.148)	0.493 (0.770)	-0.0005 (0.107)	-1.175† (0.687)	0.018 (0.099)	2.005 (1.220)	-0.136 (0.172)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/ never married	-0.243 (0.267)	-0.012 (0.032)	-0.143 (0.218)	-0.006 (0.026)	-0.146 (0.195)	-0.027 (0.023)	-0.260 (0.325)	0.045 (0.039)
Depressive symptoms	-0.065 (0.051)	-0.008 (0.007)	-0.099* (0.047)	0.001 (0.006)	-0.067† (0.039)	-0.006 (0.005)	-0.124† (0.073)	0.006 (0.010)
Self-rated health	0.222* (0.110)	0.002 (0.014)	0.164† (0.090)	0.015 (0.012)	0.152† (0.080)	0.008 (0.010)	0.269* (0.136)	0.014 (0.018)
Random Effects								
Time	0.005* (0.007)		0.004* (0.005)		0.006* (0.005)		0.001* (0.001)	
Intercept	6.234* (0.684)		4.652* (0.461)		5.390* (0.452)		3.772* (0.526)	
Covariance	0.0092 (0.058)		-0.010 (0.044)		0.034 (0.041)		0.048 (0.030)	
Residual	7.118 (0.208)		6.427* (0.151)		6.784* (0.145)		6.410* (0.206)	
Goodness of Fit								
Df	41		41		41		41	
AIC	19202.85		28527.74		35366.61		12316.17	
BIC	19457.67		28800.15		35647.15		12554.14	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix F. Full results of research question 2-a (Table 7a Model 4 & Table 7b Model 5-Model 9)

Table 7a. Results from linear growth models of the associations between work complexity, volunteering, and total cognition, HRS, 2004-2014 (n=73,136)

	Model 4	
Independent Variables		
Intercept	9.326*** (0.326)	
Age	0.017 (0.018)	
Age squared	-0.005*** (0.0002)	
	Initial level	Change over time
Total ongoing work complexity	-0.001† (0.0003)	-0.0002 (0.00001)
Volunteering		
Moderate	-0.031 (0.067)	0.021*** (0.003)
High	0.011 (0.120)	0.033*** (0.006)
Gender (female=1)	1.164*** (0.089)	-0.013** (0.004)
Race/ethnicity (reference=Non-Hispanic White)		
Non-Hispanic Black	-2.082*** (0.131)	-0.012† (0.006)
Hispanic	-0.856*** (0.164)	0.007 (0.008)
Non-Hispanic others	-1.637*** (0.267)	0.013 (0.014)
Education (in years)	0.456*** (0.017)	-0.002* (0.001)
Parental education level (in years)	0.055*** (0.014)	-0.001 (0.001)
Log-transformed income	0.010 (0.020)	0.005*** (0.001)
Wealth	0.014* (0.005)	0.001** (0.0003)
Labor force status (reference=full-time)		
Engaged in work (part-time/partly retired)	-0.095 (0.104)	0.005 (0.007)
Retired	-0.283** (0.100)	-0.006 (0.007)
Not engaged in work (unemployed/disabled/not in labor force)	-0.329** (0.110)	-0.001 (0.007)
Marital status (reference=married/partnered)		
Separated/divorced/widowed/never married	-0.139 (0.085)	0.008* (0.004)
Depressive symptoms	-0.102*** (0.016)	0.0003 (0.001)
Self-rated health	0.195*** (0.032)	-0.001 (0.001)
High blood pressure	-0.231** (0.075)	0.004 (0.004)

Random Effects		
Time	0.007* (0.001)	
Intercept	5.970* (0.275)	
Covariance	-0.058* (0.014)	
Residual	6.677* (0.042)	
Goodness of Fit		
Df	43	
AIC	374147.4	
BIC	374543	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix F (continued). Full results of research question 2-a (Table 7a Model 4 & Table 7b Model 5-Model8)
Table 7b. Results from linear growth models of the associations between work complexity, volunteering, and cognitive domains, HRS, 2004-2014 (n=73,136)

	Model 5		Model 6	
Independent Variables	Episodic memory		Working memory	
Intercept	5.572** (0.266)		1.927*** (0.129)	
Age	0.022 (0.014)		-0.013† (0.007)	
Age squared	-0.004*** (0.0002)		-0.001*** (0.0001)	
	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.0004 (0.0003)	-6.23e-06 (0.00001)	-0.0001 (0.0001)	-5.78e-06 (5.67e-06)
Volunteering				
Moderate	-0.015 (0.057)	0.016*** (0.003)	-0.004 (0.026)	0.006*** (0.001)
High	0.106 (0.101)	0.022*** (0.005)	-0.059 (0.047)	0.011*** (0.002)
Gender (female=1)	1.315*** (0.070)	-0.007* (0.003)	-0.155*** (0.036)	-0.006*** (0.002)
Race/ethnicity (reference=Non-Hispanic White)				
Non-Hispanic Black	-1.199*** (0.103)	0.006 (0.005)	-0.875*** (0.053)	-0.010*** (0.003)
Hispanic	-0.392** (0.129)	0.009 (0.006)	-0.465*** (0.066)	0.002 (0.003)
Non-Hispanic others	-1.033*** (0.210)	0.009 (0.011)	-0.502*** (0.108)	0.004 (0.006)
Education (in years)	0.291*** (0.014)	-0.002*** (0.001)	0.156*** (0.007)	5.42e-06 (0.0003)
Parental education level (in years)	0.054*** (0.011)	-0.001 (0.001)	-0.001 (0.006)	0.0003 (0.0003)
Log-transformed income	0.006 (0.017)	0.004*** (0.001)	0.005 (0.008)	0.001** (0.0004)
Wealth	0.012** (0.005)	0.00049* (0.0002)	0.002 (0.002)	0.0004*** (0.0001)
Labor force status (reference=full-time)				
Engaged in work (part-time/partly retired)	0.030 (0.088)	-0.005 (0.006)	-0.090* (0.040)	0.007** (0.003)
Retired	-0.123 (0.084)	-0.015** (0.006)	-0.092* (0.039)	0.004 (0.003)
Not engaged in work (unemployed/disabled/not in labor force)	-0.158† (0.092)	-0.011* (0.006)	-0.106* (0.043)	0.003 (0.003)
Marital status (reference=married/partnered)				
Separated/divorced/widowed/never married	-0.099 (0.069)	0.007* (0.003)	-0.033 (0.034)	0.001 (0.002)

Depressive symptoms	-0.087*** (0.013)	0.001 (0.001)	-0.017** (0.006)	-0.0003 (0.0003)
Self-rated health	0.167*** (0.027)	-0.001 (0.001)	0.038** (0.013)	0.0004 (0.0006)
High blood pressure	-0.159* (0.061)	0.005† (0.003)	-0.057† (0.030)	-0.001 (0.001)
Random Effects				
Time	0.002* (0.0004)		0.0007* (0.001)	
Intercept	3.004* (0.163)		1.051* (0.046)	
Covariance	-0.006 (0.009)		-0.006* (0.002)	
Residual	5.111* (0.031)		0.998* (0.006)	
Goodness of Fit				
Df	43		43	
AIC	349219.5		236620.4	
BIC	349615.1		237016	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix F (continued). Full results of research question 2-a (Table 7a Model 4 & Table 7b Model 5-Model 8)
Table 7b. Results from linear growth models of the associations between work complexity, volunteering, and cognitive domains, HRS, 2004-2014 (n=73,136)

