ASSOCIATION BETWEEN COGNITIVE ABILITIES AND PHYSICAL FUNCTIONAL STATUS IN A SAMPLE OF NON-DEMENTED COMMUNITY-DWELLING OLDER ADULTS

BY

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Abstract

Multiple cross-sectional studies have shown a positive association between cognitive decline and physical functional decline in demented older adults, and new research has begun to look at the temporal ordering of decline in physical and cognitive functioning prior to and following physical disability and diagnoses of mild cognitive impairment (MCI) or dementia. With the physical and mental health fields moving toward a preventative treatment approach, it will be necessary to identify modifiable factors that influence progression to physical disability and dementia in older populations. Due to difficulties recruiting older adults for clinical research trials, the inequitable geographic distribution of clinical research trials for older adults, and limitations imposed by financial problems on many of the nation's elderly, it will be important to identify clinical interventions that can be implemented by clinicians across a broad array of clinical settings. In addition, because of increasing job commands faced by many of today's clinicians, future research must provide improved metrics for the clinical assessment of cognitive and physical functioning in everyday clinical settings in ways that are not only efficacious, but also efficient and cost-effective. However, our current understanding of the association between physical functioning and cognitive status is insufficient. A gap in the existing literature exists with regard to the interplay between cognitive functioning and physical proficiency in the absence of pathology. Little research has examined the association between cognitive and physical functioning in cognitively and physically healthy older adults. What is also unclear is how the variance in demographic variables (age, gender, years of education) affects the association between cognition and physical proficiency. The present study used retrospective data from the National Alzheimer's Coordinating Center (NACC), a national database of data from participants participating in ongoing standardized clinical research at the nearly 30

Alzheimer Disease Centers (ADCs) nationwide. Data from 119 cognitively healthy, community-dwelling older adults were analyzed using confirmatory factor analyses (CFA) within a structural equation modeling (SEM) format. First, one-factor models evaluated cognitive functioning and physical functional speed as two individual latent constructs. Cognitive functioning was defined with four reflective indicators: Category Fluency – Animals, Stroop Color Naming, Digit Symbol, and Block Design. Physical functional speed was defined as a latent factor with five reflective indicators: Step Test, Time Up and Go, Walk 50 Feet, and 5-Second Chair Rise. Both one-factor models had adequate model fit, with all indicators significantly loading on their respective factors. A two-factor model then examined the relationship between the two latent constructs, and fit indices showed adequate model fit. The final model included multiple indicators multiple causes (MIMIC) to examine the moderating effects of three indicators (age, gender, and years of education) on the strength of the relationship between cognitive functioning and physical functional speed and overall model fit. After adjusting for covariates, model estimates were smaller but still demonstrated acceptable model fit. Finally, Differential Item Functioning (DIF) was employed to examine direct effects of covariates on specific indicators selected based on modification indices. Findings from the present study demonstrate an association between cognition and physical functioning without evidence of pathology, and highlight the ways in which the interplay between both factors are affected by demographic characteristics. The study also illustrates a parsimonious way of assessing for cognitive status and physical ability in older adult populations. These findings are significant as they contribute to the improved understanding of the interplay between physical and cognitive health among older adult populations. This information serves to better inform research directed toward better defining characteristics of the normal aging process, improving interventions for cognitive and

physical functional decline, and continuing existing efforts to maximize the overall functioning of older adults.