	Model 7		Model 8	
Independent Variables	Attention/ Processing speed		Self-rated memory	
Intercept	1.742*** (0.041)		1.844*** (0.079)	
Age	-0.001 (0.002)		-0.004 (0.004)	
Age squared	-0.0003*** (0.00003)		0.0003*** (0.00005)	
	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.0001† (0.0001)	-7.68e-07 (2.33e-06)	0.0003** (0.0001)	-0.00001** (3.41e-06)
Volunteering				
Moderate	-0.007 (0.009)	0.001* (0.0005)	0.045** (0.016)	-0.001 (0.001)
High	-0.017 (0.017)	0.002* (0.001)	0.043 (0.028)	0.001 (0.001)
Gender (female=1)	0.010 (0.010)	0.0002 (0.001)	-0.051* (0.022)	0.006*** (0.001)
Race/ethnicity (reference=Non-Hispanic White)				
Non-Hispanic Black	-0.013 (0.014)	-0.007*** (0.001)	-0.11** (0.033)	-0.001 (0.002)
Hispanic	0.024 (0.018)	-0.003** (0.001)	-0.029 (0.041)	-0.002 (0.002)
Non-Hispanic others	-0.074* (0.029)	0.0001 (0.002)	-0.031 (0.067)	0.002 (0.003)
Education (in years)	0.008*** (0.002)	0.001*** (0.0001)	0.063*** (0.004)	-0.002*** (0.0002)
Parental education level (in years)	0.002 (0.002)	-0.0002* (0.0001)	0.015*** (0.004)	-0.0004* (0.0002)
Log-transformed income	0.004 (0.003)	-6.04e-07 (0.0002)	0.002 (0.005)	0.00002 (0.0002)
Wealth	-0.0001 (0.001)	0.0001* (0.00004)	0.0001 (0.001)	0.00001 (0.0001)
Labor force status (reference=full-time)				
Engaged in work (part-time/partly retired)	-0.003 (0.015)	0.0002 (0.001)	-0.040 (0.025)	0.002 (0.002)
Retired	-0.026† (0.014)	0.001 (0.001)	-0.100*** (0.024)	0.003* (0.002)
Not engaged in work (unemployed/disabled/not in labor force)	-0.048** (0.015)	0.003** (0.001)	-0.034 (0.025)	0.0002 (0.002)

Marital status (reference=married/partnered)				
Separated/divorced/widowed/never married	-0.022* (0.010)	0.001** (0.001)	0.031 (0.020)	0.0003 (0.001)
Depressive symptoms	-0.005* (0.002)	-0.0001 (0.0001)	-0.038*** (0.004)	0.0001 (0.0002)
Self-rated health	0.004 (0.004)	-0.0002 (0.0002)	0.177*** (0.008)	-0.001*** (0.0003)
High blood pressure	-0.007 (0.009)	-0.0003 (0.0005)	-0.001 (0.018)	-0.001 (0.001)
Random Effects				
Time	0.0002* (0.00001)		0.001* (0.00004)	
Intercept	0.029* (0.003)		0.492* (0.018)	
Covariance	-0.001* (0.0002)		-0.009* (0.001)	
Residual	0.175* (0.001)		0.359 (0.002)	
Goodness of Fit				
Df	43		43	
AIC	92508.32		160925	
BIC	92903.92		161320.7	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix G. Full results of stratified models of research question 2-a (Figure 3)

Table 7c. Stratified results from linear growth models of the associations between work complexity, volunteering, and total cognition, HRS, 2004-2014 (n=73,136)

	Model 9		Model 10		Model 11		Model 12	
Independent Variables	Male		Female		White		Minorities	
Intercept	9.540*** (0.479)		10.246*** (0.434)		6.435* (0.046)		9.619*** (0.470)	
Age	0.016 (0.027)		0.009 (0.024)		0.059** (0.022)		-0.038 (0.028)	-0.004*** (0.0004)
Age squared	-0.005*** (0.0003)		-0.005*** (0.0003)		-0.006*** (0.0002)			
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.0003 (0.001)	-0.00003 (0.00002)	-0.001* (0.0004)	-0.001* (0.0004)	-0.001** (0.0004)	-7.31e-06 (0.00002)	0.0003 (0.001)	-0.00001 (0.00003)
Volunteering								
Moderate	-0.085 (0.103)	0.023*** (0.005)	0.005 (0.087)	0.005 (0.087)	-0.069 (0.075)	0.021*** (0.004)	0.006 (0.144)	0.023** (0.008)
High	0.220 (0.183)	0.027** (0.009)	-0.116 (0.157)	-0.116 (0.157)	-0.018 (0.134)	0.033*** (0.006)	-0.024 (0.267)	0.035* (0.015)
Gender (female=1)	-	-	-	-	1.406*** (0.100)	-0.017*** (0.005)	0.551** (0.190)	-0.005 (0.009)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-1.614*** (0.208)	-0.023* (0.010)	-2.386*** (0.168)	-0.006 (0.008)	-	-	-	-
Hispanic	-0.162 (0.253)	-0.005 (0.013)	-1.324*** (0.215)	0.015 (0.011)	-	-	-	-
Non-Hispanic others	-1.219** (0.400)	0.032 (0.021)	-1.972*** (0.357)	0.002 (0.019)	-	-	-	-

Education (in years)	0.449*** (0.025)	-0.001 (0.001)	0.463*** (0.024)	-0.002 (0.001)	0.494*** (0.023)	-0.002* (0.001)	0.386*** (0.028)	-0.001 (0.001)
Parental education level (in years)	0.088*** (0.022)	-0.003* (0.001)	0.033† (0.019)	0.001 (0.001)	0.075*** (0.018)	-0.002* (0.001)	0.012 (0.024)	0.001 (0.001)
Log-transformed income	-0.019 (0.030)	0.005** (0.002)	0.033 (0.026)	0.004** (0.001)	0.004 (0.027)	0.005*** (0.001)	0.016 (0.029)	0.004* (0.002)
Wealth	0.016† (0.008)	0.001* (0.0005)	0.012† (0.007)	0.001* (0.0004)	0.015* (0.007)	0.001* (0.0004)	0.013 (0.009)	0.001† (0.0005)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	-0.259 (0.162)	0.012 (0.010)	0.071 (0.138)	-0.004 (0.010)	-0.135 (0.119)	0.007 (0.008)	0.038 (0.215)	-0.004 (0.015)
Retired	-0.604*** (0.149)	0.009 (0.009)	-0.004 (0.137)	-0.021* (0.010)	-0.289* (0.115)	-0.006 (0.008)	-0.366† (0.203)	0.001 (0.014)
Not engaged in work (unemployed/disabled/ not in labor force)	-0.259 (0.198)	-0.004 (0.014)	-0.212 (0.141)	-0.009 (0.010)	-0.368** (0.132)	-0.001 (0.008)	-0.342† (0.203)	0.008 (0.014)
Marital status (reference= married/partnered)								
Separated/divorced/widowed/never married	-0.247† (0.134)	0.005 (0.006)	-0.106 (0.111)	0.013* (0.005)	-0.026 (0.099)	0.005 (0.004)	-0.397* (0.166)	0.009 (0.008)
Depressive symptoms	-0.123*** (0.026)	0.001 (0.001)	-0.092*** (0.020)	-0.0002 (0.001)	-0.098*** (0.019)	0.001 (0.001)	-0.099** (0.029)	-0.002 (0.001)
Self-rated health	0.170*** (0.048)	-0.001 (0.002)	0.203*** (0.043)	-0.0004 (0.002)	0.198*** (0.037)	-0.001 (0.002)	0.193** (0.064)	-0.001 (0.003)
High blood pressure	-0.339** (0.111)	0.009† (0.005)	-0.146 (0.102)	-0.0005 (0.005)	-0.236** (0.086)	-0.005 (0.004)	-0.191 (0.154)	-0.007 (0.008)
Random Effects								
Time	0.006* (0.001)		0.007* (0.001)		0.007* (0.001)		0.003* (0.002)	
Intercept	5.980* (0.404)		5.860* (0.370)		5.266* (0.302)		7.133* (0.597)	
Covariance	-0.070* (0.021)		-0.046* (0.019)		-0.056* (0.016)		-0.011 (0.031)	
Residual	6.049* (0.060)		7.091* (0.057)		6.435* (0.046)		7.460* (0.096)	

Goodness of Fit								
Df	41		41		37		37	
AIC	148463.7		225447.5		283814.3		90265.91	
BIC	148803.7		225803.5		284144.7		90552.86	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix G (continued). Full results of stratified models of research question 2-a (Figure 3)

Table 7c. Stratified results from linear growth models of the associations between work complexity, volunteering, and total cognition, HRS, 2004-2014 (n=73,136)

	Model 9		Model 10		Model 11		Model 12	
Independent Variables	Low edu.		High edu.		Low parental edu.		High parental edu.	
Intercept	13.364*** (0.411)		15.347*** (0.469)		9.767*** (0.352)		9.723*** (0.879)	
Age	-0.018 (0.022)		0.012 (0.027)		0.004 (0.018)		0.041 (0.054)	
Age squared	-0.005*** (0.0003)		-0.006*** (0.0003)		-0.005*** (0.0002)		-0.006*** (0.001)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.00004 (0.0005)	-0.00004† (0.00002)	-0.001* (0.0005)	7.23e-06 (0.00002)	-0.0004 (0.0004)	-0.00002 (0.00001)	-0.001 (0.001)	8.96e-06 (0.00004)
Volunteering								
Moderate	0.214* (0.107)	0.015** (0.005)	-0.084 (0.085)	0.023*** (0.004)	-0.011 (0.077)	0.020*** (0.004)	-0.157 (0.138)	0.028*** (0.008)
High	0.236 (0.228)	0.026* (0.010)	-0.002 (0.140)	0.035*** (0.007)	0.112 (0.142)	0.029*** (0.007)	-0.290 (0.227)	0.046*** (0.012)
Gender (female=1)	1.302*** (0.139)	-0.012† (0.006)	1.018*** (0.117)	-0.012* (0.006)	1.163*** (0.102)	-0.014** (0.005)	1.140*** (0.183)	-0.005 (0.010)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-2.358*** (0.191)	-0.023** (0.009)	-1.811*** (0.185)	-0.004 (0.010)	-2.214*** (0.142)	-0.008 (0.007)	-1.804*** (0.332)	-0.014 (0.021)
Hispanic	-1.664*** (0.220)	-0.0003 (0.010)	-1.412*** (0.266)	-0.002 (0.016)	-1.023*** (0.170)	0.012 (0.008)	-1.378** (0.479)	0.008 (0.030)
Non-Hispanic others	-2.336*** (0.441)	0.011 (0.022)	-1.281*** (0.337)	0.021 (0.019)	-1.906*** (0.312)	0.022 (0.016)	-1.007† (0.517)	-0.012 (0.032)

Education (in years)	-	-	-	-	0.474*** (0.018)	-0.001† (0.001)	0.488*** (0.045)	-0.005* (0.002)
Parental education level (in years)	0.136*** (0.021)	0.001 (0.001)	0.109*** (0.019)	-0.003** (0.001)	-	-	-	-
Log-transformed income	0.046† (0.025)	0.004** (0.001)	0.006 (0.031)	0.007*** (0.002)	0.016 (0.021)	0.004*** (0.001)	-0.056 (0.051)	0.011** (0.003)
Wealth	0.006 (0.008)	0.001*** (0.0004)	0.022** (0.0008)	0.001 (0.0005)	0.013* (0.006)	0.001** (0.0003)	0.019 (0.013)	-0.0001 (0.001)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	-0.132 (0.164)	0.009 (0.011)	-0.102 (0.134)	0.004 (0.009)	-0.127 (0.121)	0.009 (0.008)	0.001*** (0.202)	-0.009 (0.014)
Retired	-0.338* (0.149)	-0.001 (0.010)	-0.302* (0.137)	-0.005 (0.009)	-0.223† (0.113)	-0.006 (0.007)	-0.548* (0.219)	0.002 (0.015)
Not engaged in work (unemployed/disabled/ not in labor force)	-0.480** (0.157)	0.005 (0.010)	-0.236 (0.159)	-0.007 (0.011)	-0.361** (0.123)	0.001 (0.008)	-0.174 (0.252)	-0.006 (0.018)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/never married	-0.087 (0.124)	0.002 (0.006)	-0.122 (0.117)	0.013* (0.006)	-0.185† (0.096)	0.010* (0.004)	0.092 (0.185)	-0.001 (0.010)
Depressive symptoms	-0.127*** (0.022)	0.0003 (0.001)	-0.083*** (0.024)	0.001 (0.001)	-0.108*** (0.017)	0.001 (0.001)	-0.072† (0.038)	-0.002 (0.002)
Self-rated health	0.185*** (0.046)	-0.0005 (0.002)	0.258*** (0.045)	-0.001 (0.002)	0.156*** (0.036)	0.0003 (0.002)	0.336*** (0.073)	-0.004 (0.004)
High blood pressure	-0.264* (0.112)	0.003 (0.005)	-0.228* (0.103)	0.006 (0.005)	-0.259** (0.085)	0.004 (0.004)	-0.137 (0.165)	0.0002 (0.009)
Random Effects								
Time	0.007* (0.001)		0.007* (0.001)		0.007* (0.001)		0.009* (0.002)	
Intercept	7.918* (0.485)		4.955* (0.332)		6.421* (0.327)		4.929* (0.519)	
Covariance	-0.073* (0.023)		-0.050* (0.019)		-0.065* (0.016)		-0.065* (0.032)	
Residual	6.805* (0.058)		6.533* (0.060)		6.722* (0.046)		6.433* (0.093)	

Goodness of Fit								
Df	41		41		41		41	
AIC	206171		168802.5		305999.7		68166.67	
BIC	206523.3		169147.4		306368.5		68474.53	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix H. Full results of research question 2-b (Table 10a Model 4 & Table 10b Model 5-Model 8)

Table 10a. Results from linear growth models of the associations between work complexity, volunteering, leisure activities and total cognition, HRS, 2004-2014 (n=12,430)

Independent Variables	Model 4	
Intercept	9.587*** (0.811)	
Age	0.007 (0.044)	
Age squared	-0.004*** (0.0004)	
	Initial level	Change over time
Total ongoing work complexity	-0.001 (0.001)	-2.67e-06 (0.00004)
Volunteering		
Mid	-0.042 (0.163)	0.012 (0.008)
High	0.120 (0.277)	0.015 (0.013)
Total leisure	0.001 (0.007)	0.001** (0.0003)
Gender (female=1)	1.168*** (0.215)	-0.015 (0.010)
Race/ethnicity (reference=Non-Hispanic White)		
Non-Hispanic Black	-2.381*** (0.319)	0.003 (0.015)
Hispanic	-0.921* (0.422)	0.001 (0.021)
Non-Hispanic others	-0.900 (0.704)	-0.017 (0.037)
Education (in years)	0.470*** (0.043)	-0.004* (0.002)
Parental education level (in years)	0.045 (0.034)	-0.001 (0.002)
Log-transformed income	-0.002 (0.049)	0.003 (0.003)
Wealth	0.020 (0.014)	0.001 (0.001)
Labor force status (reference=full-time)		
Engaged in work (part-time/partly retired)	0.103 (0.248)	-0.006 (0.016)
Retired	-0.202 (0.239)	-0.010 (0.016)
Not engaged in work (unemployed/disabled/not in labor force)	-0.510† (0.276)	0.005 (0.017)
Marital status (reference=married/partnered)		
Separated/divorced/widowed/never married	-0.056 (0.195)	0.015 (0.009)
Depressive symptoms	-0.106**(0.039)	0.001 (0.002)
Self-rated health	0.148† (0.077)	0.003 (0.004)

Random Effects		
Time	0.006* (0.002)	
Intercept	6.091* (0.644)	
Covariance	-0.072* (0.033)	
Residual	6.141* (0.095)	
Goodness of Fit		
Df	43	
AIC	62820.34	
BIC	63139.74	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix H (continued). Full results of research question 2-b (Table 10a Model 4 & Table 10b Model 5-Model 8)
Table 10b. Results from linear growth models of the associations between work complexity, volunteering, leisure activities and total cognition, HRS, 2004-2014 (n=12,430)