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Chapter I

Introduction

With the baby boomer generation reaching retirement age, the United States is experiencing a rapid increase in the elderly population – those individuals aged 65 years and older (McLaughlin, Connell, Heeringa, Lydia, & Roberts, 2010). Never before in history has there been such a large percentage of older adults in the U.S. population. Currently, approximately 13% of the U.S. population is aged 65 years and older, with current trajectories predicting that figure to rise to 19% by the year 2030 (Vincent & Velkoff, 2010). This growth has led some to consider further classification of sub-groups of the elderly population in an effort to recognize and respect the diversity of old age, which can now span more than four decades! One classification method is based on age by decade and is designated as follows: sexagenarians refer to those in their sixties; septuagenarians refer to those in their seventies; octogenarians refer to those in their eighties; nonagenarians refer to those in their nineties; and centenarians describe those who are 100 years or older. Another designation system to describe older adults takes a broader approach wherein older adults between 65 and 74 years of age are classified as “young old”, those 75 to 84 years are considered “middle-old”, and those older adults aged 85 years or older are consider “oldest-old”. Accompanying the expansion of the older adult population will be certain increases in the rates of disability, dependence, and morbidity, all of which will yield unprecedented demands for health care services (McLaughlin et al., 2010). In light of this daunting forecast, the fields of gerontology and geropsychology have responded with a mission to promote the well-being of older adults, prevent or delay the onset of disease, and understand what underlying factors contribute to both. In the past twenty years, an outpouring of research has explored what it means to age well. Emerging from this exploration is the concept of "successful aging". Originally presented by Rowe and Kahn (1997), successful aging is rooted in the scientific study to uncover and promote protective factors for optimal health, identify risk factors for ill health, and prevent and effectively treat age-related illnesses and disability. Determining what factors contribute to healthy aging is crucial; empirical evidence is pointing toward the interrelationship between cognition and physical function as a way to understand what it means to age well.

Dealing with a rapidly aging population will require changes in the ways different vectors of our society operate including medicine, public policy, economic development, labor force, and social service. The increased number of older adults is already creating a need for improved social welfare, public policy, and health care services to elucidate the demands of elderly Americans, but efforts made thus far are unable to appease the unique needs of this target population over the long-term. Without adjusting for the shift in the proportion of Americans who are elderly, the likelihood of continued prosperity of our nation is jeopardized. Our society must determine how best to transform its current structure of policies, priorities, and services in order to provide accommodation for needs specific to older adults.

As people age, they become at greater risk for major health conditions, disability, as well as a reduced quality of life (Daly et al., 2008; Stuck et al., 1999). Factors contributing to this increased risk of ill health are major life transitions and common elder age experiences. These transitions and experiences include but are not limited to: retirement and the relinquishment of an identity associated with a role in the occupational field; "downsizing" living space and moving into smaller homes and/or senior living communities; assuming the caregiver role of a spouse or loved one or taking on the role of a care recipient; and grieving the loss of siblings and longtime friends. The stress of these transitions and the adjustment to a new way of life unfortunately have the potential to negatively impact older adults' immune system, physical functioning, mental health, cognitive functioning, and quality of life – all of which can serve to exacerbate risk for morbidity and death. Negative outcomes of cognitive decline result in the increased need for care for those affected, as well as the subsequently greater demand for human and monetary resources (Haan & Wallace, 2004). Identifying what factors promote healthy aging, uncovering those that increase risk for disability and disease, and developing ways to use this information to improve clinical practice will not only benefit older adults, but may alleviate some of the potential burden to the healthcare system. This comes at a crucial point when our current knowledge of the aging process and best practices for working with older adults appears questionably insufficient to adequately meet the needs of the fast-growing older adult population. What is known is the normal aging process is associated with a need for accommodations, especially for reduced memory functioning, a tendency to lose balance, and general frailty (Daly et al., 2008). By furthering clinicians' competencies with regards to the various facets of healthy aging, clinicians will be instilled with the conceptual tools necessary to more accurately pinpoint the time at which their older clients' functioning deviates from the expected changes associated with normal aging process. This will serve as the foundation for the development of future interventions to prevent and treat age-related illness and disorders and to maintain and improve quality of life, overall health, independent status, and contribution to and involvement in society.