	Model 5		Model 6		Model 7		Model 8	
	Episodic memory		Working memory		Attention/ Processing speed		Self-rated memory	
Age	0.013 (0.037)		-0.006 (0.017)		0.007 (0.006)		0.007 (0.010)	
Age squared	-0.003*** (0.0004)		-0.001*** (0.0002)		-0.0002*** (0.0001)		0.0004*** (0.0001)	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	5.885*** (0.680)		1.761*** (0.316)		1.681*** (0.097)		1.540*** (0.195)	
Total ongoing work complexity	-0.001 (0.001)	2.77e-06 (0.00003)	0.0001 (0.003)	-8.13e-06 (0.00001)	-0.0001 (0.0001)	1.61e-06 (5.39e-06)	0.0003 (0.0002)	-0.00001 (8.23e-06)
Volunteering								
Moderate	-0.037 (0.140)	0.009 (0.007)	0.005 (0.063)	0.003 (0.003)	0.009 (0.022)	-0.0005 (0.001)	0.097* (0.038)	-0.004* (0.002)
High	0.104 (0.239)	0.009 (0.011)	-0.006 (0.107)	0.007 (0.005)	0.011 (0.037)	0.0005 (0.002)	0.006 (0.065)	0.001 (0.003)
Total leisure activity	-0.001 (0.001)	0.0003 (0.0003)	-0.004 (0.003)	0.0004** (0.0001)	-0.001 (0.001)	0.0001† (0.00004)	0.003 (0.002)	-0.0001 (0.0001)
Gender (female=1)	1.297*** (0.174)	-0.006 (0.008)	-0.093 (0.085)	-0.011** (0.004)	-0.042† (0.022)	0.002† (0.001)	-0.001 (0.053)	0.004† (0.002)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-1.446*** (0.257)	0.016 (0.012)	-0.938*** (0.125)	-0.008 (0.006)	0.015 (0.033)	-0.006*** (0.002)	-0.168* (0.079)	0.002 (0.004)
Hispanic	-0.533 (0.341)	0.010 (0.017)	-0.418* (0.166)	-0.004 (0.008)	0.042 (0.043)	-0.006* (0.003)	-0.094 (0.105)	0.002 (0.005)

Non-Hispanic others	-0.294 (0.574)	-0.025 (0.030)	-0.517† (0.275)	0.004 (0.014)	-0.073 (0.072)	0.003 (0.004)	0.067 (0.175)	-0.004 (0.009)
Education (in years)	0.301*** (0.035)	-0.003* (0.002)	0.169*** (0.017)	-0.001† (0.001)	0.004 (0.004)	0.0004* (0.0002)	0.092*** (0.011)	-0.002*** (0.0005)
Parental education level (in years)	0.036 (0.028)	-0.0003 (0.001)	0.0003 (0.013)	0.0002 (0.001)	0.010** (0.003)	-0.001*** (0.0002)	-0.005 (0.008)	0.001 (0.0004)
Log-transformed income	-0.026 (0.042)	0.003 (0.002)	0.023 (0.019)	0.0004 (0.001)	0.009 (0.007)	-0.001 (0.0004)	0.004 (0.011)	-0.0003 (0.001)
Wealth	0.007 (0.012)	0.001 (0.001)	0.009† (0.005)	0.0004 (0.0003)	0.003† (0.002)	0.0001 (0.0001)	0.002 (0.003)	0.0001 (0.0002)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	0.266 (0.214)	-0.019 (0.014)	-0.150 (0.096)	0.011† (0.006)	0.008 (0.033)	0.0004 (0.002)	0.020 (0.058)	-0.001 (0.004)
Retired	0.015 (0.205)	-0.023† (0.013)	-0.160† (0.093)	0.009 (0.006)	-0.021 (0.031)	0.002 (0.002)	-0.081 (0.056)	0.001 (0.004)
Not engaged in work (unemployed/disabled/not in labor force)	-0.449† (0.237)	-0.004 (0.015)	-0.024 (0.107)	0.005 (0.007)	-0.007 (0.036)	0.001 (0.002)	-0.048 (0.065)	-0.0002 (0.004)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/never married	-0.050 (0.163)	0.012 (0.008)	0.055 (0.076)	-0.001 (0.004)	-0.011 (0.022)	0.001 (0.001)	0.087† (0.047)	-0.002 (0.002)
Depressive symptoms	-0.074* (0.034)	-0.0002 (0.002)	-0.042** (0.015)	0.001† (0.001)	0.004 (0.005)	-0.0004 (0.0003)	-0.031** (0.009)	-0.0002 (0.0004)
Self-rated health	0.148* (0.066)	-0.0002 (0.003)	0.015 (0.030)	0.002 (0.001)	-0.003 (0.010)	0.001 (0.0005)	0.156*** (0.018)	-0.001 (0.001)
Random Effects								
Time	0.003* (0.001)		0.0005* (0.0003)		0.0001* (0.00002)		0.0005* (0.0001)	
Intercept	3.477* (0.405)		0.879* (0.105)		0.022* (0.006)		0.465* (0.040)	
Covariance	-0.040 (0.021)		-0.002 (0.005)		-0.001 (0.0004)		-0.009 (0.002)	
Residual	4.870*(0.074)		0.920* (0.014)		0.149* (0.002)		0.322* (0.005)	

Goodness of Fit								
Df	43		43		43		43	
AIC	58969.16		39562.57		13593.77		26611.53	
BIC	59288.56		39881.97		13913.17		26930.93	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix H (continued). Results of research question 2-b (supplemental analysis focusing on each leisure type)

	Model 9		Model 10		Model 11	
Independent Variables	Cognitive leisure		Physical leisure		Social leisure	
Intercept	9.548*** (0.811)		9.670*** (0.810)		9.582*** (0.810)	
Age	0.004 (0.044)		0.012 (0.044)		0.012 (0.044)	
Age squared	-0.004*** (0.0004)		-0.004*** (0.0004)		-0.004*** (0.0004)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.001 (0.001)	-2.97e-06	-0.001 (0.001)	-1.76e-06 (0.00004)	-0.001 (0.001)	-2.78e-06 (0.00004)
Volunteering						
Mid	-0.055 (0.163)	0.012 (0.008)	-0.030 (0.162)	0.014† (0.008)	-0.039 (0.163)	0.012 (0.008)
High	0.106 (0.276)	0.015 (0.013)	0.138 (0.276)	0.016 (0.013)	0.123 (0.277)	0.015 (0.013)
Cognitive leisure	0.009 (0.014)	0.002** (0.001)				
Physical leisure			-0.023 (0.028)	0.003* (0.001)		
Social leisure					-0.001 (0.017)	0.002* (0.001)
Random Effects						
Time	0.006* (0.002)		0.006* (0.002)		0.006* (0.002)	
Intercept	6.045* (0.642)		6.158* (0.646)		6.114* (0.644)	
Covariance	-0.070 (0.033)		-0.075 (0.033)		-0.073 (0.033)	
Residual	6.141* (0.095)		6.139* (0.095)		6.143* (0.095)	
Goodness of Fit						
Df	43		43		43	
AIC	62805.94		62843.08		62831	
BIC	63125.34		63162.48		63150.4	

***p<.001; **p<.01; *p<.05; †p<.10; Models 9-11 include all controls.

Appendix I. Full results of stratified models of research question 2-b (Figure 4)

Table 10c. Results from linear growth models of the associations between work complexity, volunteering, leisure activities and total cognition, HRS, 2004-2014 (n=12,430)

Independent Variables	Male		Female		White		Minorities	
Intercept	9.604*** (1.286)		10.630*** (1.029)		8.874*** (0.976)		10.121*** (1.391)	
Age	0.017 (0.069)		-0.009 (0.055)		0.048 (0.051)		-0.092 (0.082)	
Age squared	-0.004*** (0.001)		-0.004*** (0.001)		-0.005*** (0.0005)		-0.002* (0.001)	
	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Total ongoing work complexity	-0.002 (0.001)	0.00003 (0.0001)	-0.0004 (0.001)	-0.00001 (0.00004)	-0.001 (0.001)	-0.00002 (0.00004)	-0.002 (0.002)	0.0001 (0.0001)
Volunteering								
Moderate	-0.346 (0.265)	0.027* (0.013)	0.144 (0.206)	0.004 (0.010)	-0.036 (0.178)	0.009 (0.008)	-0.309 (0.402)	0.039† (0.021)
High	0.228 (0.461)	0.005 (0.021)	0.095 (0.346)	0.018 (0.017)	0.233 (0.299)	0.007 (0.014)	-0.976 (0.730)	0.089* (0.040)
Total leisure	0.002 (0.011)	0.001 (0.001)	-0.001 (0.008)	0.001* (0.0004)	0.006 (0.008)	0.001* (0.0003)	-0.009 (0.014)	0.001 (0.001)
Gender (female=1)	-	-	-	-	1.539*** (0.232)	-0.029** (0.011)	-0.452 (0.534)	0.045† (0.026)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-0.503 (0.586)	-0.060* (0.028)	-3.099*** (0.379)	0.025 (0.019)	-	-	-	-
Hispanic	-0.743 (0.736)	0.007 (0.037)	-0.994† (0.514)	-0.004 (0.025)	-	-	-	-
Non-Hispanic others	-0.441 (1.152)	-0.009 (0.063)	-1.278 (0.886)	-0.011 (0.045)	-	-	-	-
Education (in years)	0.490*** (0.067)	-0.004 (0.003)	0.456*** (0.056)	-0.004† (0.002)	0.476*** (0.052)	-0.004 (0.003)	0.420*** (0.079)	-0.005 (0.003)

Parental education level (in years)	0.027 (0.054)	-0.001 (0.003)	0.070 (0.044)	-0.001 (0.002)	0.056 (0.041)	-0.002 (0.002)	0.024 (0.064)	0.002 (0.003)
Log-transformed income	-0.026 (0.075)	0.002 (0.004)	0.010 (0.064)	0.004 (0.003)	0.004 (0.062)	0.002 (0.003)	0.001 (0.082)	0.003 (0.005)
Wealth	0.011 (0.023)	0.001 (0.001)	0.025 (0.017)	0.001 (0.001)	0.024 (0.017)	0.001 (0.001)	0.011 (0.026)	0.002 (0.001)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	-0.110 (0.402)	0.014 (0.025)	0.319 (0.317)	-0.028 (0.022)	-0.191 (0.273)	0.010 (0.018)	1.268* (0.585)	-0.084* (0.042)
Retired	-0.627† (0.380)	0.018 (0.024)	0.130 (0.310)	-0.037† (0.021)	-0.379 (0.264)	-0.001 (0.017)	0.044 (0.561)	-0.024 (0.038)
Not engaged in work (unemployed/disabled/ not in labor force)	-0.945 (0.600)	0.053 (0.040)	-0.289 (0.331)	-0.018 (0.022)	-0.651* (0.317)	0.013 (0.019)	-0.470 (0.573)	0.006 (0.039)
Marital status (reference= married/partnered)								
Separated/divorced/widowed/never married	-0.206 (0.316)	0.004 (0.014)	-0.012 (0.249)	0.023† (0.012)	-0.109 (0.214)	0.023* (0.010)	0.284 (0.472)	-0.044† (0.025)
Depressive symptoms	-0.126† (0.073)	0.002 (0.004)	-0.102* (0.047)	0.0001 (0.002)	-0.133** (0.045)	0.001 (0.002)	-0.059 (0.084)	0.002 (0.004)
Self-rated health	0.294* (0.123)	-0.005 (0.006)	0.061 (0.099)	0.007 (0.004)	0.150† (0.085)	0.002 (0.004)	0.148 (0.178)	0.002 (0.009)
Random Effects								
Time	0.006* (0.002)		0.005* (0.002)		0.006* (0.002)		0.0004* (0.006)	
Intercept	6.552* (1.069)		5.620* (0.800)		5.235* (0.678)		7.330* (1.732)	
Covariance	-0.098 (0.052)		-0.050 (0.042)		-0.057 (0.034)		-0.006 (0.101)	
Residual	5.587* (0.142)		6.445* (0.125)		5.935* (0.101)		7.029* (0.262)	
Goodness of Fit								
Df	41		41		37		37	
AIC	22477.03		40344.09		50769.93		12042.44	
BIC	22740.14		40630.07		51037.17		12254.91	

***p<.001; **p<.01; *p<.05; †p<.10

Appendix I (continued). Full results of stratified models of research question 2-b (Figure 4)

Table 10c. Results from linear growth models of the associations between work complexity, volunteering, leisure activities and total cognition, HRS, 2004-2014 (n=12,430)

	Low edu.		High edu.		Low parental edu.		High parental edu.	
Independent Variables	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time	Initial level	Change over time
Intercept	13.307*** (1.126)		16.835*** (1.051)		9.543*** (0.894)		11.783*** (2.035)	
Age	0.001 (0.061)		-0.098 (0.060)		0.006 (0.046)		-0.025 (0.124)	
Age squared	-0.004*** (0.001)		-0.005*** (0.001)		-0.004*** (0.0005)		-0.006*** (0.001)	
Total ongoing work complexity	-0.001 (0.001)	-6.51e-06	-0.001 (0.001)	-5.41e-07 (0.0001)	-0.001 (0.001)	-6.14e-06 (0.00004)	-0.001 (0.002)	0.00004 (0.0001)
Volunteering								
Moderate	0.573* (0.267)	-0.010 (0.012)	-0.355† (0.205)	0.027** (0.010)	-0.045 (0.186)	0.012 (0.009)	-0.182 (0.349)	0.021 (0.019)
High	0.895† (0.525)	-0.011 (0.023)	-0.193 (0.326)	0.031† (0.016)	0.476 (0.327)	-0.002 (0.015)	-0.812 (0.531)	0.065* (0.028)
Total leisure	-0.002 (0.010)	0.001* (0.0004)	0.006 (0.009)	0.0004 (0.0004)	-0.002 (0.008)	0.001** (0.0003)	0.012 (0.014)	0.0005 (0.001)
Gender (female=1)	1.203*** (0.338)	-0.011 (0.015)	1.102*** (0.284)	-0.021 (0.014)	1.113*** (0.247)	-0.015 (0.011)	1.244** (0.441)	-0.017 (0.024)
Race/ethnicity (reference=Non-Hispanic White)								
Non-Hispanic Black	-2.959*** (0.473)	0.012 (0.021)	-2.035*** (0.448)	-0.006 (0.024)	-2.666*** (0.340)	0.012 (0.016)	-1.024 (0.879)	-0.037 (0.051)
Hispanic	-1.447* (0.568)	-0.015 (0.026)	-1.724* (0.684)	0.006 (0.039)	-0.788† (0.448)	-0.008 (0.022)	-3.116* (1.204)	0.170† (0.090)
Non-Hispanic others	-3.925** (1.201)	0.081 (0.059)	0.847 (0.882)	-0.071 (0.047)	-0.471 (0.903)	-0.037 (0.044)	-1.710 (1.144)	0.025 (0.071)
Education (in years)	-	-	-	-	0.526*** (0.046)	-0.005** (0.002)	0.339** (0.104)	-0.002 (0.006)

Parental education level (in years)	0.123* (0.051)	-0.0004 (0.002)	0.069 (0.045)	-0.002 (0.002)	-	-	-	-
Log-transformed income	0.106 (0.074)	-0.004 (0.004)	-0.072 (0.064)	0.011** (0.004)	0.015 (0.055)	0.002 (0.003)	-0.096 (0.109)	0.009 (0.007)
Wealth	0.006 (0.020)	0.002* (0.001)	0.034† (0.019)	0.0004 (0.001)	0.022 (0.016)	0.001 (0.001)	0.010 (0.031)	0.002 (0.002)
Labor force status (reference=full-time)								
Engaged in work (part-time/partly retired)	0.249 (0.410)	-0.016 (0.027)	-0.067 (0.311)	0.005 (0.021)	0.232 (0.291)	-0.010 (0.019)	-0.215 (0.477)	0.003 (0.033)
Retired	-0.356 (0.375)	-0.012 (0.025)	-0.171 (0.315)	-0.002 (0.021)	0.025 (0.272)	-0.022 (0.018)	-1.184* (0.513)	0.043 (0.035)
Not engaged in work (unemployed/disabled/ not in labor force)	-0.673† (0.406)	0.003 (0.026)	-0.455 (0.394)	0.010 (0.025)	-0.550† (0.311)	0.001 (0.019)	-0.496 (0.628)	0.035 (0.043)
Marital status (reference=married/partnered)								
Separated/divorced/widowed/never married	0.114 (0.294)	-0.001 (0.013)	-0.274 (0.265)	0.033** (0.013)	-0.085 (0.223)	0.016 (0.010)	0.034 (0.412)	0.017 (0.022)
Depressive symptoms	-0.155** (0.056)	0.002 (0.003)	-0.037 (0.056)	-0.003 (0.003)	-0.104* (0.044)	0.001 (0.002)	-0.066 (0.090)	-0.007 (0.005)
Self-rated health	0.106 (0.115)	0.005 (0.005)	0.198† (0.105)	0.001 (0.005)	0.066 (0.087)	0.005 (0.004)	0.460** (0.172)	-0.007 (0.009)
Random Effects								
Time	0.005* (0.003)		0.008* (0.002)		0.004* (0.002)		0.012* (0.004)	
Intercept	7.391* (1.122)		5.914* (0.795)		6.120* (0.751)		5.805* (1.284)	
Covariance	-0.071 (0.054)		-0.107* (0.042)		-0.049 (0.037)		-0.153* (0.075)	
Residual	6.372* (0.138)		5.856* (0.129)		6.165* (0.105)		5.939* (0.212)	
Goodness of Fit								
Df	41		41		41		41	
AIC	33267.2		29692.77		51135.97		11706.36	
BIC	33545.05		29967.09		51431.96		11942.45	