Cognition is inarguably related to many aspects of human life, and contributes to academic achievement, occupational successes, and quality of life. A key point of scholarly interest is understanding the point at which age-related cognitive slowing deviates from the normal aging process and transitions to abnormal degeneration. Previous research has described the various changes in neuroanatomy and cognition that are associated with the normal aging process (Horn & Cattell, 1966, 1967; Salthouse, 1992; Craik & Salthouse, 2008). Healthy aging is associated with slight decreased mental efficiency, capacity to learn and store new information, and ease with which to recall previously learned information. At the point with which such changes become pathological, age-related cognitive decline begins to affect the ability to function independently and perform activities of daily living. Such functional deficits not only burden the individuals themselves, but also then loved ones who often must assume the responsibilities of caring for the older adult with both cognitive and functional deficits. Viewing the issue from a broader perspective, age-related cognitive and functional decline places a toll on health care systems because of the time and resources necessary to provide sufficient care to individuals with compromised cognitive and functional capacity.

When considering potential solutions, some researchers have sought a preventative approach to preserve older adults' cognitive functioning so as to maintain their functional independence for as long as possible. Over the past twenty years, numerous research endeavors, empirically supported treatments, and therapeutic intervention strategies have been developed in an effort to prevent and delay dementia onset. One area of related research involves the relationship between cognition and physical functioning.

In order to guarantee the continuation of best research and clinical practices, it is vital for clinicians and researchers to demonstrate an improved understanding of the association between physical performance and cognitive functioning and what, if any, underlying factors that may be contributing to the association. However, complications exist concerning interpreting the existing research regarding the association between cognition and physical functioning. Methodological limitations, inconsistent use of psychological terminology, and varying methods for assessing physical performance and cognition make it difficult to compare findings across multiple studies, thereby limiting the generalizability and usefulness of the literature as a whole. Further, little is known about the association between physical functioning and cognition in the absence of disease. Understanding what is normal, not just simply what marks abnormal, will increase our ability to accurately gauge changes at an early stage of cognitive impairment, perhaps even pre-clinical.

Recently, researchers and clinicians have examined applied strategies for preventing or delaying the onset of disability and clinically significant cognitive decline in older adults. This is an area of research quickly growing in popularity, especially with findings demonstrating the efficacy of community-based intervention programs for older adults targeted towards improved functional outcomes, reduced nursing home admissions and hospitalizations, and maintained cognitive functioning. With current trajectories projecting that the older adult population will only increase in size in the near future, the United States is experiencing a change in the demographics of its citizens. Thus, the nation is currently undergoing a transitional period to allow for improved accommodations and increased consideration for the unique needs of older adults. As the population ages, it becomes increasingly important, if not necessary, for clinicians to understand this life stage and the unique challenges that older persons face. In order to provide appropriate assessment, intervention, and treatment, health care providers must consider ways in which sexagenarians, septuagenarians, octogenarians, nonagenarians, and centenarians differ from one another because of the unique political, economic, and cultural realities of the time in which they were raised. Unfortunately, these individuals are often mistakenly grouped together under an umbrella term of "older adults" without taking into consideration the specific qualities and different intergenerational experiences of each respective age cohort. However, there are certain experiences unique to the aging population that all older adults, regardless of cohort, will eventually encounter.

Two of the most prominent changes that occur because of advanced age are deteriorations in cognitive functioning and physical performance. Although the degree of change typically differs across cohorts of older adults, the deterioration in cognition and functional ability is a shared eventuality among all older persons. Cognitive decline is not a normal part of aging. In fact, a large proportion of older adults maintain a high level of cognitive performance throughout their lives. Differences in physical performance and medical status appear to partly explain variations in cognitive performance, yet the extent of its contributions remains understudied.

Multiple studies have demonstrated an inverse relationship between self-reported physical activity and cognitive decline, wherein increased physical activity is associated with maintained cognitive functioning (Rajan, Hebert, Scherr, Mendes de Leon, & Evans, 2015; Tabbarah, Crimmins, & Seeman, 2002; Albert et al., 1995). Similar findings demonstrated the significant relationship between physical functioning and risk of various dementias including vascular dementia and Alzheimer's disease (AD; Alexopoulos, 2003; Fried et al., 1998). Studies of intervention trials have shown improved cognitive functioning in response to physical fitness training (Colcombe & Kramer, 2003). There have been few studies however, that have examined the relationship between cognition and basic physical performance tasks.

The present study aims to amend this by untangling the complex interweaving of cognitive functioning and physical performance in older adults. The author hopes to identify factors of cognitive functioning and physical proficiency using validated yet easy-to-administer assessments, and to demonstrate that the relationship with healthy older adults without evidence of disability or decline. In order to identify cognitive functioning, the author employed objective cognitive assessments with both strong validity and easy administration procedures. These assessments were selected due to their brevity, cost-effectiveness, and ease of administration and scoring procedures. This would support generalist clinicians' ability to gauge patients' cognitive status when access to advanced medical technology and consultation with highly specialized practitioners is often limited or unavailable. These would not only provide a cost-effective solution for cognitive screenings that could be easily incorporated into their existing standard of practice but also allowing for improved opportunities to provide immediate treatments and interventions. Similarly, by using easy-to-administer performance-based measures of physical functioning, the author hopes to show that physical proficiency can be assessed in a general clinical setting. Findings also intent to show the ability for these objective assessments to gauge physical proficiency more accurately than previous research attempts that relied heavily on subjective assessments. Finally, the author will examine how other variables affect the strength of the relationship between cognition and physical performance to provide direction for future research and program development.

Chapter II

Review of the Literature

The current chapter begins with a description of general perceptions towards older adults and aging in our society. It gives an overview of historical perspectives as well as myths and stereotypes of aging. The chapter then discusses age-related changes in neuroanatomy and cognition and differentiates between normal age-related changes in cognition and pathological cognitive decline. We then shift our attention to physical functioning. Age-related change in physical functioning, different types of physical activities, and the benefits of physical activity for older adults is presented. The cognitive functioning of older adults is then discussed, and findings from existing literature regarding the association between cognitive functioning and various types of physical performances in the aging population are reviewed. The chapter concludes with a summarization of main findings and limitations of the literature, a brief description of the current study, along with research questions and study hypotheses.

Despite the growing number of elderly in the population, aging remains a largely misunderstood and often stigmatized experience that, with the exception of premature mortality, each of us must inevitably face. A growing trend in research is devoted to identifying the physiological, cognitive, and emotional changes that characterize healthy aging. Healthy aging is associated with varying degrees of change in various areas of functioning, with some variations in functioning indicative of abnormal decline. Such abnormal decline not only negatively affects the quality of life for the elderly individual, but also those of their loved ones and caregivers, as well as the healthcare field and society as a whole. Unfortunately, differentiating between healthy age-related shifts and pathologically-influenced declines can be challenging. In order to provide sufficient treatment and care to the aging population, we must first understand the factors associated with not only healthy aging, but also those related to abnormal decline. Now, let us first orient our attention to non-pathological cognitive changes that we typically see in older adults.

As the U.S. population continues to grow older, there is a growing concern about the implications of cognitive dysfunction. Many of these concerns are based on the supposition that all older adults will eventually experience some level of senility, and that, given enough time, developing dementia is ultimately inevitable. However, this is a false assumption. However, memory complaints are rather common among the older adult population, with the frequency of these complaints often increasing with age. For instance, many older adults report difficulty with recalling addresses, names of people, or titles of films or television shows. Other common complaints include occasionally forgetting the location of regularly used items (e.g., eyeglasses, car keys), difficulty remembering details of a conversation, walking into a room and then forgetting the reason for doing so, being easily distracted, and difficulty expressing information that "is on the tip of your tongue" (Grundman et al., 2004; Levy, 1994). Although many older adults experience some declines in memory functioning and the speed with which they process information, these declines are part of the normal aging process and generally are not indicative of serious cognitive deterioration or a warning sign for oncoming dementia. For example, aging itself is associated with reduced basic attention (Bopp & Verhaeghen, 2005), slowed processing speed (Salthouse, 1996), and the amount of information that can be learned and then retrieved over time (Salthouse, 2003). However, it must be noted that these cognitive changes typically do not affect functioning, or significantly affect individuals' ability to adequately perform everyday activities.