***p<.001; **p<.01; *p<.05; †p<.10

BIBLIOGRAPHY

Alzheimer's Association. (2018). 2018 Alzheimer's disease facts and figures. *Alzheimer's & Dementia*, *14*(3), 367-429. Retrieved from https://www.alz.org/documents_custom/2018-facts-and-figures.pdf

Alzheimer’s Impact Movement (2018). Alzheimer's Research Receives Largest Ever Funding Boost in 2019 Budget. Retrieved from https://alzimpact.org/press/press_release/id/136

Andel, R., Crowe, M., Pedersen, N. L., Mortimer, J., Crimmins, E., Johansson, B., & Gatz, M. (2005). Complexity of work and risk of Alzheimer’s dementia: a population-based study of Swedish twins. *The Journals of Gerontology. Series B: Psychological Sciences and Social Sciences*, *60*(5), P251-P258.

Andel, R., Dávila-Roman, A. L., Grotz, C., Small, B. J., Markides, K. S., Crowe, M., & Neupert, S. (2017). Complexity of Work and Incident Cognitive Impairment in Puerto Rican Older Adults. *The Journals of Gerontology. Series B: Psychological Sciences and Social Sciences*. doi: 10.1093/geronb/gbx127

Andel, R., Finkel, D., & Pedersen, N. L. (2016). Effects of preretirement work complexity and postretirement leisure activity on cognitive aging. *Journals of Gerontology. Series B: Psychological Sciences and Social Sciences*, *71*(5), 849-856.

Andel, R., Infurna, F. J., Rickenbach, E. A. H., Crowe, M., Marchiondo, L., & Fisher, G. G. (2015). Job strain and trajectories of change in episodic memory before and after retirement: results from the Health and Retirement Study. *Journal of Epidemiology and Community Health*, *69*(5), 442-446.

Andel, R., Silverstein, M., & Kåreholt, I. (2014). The role of midlife occupational complexity and leisure activity in late-life cognition. *Journals of Gerontology. Series B: Psychological Sciences and Social Sciences*, *70*(2), 314-321.

Anderson, N. D., Binns, M. A., Kröger, E., Damianakis, T., Wagner, L. M., Dawson, D. R., . . . the BRAVO Team. (2018, March). *Less is more: Complex volunteer jobs and more volunteering attenuate the benefits of volunteering*. Poster session presented the Cognitive Aging Conference, Atlanta, GA.

Anderson, N. D., Damianakis, T., Kröger, E., Wagner, L. M., Dawson, D. R., Binns, M. A., ... & Cook, S. L. (2014). The benefits associated with volunteering among seniors: a critical review and recommendations for future research. *Psychological Bulletin*, *140*(6), 1505.

Bass, S. A., Caro, F. G., & Chen, Y. P. (Eds.). (1993). *Achieving a productive aging society*. Westport, CT: Auburn House.

Bollen, K. A., & Pearl, J. (2013). Eight myths about causality and structural equation models. In *Handbook of causal analysis for social research* (pp. 301-328). Springer, Dordrecht.

Boots, E. A., Schultz, S. A., Almeida, R. P., Oh, J. M., Koscik, R. L., Dowling, M. N., ... & Asthana, S. (2015). Occupational complexity and cognitive reserve in a middle-aged cohort at risk for Alzheimer’s dementia. *Archives of Clinical Neuropsychology*, *30*(7), 634-642.

Bugliari, D., Campbell, N., Chan, C., Hayden, O., Hurd, M., Main, R.,…St. Clair, P. (2016). *RAND HRS Data Documentation, Version P.* Santa Monica, CA: RAND Center for the Study of Aging.

Burda, M., Hamermesh, D. S., & Weil, P. (2007). *Total work, gender and social norms* (No. w13000). National Bureau of Economic Research.

Burdenski, T. K., Jr. (2000). Evaluating Univariate, Bivariate, and Multivariate Normality Using Graphical Procedures. Retrieved from https://eric.ed.gov/?id=ED440989

Caban-Martinez, A. J., Lee, D. J., Fleming, L. E., LeBlanc, W. G., Arheart, K. L., Chung-Bridges, K., ... & Pitman, T. (2007). Leisure-time physical activity levels of the US workforce. *Preventive Medicine*, *44*(5), 432-436.

Carlson, M. C., Erickson, K. I., Kramer, A. F., Voss, M. W., Bolea, N., Mielke, M., ... & Fried, L. P. (2009). Evidence for neurocognitive plasticity in at-risk older adults: the experience corps program. *Journals of Gerontology. Series A: Biomedical Sciences and Medical Sciences*, *64*(12), 1275-1282.

Chang, P. J., Wray, L., & Lin, Y. (2014). Social relationships, leisure activity, and health in older adults. *Health Psychology*, *33*(6), 516.

Choi, N. G., & Bohman, T. M. (2007). Predicting the changes in depressive symptomatology in later life: How much do changes in health status, marital and caregiving status, work and volunteering, and health-related behaviors contribute? *Journal of Aging and Health*, *19*(1), 152-177.

Clougherty, J. E., Souza, K., & Cullen, M. R. (2010). Work and its role in shaping the social gradient in health. *Annals of the New York Academy of Sciences*, *1186*(1), 102-124.

Corporation for National and Community Service. (n.d.). Edward M. Kennedy Serve America Act. Retrieved from https://www.nationalservice.gov/about/legislation/edward-m-kennedy-serve-america-act

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research*, *169*, 323-338.

Crimmins, E. M., Kim, J. K., Langa, K. M., & Weir, D. R. (2011). Assessment of cognition using surveys and neuropsychological assessment: the health and retirement study and the aging, demographics, and memory study. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *66B(S1),* i162–i171, doi:10.1093/geronb/gbr048

Curran, P. J., Obeidat, K., & Losardo, D. (2010). Twelve frequently asked questions about growth curve modeling. *Journal of Cognition and Development*, *11*(2), 121-136.

Estes, C. L., & Mahakian, J. L. (2001). The political economy of productive aging. In N. Morrow-Howell, J. Hinterlong, and M. Sherraden (eds.), *Productive Aging: Concepts and Challenges*, 197-213. Baltimore, MD: Johns Hopkins University Press.

Finkel, D., Andel, R., Gatz, M., & Pedersen, N. L. (2009). The role of occupational complexity in trajectories of cognitive aging before and after retirement. *Psychology and Aging*, *24*(3), 563.

Fisher, G. G., Hassan, H., Faul, J. D., Rodgers, W. L., Weir, D. R. (2015). Health and Retirement Study Imputation of Cognitive Functioning Measures: 1992–2014 (Final Release Version) Data Description Prepared by Survey Research Center University of Michigan. Retrieved from http://hrsonline.isr.umich.edu/modules/meta/xyear/cogimp/desc/COGIMPdd.pdf

Fisher, G. G., Stachowski, A., Infurna, F. J., Faul, J. D., Grosch, J., & Tetrick, L. E. (2014). Mental work demands, retirement, and longitudinal trajectories of cognitive functioning. *Journal of Occupational Health Psychology*, *19*(2), 231.

Fissler, P., Küster, O., Schlee, W., & Kolassa, I. T. (2013). Novelty interventions to enhance broad cognitive abilities and prevent dementia: synergistic approaches for the facilitation of positive plastic change. *Progress in Brain Research*, *207*, 403-434.

Fredriksen-Goldsen, K. I., & Scharlach, A. E. (2006). An interactive model of informal adult care and employment. *Community, Work and Family*, *9*(4), 441-455.

Fried, L. P., Carlson, M. C., Freedman, M., Frick, K. D., Glass, T. A., Hill, J., ... & Wasik, B. A. (2004). A social model for health promotion for an aging population: initial evidence on the Experience Corps model. *Journal of Urban Health*, *81*(1), 64-78.

Fu, C., Li, Z., & Mao, Z. (2018). Association between social activities and cognitive function among the elderly in China: a cross-sectional study. *International Journal of Environmental Research and Public Health*, *15*(2), 231.

Global Council on Brain Health (2017). "Engage Your Brain: GCBH Recommendations on Cognitively Stimulating Activities." Retrieved from www.GlobalCouncilOnBrainHealth.org

Gonzales, E., Matz-Costa, C., & Morrow-Howell, N. (2015). Increasing opportunities for the productive engagement of older adults: A response to population aging. *The Gerontologist*, *55*(2), 252-261.

Grand Challenges for Social Work (n.d.). 12 Challenges. Retrieved from http://grandchallengesforsocialwork.org/grand-challenges-initiative/12-challenges/

Grzywacz, J. G., Segel-Karpas, D., & Lachman, M. E. (2016). Workplace exposures and cognitive function during adulthood: Evidence from National Survey of Midlife Development and the O* NET. *Journal of Occupational and Environmental Medicine*, *58*(6), 535.

Guiney, H., & Machado, L. (2017). Volunteering in the community: potential benefits for cognitive aging. *The Journals of Gerontology. Series B: Psychological Sciences and Social Science*, *73*(3), 399-408.

Hao, Y. (2008). Productive activities and psychological well-being among older adults. *The Journals of Gerontology. Series B: Psychological Sciences and Social Sciences, 63*(2), S64-S72.

Hassing, L. B. (2017). Gender Differences in the Association Between Leisure Activity in Adulthood and Cognitive Function in Old Age: A Prospective Longitudinal Population-Based Study. *The Journals of Gerontology: Series B, Psychological Sciences and Social Science*. doi: 10.1093/geronb/gbx170

He, W., Goodkind, D., & Kowal, P. (2016). *US Census Bureau, international population reports*. P95/16-1, An Aging World: 2015. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2016/demo/p95-16-1.pdf

Health and Retirement Study, Public Use Dataset. (2019a). *Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740)*. Ann Arbor, MI: University of Michigan.

Health and Retirement Study, Restricted Access Datasets [Industry and Occupation Data]. (2019b). *Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740)*. Ann Arbor, MI: University of Michigan.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews. Neuroscience*, *9*(1), 58.

Hooyman, N. R., & Kiyak, H. A. (2018). *Social gerontology: A multidisciplinary perspective* (10th ed.). New York, NY: Pearson Press.

Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. (1999). Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging? *Psychology and Aging*, *14*(2), 245.

Hurd, M. D., Martorell, P., Delavande, A., Mullen, K. J., & Langa, K. M. (2013). Monetary costs of dementia in the United States. *New England Journal of Medicine*, *368*(14), 1326-1334.

Hurd, M. D., & Rohwedder, S. (2009). Methodological innovations in collecting spending data: The HRS Consumption and Activities Mail Survey. *Fiscal Studies*, *30*(3-4), 435-459.

Johnson, R. W., Mermin, G. B., & Resseger, M. (2011). Job demands and work ability at older ages. *Journal of Aging & Social Policy*, *23*(2), 101-118.

Karp, A., Andel, R., Parker, M. G., Wang, H. X., Winblad, B., & Fratiglioni, L. (2009). Mentally stimulating activities at work during midlife and dementia risk after age 75: follow-up study from the Kungsholmen Project. *The American Journal of Geriatric Psychiatry*, *17*(3), 227-236.

Karp, A., Paillard-Borg, S., Wang, H. X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65-73.

Kaufmann, C. N., Montross-Thomas, L. P., & Griser, S. (2018). Increased Engagement With Life: Differences in the Cognitive, Physical, Social, and Spiritual Activities of Older Adult Music Listeners. *The Gerontologist*, *58*(2), 270–277.

Koerner, T., & Zhang, Y. (2017). Application of linear mixed-effects models in human neuroscience research: a comparison with Pearson correlation in two auditory electrophysiology studies. *Brain Sciences*, *7*(3), 26.

Kohn, M. L., & Schooler, C. (1978). The reciprocal effects of the substantive complexity of work and intellectual flexibility: A longitudinal assessment. *American Journal of Sociology*, *84*(1), 24-52.

Kramer, A. F., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends in Cognitive Sciences, 11*(8), 342-348.

Kröger, E., Andel, R., Lindsay, J., Benounissa, Z., Verreault, R., & Laurin, D. (2008). Is complexity of work associated with risk of dementia? The Canadian Study of Health and Aging. *American Journal of Epidemiology*, *167*(7), 820-830.

Kromer, B., & Howard, D. (2013). *Labor force participation and work status of people 65 years and older*. US Department of Commerce, Economics and Statistics Administration, US Census Bureau.

Lee, M. P., Hudson, H., Richards, R., Chang, C. C., Chosewood, L. C., & Schill, A. L. (2016). Fundamentals of total worker health approaches: essential elements for advancing worker safety, health, and well-being. National Institute for Occupational Safety and Health (NIOSH) Office for Total Worker Health. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 2017-112. Retrieved from https://www.cdc.gov/niosh/docs/2017-112/pdfs/2017_112.pdf?id=10.26616/NIOSHPUB2017112

Lee, Y., Min, J., & Chi, I. (2017). Life transitions and leisure activity engagement in later life: findings from the Consumption and Activities Mail Survey (CAMS). *Ageing & Society*, 1-21.

Lee, T., Lipnicki, D. M., Crawford, J. D., Henry, J. D., Trollor, J. N., Ames, D., . . .OATS Research Team. (2014). Leisure activity, health, and medical correlates of neurocognitive performance among monozygotic twins: the Older Australian Twins Study. *Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *69*(4), 514–522, doi:10.1093/geronb/gbt031.

Luoh, M. C., & Herzog, A. R. (2002). Individual consequences of volunteer and paid work in old age: Health and mortality. *Journal of Health and Social Behavior*, 490-509.

Matz-Costa, C., Carr, D. C., McNamara, T. K., & James, J. B. (2016). Physical, cognitive, social, and emotional mediators of activity involvement and health in later life. *Research on Aging*, *38*(7), 791-815.

Mikelson, K. S. (2017). The Role of SCSEP in Workforce Training for Low-Income Older Workers. Washington, DC: Urban Institute. https://www. urban. org/research/publication/role-scsep-workforce-training-low-incomeolder-workers.

Miller, D. P. (2009). *Environmental influences on child obesity: Maternal work and other factors*. Doctoral dissertation, Columbia University.

Morrow-Howell, N. (2010). Volunteering in later life: Research frontiers. *The Journals of Gerontology: Series B*, *65*(4), 461-469.

Morrow-Howell, N., Gonzales, E., Matz-Costa, C., & Greenfield, E. A. (2015). Increasing productive engagement in later life. *American Academy of Social Work and Social Welfare (Ed.), Grand challenges for social work initiative. Working Paper*, (8).

Morrow-Howell, N., Gonzales, E., Matz-Costa, C., James, J. & Putnam, P. (2018). Advance long and productive lives. In R. Fong, J. Lubben, & R. P. Barth (Eds.), *Grand Challenges for Social Work and Society* (chapter 5). New York and Washington, DC: Oxford University Press/NASW Press.