Theories on Age-Related Cognitive Change

Cognitive slowing as part of normal aging. A large body of scientific evidence in the fields of gerontology, neuropsychology, and neurology has demonstrated that the normal aging process, even without the presence of pathology, involves age-related decline in cognitive processes and physical functional abilities (Grigsby, Kaye, Baxter, Shetterly, and Hamman, 1998). One of the most well-studied age-related changes to cognition involves decreased processing speed (Cerella, 1985; Salthouse, 1996, 2000; Fisk & Sharp, 2004) and working memory (Morris, Gick, & Craik, 1988). Typically referred to as the general slowing hypothesis of cognitive functioning or, more simply, the cognitive speed hypothesis, the theory purports the slowing phenomenon in old age is largely a result of a generally decreased rate of information processing speed. Age-related slowing has been one of the most well-documented and least controversial behavioral phenomena of aging. This slowing phenomenon has been observed across a wide range of activities (Salthouse 1985), including attentional selection tasks like Stroop Color Naming (Spieler, Balota, & Faust, 2006) and measures of visuospatial processing (Balota, Tse, Hutchison, Spieler, Duchek, & Morris, 2010) like the Block Design subtest from the Wechsler Adult Intelligence Scale – Revised (Wechsler, 1981). Many believe that this observed slowing most notably affects perceptual and cognitive processes, and is the primary predictor of negative age-associated changes in cognitive functioning (Birren, 1964; Salthouse, 1985). Some researchers have theorized that the primary reasons for differences in cognitive functioning between younger and older adults are primarily age differences in cognitive speed. Several researchers in the area of cognitive aging agree that performance on information-processing tasks purported to assess cognitive or perceptual processes is markedly slowed in old age (Hertzog & Rympa, 1991; Salthouse, 1985). Salthouse (1985), one of the strongest proponents of the cognitive slowing hypothesis, posited that this phenomenon is reflective of the depletion of an overall general resource that is unspecific to any sort of task or cognitive domain. Findings from these large scale studies have led many researchers to hypothesize that cognitive processes supported by the frontal lobe, more specifically the prefrontal cortex, are among the first to decline with increasing age (Raz, 2000; West, 1996). In studies examining the effects of age on varying facets of cognition, healthy older adults, as compared to younger adults, demonstrate poorer performance on measures of: executive functioning, working memory, episodic memory, prospective memory, inhibition, visuospatial processing, visual spatial organization, basic attention, and processing speed (Cerella, 1985; Morris, Gick, & Craik, 1988; Fisk & Sharp, 2004; Salthouse, 1990, 1996, 2004, 2009, 2012; Sattler, Ryan, & Lopez, 2000; West, 1996). Generalized slowing has even been observed at the elementary processing level on tasks such as finger tapping (Villardita, Cultrera, Cupone, & Mejia, 1985) and cancellation tests (Earles & Salthouse, 1995). It has also been shown to affect higher order cognitive processes such as semantically restricted word list generation, perceptual reasoning, perceptual speed, psychomotor speed, and reaction time (Godefroy, Roussel, Despretz, Quaglino, & Boucart, 2010; Villardita, Cultrera, Cupone, & Mejìa, 1985). However, Salthouse (1985) cautions against assuming that this general resource affects all domains of cognition to the same extent or in the same way. For instance, some cognitive domains may be less affected by slowing than others because of the compensatory effects of factors such as life-long knowledge accumulation. Consistent with this assumption is empirical evidence showing that slowing is less pronounced in tasks involving lexical decision-making as compared to more analogous tasks requiring non-lexical decision-making (Cerella, 1985). For example, multiple researchers have repeatedly documented age-related cognitive declines in Block Design performance (Salthouse, 1982, 1987;

Storandt, 1977). Based on a cross-sectional analysis of Block Design performance, Salthouse (1982) found a roughly 8% decline per decade in speed of completion time. He posited that this slowing phenomenon may be due the speeded nature of the task. Although slowed performance on Block Design is noted even in cognitively normal older adults, the task is commonly included as part of neuropsychology test batteries for older adult due to its sensitivity for predicting conversion to dementia (Balota et al., 2010). Although understanding which specific cognitive changes occur with the healthy aging process is vital, this feat is not a simple one. Individual trajectories of cognitive changes are highly heterogeneous; with some older adults' cognition declining rapidly, others declining only slightly, several not declining at all, and some with increasing cognitive speed and functioning from what it was previously (Reed et al., 2010; Wilson et al., 2002).

Crystallized and fluid intelligence. It has been suggested that fluid intelligence (e.g., activities requiring sensorimotor coordination, original learning, swift performance, novel problem solving) decreases with age while crystallized intelligence (e.g., activities involving language skills, established habits, school learning) is largely preserved. For the past two decades, extensive literature in the field of lifespan development has examined the multi-dimensionality, plasticity, and multidirectionality of human thought; the different ways humans store and encode information; and how the aging process affects those different cognitive capacities.

Probably one of the most well-known theories of cognition in its relation to lifelong development and increased age is the life-span theory of crystallized and fluid intelligence (Horn and Cattell, 1966, 1967). The crystallized and fluid intelligence theory suggests less pronounced negative age trends on measures of interindividual differences in knowledge than on tasks measuring novel reasoning or processing speed. In general, the empirical findings are consistent with this prediction. In middle and late adulthood, the largest negative age differences are typically seen in measures of intellectual speed, followed by tests of fluid abilities such as spatial visualization and reasoning, which in turn are followed by more knowledge-dependent measures (Salthouse, 2004). For instance, the Digit Symbol subtest of the Wechsler Adult Intelligence Scale (WAIS-R; Wechsler, 1981), a widely-use measure of cognitive processing speed, shows highly pronounced age decrements, whereas the Vocabulary subtest of the WAIS, a common measure of general knowledge, remains stable into the late adult years (Salthouse, 1996). Findings from psychometric literature demonstrating pronounced negative age differences for processing speed and reasoning, and smaller differences on measures of verbal knowledge, are consistent with the notion that negative age trends in processing speed may be responsible for similar trends in other intellectual abilities.

Cognitive reserve. Although noted structural and functional changes can occur as part of the normal aging process, overall evidence across a broad age range of elder persons suggests that years education, intelligence, and quality of life may have a protective effect on cognitive functioning (Stern, 2009). This finding supports the cognitive reserve theory, which posits that individual differences in levels of resiliency to age-related cognitive decline may be attenuated by years of education, intelligence, and psychosocial factors due to their beneficial effects on brain structure and functioning (Stern, 2006). The notion behind cognitive reserve is that basic neurocognitive processes and/or differences in preexisting neural networks may allow certain individuals the ability to better cope with brain damage because of greater degrees of cognitive reserve (Stern, 2006, 2009). Supporting this theory is evidence demonstrating an association between decreased dementia incidence rates and the protective effects of higher education intelligence and increased quality of life on older persons' neurocognitive functioning, even in the face of neural insult (Stern, 2009).