Morrow-Howell, N., Hinterlong, J., Rozario, P. A., & Tang, F. (2003). Effects of volunteering on the well-being of older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(3), S137-S145.

Morrow-Howell, N., Hinterlong, J., & Sherraden, M. (Eds.). (2001). *Productive aging: Concepts and challenges*. JHU Press.

Morrow-Howell, N., Putnam, M., Lee, Y. S., Greenfield, J. C., Inoue, M., & Chen, H. (2014). An investigation of activity profiles of older adults. *Journals of Gerontology. Series B: Psychological Sciences and Social Sciences, 69(5),* 809–821, doi:10.1093/geronb/gbu002.

National Association of Social Workers. (n.d.). Read the Code of Ethics. Retrieved from Retrieved from https://www.socialworkers.org/About/Ethics/Code-of-Ethics/Code-of-Ethics-English

National Center for O*NET Development. (n.d.). Retrieved from http://www.onetonline.org

Obisesan, T. O., & Gillum, R. F. (2009). Cognitive function, social integration and mortality in a US national cohort study of older adults. *BMC Geriatrics*, *9*(1), 33.

Oltmanns, J., Godde, B., Winneke, A. H., Richter, G., Niemann, C., Voelcker-Rehage, C., ... & Staudinger, U. M. (2017). Don’t lose your brain at work–The role of recurrent novelty at work in cognitive and brain aging. *Frontiers in Psychology*, *8*, 117.

O*NET OnLine. (2019). O*NET OnLine Help. Scales, Ratings, and Standardized Scores. Retrieved from https://www.onetonline.org/help/online/scales

O'Reilly, D., Rosato, M., Ferry, F., Moriarty, J., & Leavy, G. (2017). Caregiving, volunteering or both? Comparing effects on health and mortality using census-based records from almost 250,000 people aged 65 and over. *Age and Ageing*, *46*(5), 821-826.

Pool, L. R., Weuve, J., Wilson, R. S., Bültmann, U., Evans, D. A., & Mendes de Leon, C. F. (2016). Occupational cognitive requirements and late-life cognitive aging. *Neurology*, *86*(15), 1386-1392.

Pressman, S. D., Matthews, K. A., Cohen, S., Martire, L. M., Scheier, M., Baum, A., & Schulz, R. (2009). Association of enjoyable leisure activities with psychological and physical well-being. *Psychosomatic Medicine*, *71*(7), 725.

Proulx, C. M., Curl, A. L., & Ermer, A. E. (2017). Longitudinal Associations Between Formal Volunteering and Cognitive Functioning. *The Journals of Gerontology: Series B, Psychological Sciences and Social Sciences*.

Putnam, M., Morrow-Howell, N., Inoue, M., Greenfield, J. C., Chen, H., & Lee, Y. (2013). Suitability of public use secondary data sets to study multiple activities. *The Gerontologist*, *54*(5), 818-829.

Quach, E. D. (2018). Work and the Family in Later Life: The Effects of Role Stressors, Role Enhancement, and Role Conflict on Self-Perceptions on Aging. *The International Journal of Aging and Human Development*, 0091415018812404.

Ritchie, S. J., Bates, T. C., Der, G., Starr, J. M., & Deary, I. J. (2013). Education is associated with higher later life IQ scores, but not with faster cognitive processing speed. *Psychology and Aging*, *28*(2), 515.

Sachdev, P. S., Blacker, D., Blazer, D. G., Ganguli, M., Jeste, D. V., Paulsen, J. S., & Petersen, R. C. (2014). Classifying neurocognitive disorders: the DSM-5 approach. *Nature Reviews. Neurology*, *10*(11), 634.

Salthouse, T. A. (2006). Mental exercise and mental aging: Evaluating the validity of the "use it or lose it" hypothesis. *Perspectives on Psychological Science*, *1*(1), 68-87.

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548.

Schooler, C. (1984). Psychological effects of complex environments during the life span: A review and theory. *Intelligence*, *8*(4), 259-281.

Schooler, C., & Mulatu, M. S. (2001). The reciprocal effects of leisure time activities and intellectual functioning in older people: a longitudinal analysis. *Psychology and Aging*, *16*(3), 466.

Schooler, C., Mulatu, M. S., & Oates, G. (2004). Occupational self-direction, intellectual functioning, and self-directed orientation in older workers: Findings and implications for individuals and societies. *American Journal of Sociology*, *110*(1), 161-197.

Schreurs, B., Van Emmerik, H., De Cuyper, N., Notelaers, G., & De Witte, H. (2011). Job demands-resources and early retirement intention: Differences between blue- and white-collar workers. *Economic and Industrial Democracy, 32*(1), 47-68.

Singer, J. D., & Willet, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence.* New York, NY: Oxford University Pres.

Smart, E. L., Gow, A. J., & Deary, I. J. (2014). Occupational complexity and lifetime cognitive abilities. *Neurology*, *83*(24), 2285-2291.

Sonnega, A., Helppie-McFall, B., Hudomiet, P., Willis, R. J., & Fisher, G. G. (2017). A comparison of subjective and objective job demands and fit with personal resources as predictors of retirement timing in a national US sample. *Work, Aging and Retirement*, *4*(1), 37-51.

St John, P., & Montgomery, P. (2002). Are cognitively intact seniors with subjective memory loss more likely to develop dementia? *International Journal of Geriatric Psychiatry*, *17*(9), 814-820.

StataCorp. (2017). *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC.

Staudinger, U. M., Finkelstein, R., Calvo, E., & Sivaramakrishnan, K. (2016). A global view on the effects of work on health in later life. *The Gerontologist, 56*(Suppl. 2), S281-S292.

Stern, C., & Munn, Z. (2010). Cognitive leisure activities and their role in preventing dementia: a systematic review. *International Journal of Evidence-Based Healthcare*, *8*(1), 2-17.

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, *47*(10), 2015-2028.

Swaab, D. F. (1991). Brain aging and Alzheimer's disease, "wear and tear" versus "use it or lose it". *Neurobiology of Aging*, *12*(4), 317-324.

Tarawneh, R., & Holtzman, D. M. (2012). The clinical problem of symptomatic Alzheimer disease and mild cognitive impairment. *Cold Spring Harbor Perspectives in Medicine*, *2*(5), a006148.

Tucker-Drob, E. M., Johnson, K. E., & Jones, R. N. (2009). The cognitive reserve hypothesis: a longitudinal examination of age-associated declines in reasoning and processing speed. *Developmental Psychology, 45*(2), 431.

Tulving, E. (2002). Episodic memory: from mind to brain. *Annual Review of Psychology*, *53*(1), 1-25.

U.S. Bureau of Labor Statistics (n.d.). Standard Occupational Classification. Retrieved from https://www.bls.gov/soc/

Van Willigen, M. (2000). Differential benefits of volunteering across the life course. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 55*(5), S308-S318.

Vance, D. E., Webb, N. M., Marceaux, J. C., Viamonte, S. M., Foote, A. W., & Ball, K. K. (2008). Mental stimulation, neural plasticity, and aging: directions for nursing research and practice. *Journal of Neuroscience Nursing*, *40*(4), 241-249.

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., ... & Buschke, H. (2003). Leisure activities and the risk of dementia in the elderly. *New England Journal of Medicine*, *348*(25), 2508-2516.

Wang, H. X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: a longitudinal study from the Kungsholmen project. *American Journal of Epidemiology*, *155*(12), 1081-1087.

Wang, H. X., Xu, W., & Pei, J. J. (2012). Leisure activities, cognition and dementia. *Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease*, *1822*(3), 482-491.

Wayne, P. M., Walsh, J. N., Taylor-Piliae, R. E., Wells, R. E., Papp, K. V., Donovan, N. J., & Yeh, G. Y. (2014). Effect of tai chi on cognitive performance in older adults: systematic review and meta-analysis. *Journal of the American Geriatrics Society*, *62*(1), 25-39.

Xue, B., Cadar, D., Fleischmann, M., Stansfeld, S., Carr, E., Kivimäki, M., ... & Head, J. (2018). Effect of retirement on cognitive function: the Whitehall II cohort study. *European Journal of Epidemiology*, *33*(10), 989-1001.

CURRICULUM VITAE

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