Physical Performance

The physiology and physical activity of older adults is inarguably different from those of younger people. Inevitably, as people grow older they show deterioration in nearly all physiological indicators and decreased physical performance capabilities. Looking at the changes throughout the life course, physical energy expenditure typically improves through childhood and typically peaks somewhere between late adolescence and the early 30s, at which time functional capacity begins to decline. Physical deteriorations that occur with age include muscular atrophy, reduced muscular strength, reduced level of oxygen consumption uptake, increased body fat, and reduced lung capacity. Findings from functional assessment research make it inarguably clear that at least some level of physiological deterioration occurs because of increased age. However, the extent of deterioration is attenuated by improved lifestyle choices and behaviors over which people have control. Healthy lifestyle behaviors such as regular physical exercise and a low-sodium diet have been shown to help moderate age-related physiological decline, as well as serve to increase the average life expectancy by limiting the development and progression of chronic diseases and disabling conditions such as diabetes, high cholesterol, obesity, and congestive heart failure (Chodzko-Zajko et al., 2009). However, it is unclear the extent to which this decline affects the capacity to carry out various activities of everyday life. Confounding this relationship are the various indicators that have been shown to significantly affect the ability to carry out various physical activities including those related to activities of daily living, leisure activities, exercise, and physical fitness. Although all body systems show a certain level of decline with increased age, it is not fully understood how much decline is attenuated by other factors including physical inactivity, pathology, illness, injury, etc. To provide an example for these confounding factors, roughly 80% of older Americans report having at least one chronic and debilitating condition, with half reporting that they suffer from two or more chronic conditions (Mehrotra & Wagner, 2008). Not surprisingly, the costs of providing health care and medical treatment for these conditions are substantial. In a 2007 report, the Centers for Disease Control and Prevention (CDC) and the Merck Company Foundation cited that the average cost for providing health care to older adults in America was three to five times greater than the costs for persons under the age of 65 (Centers for Disease Control and The Merck Company Foundation, 2007). Unfortunately, it is still unclear the extent to which differences in performance abilities between older and younger adults is attributable to true biological aging, as opposed to the result of pathological conditions and/or inactive lifestyles.

Although it may not be immediately apparent, the construct and sub-classification indexes of physical performance are complex. Castilllo-Garzón, Ruiz, Ortega, & Gutiérrez (2006) describe physical activity as a large range of physical abilities including aerobic capacity, speed, strength, agility, flexibility, and coordination; the measurement of all of these facets of physical activity requires an integration of all functions and structures involved in engaging in physical activity and/or exercise. Before we look at existing research on the link between physical functioning, aging, and cognition, it is important to first provide some clarification on terminology in order to understand the complexities of physical performance.

The complexity of physical performance. Physical activity is defined as any bodily movement produced by skeletal muscles that require energy expenditure. The amount of energy required to perform any specific physical activity is measured in kilojoules (kJ) or kilocalories (kcal), with 4.184 kJ being essentially equivalent to 1 kcal. Energy consumption is determined by five specific factors: duration – amount of time spent participating in a single incident of physical activity; frequency – number of events involving physical activity with a specific time period; intensity – amount of physiological effort expended by participating in a special type of physical activity; amount of muscle mass that produces the bodily movement; and type of activity. Physical activity is categorized in several ways, with a common approach being to segment physical activity based on identifiable portions of daily living. Examples of this approach would involve identifying specific physical activities that occur at work, at home, at leisure, and during sleep. Leisure-time physical activity can be further divided into categories such as cleaning, home repairs, yard work, and sports. Guralnik & Ferrucci (2003) discovered that one of the key indicators for predicting older adults' quality of life and well-being is their ability to perform daily life functions. Physical exercise has been used interchangeably with physical activity. This error is rather understandable however, especially given the positive association between physical activity and exercise, as well as the number of common elements shared between the two constructs. For example, physical activity and exercise are both described as any bodily movement produced by the skeletal muscles that expends energy (measured by kilocalories) ranging from low to high levels. Additionally, both physical activity and exercise are positively correlated with physical fitness, and this association only grows stronger as the intensity, frequency, and duration of bodily movements increase. Exercise is not the same as physical activity however; rather, it is a subcategory of physical activity.

Activities such as occupational, household, and everyday tasks are typically performed in the most pragmatic and efficient way possible. Typically speaking, most people perform these everyday activities with little regard to physical fitness; in fact, many of these activities are structured with conservation of energy expenditure as a goal. However, an individual may choose to mindfully plan and structure the performance of his or her work responsibilities in a way that is less-than-efficient and labor-producing as opposed to labor-saving; individuals may do this in order to "burn up" extra calories, develop muscular strength, or increase endurance. An example of this type of modified occupational activity might involve climbing the stairs as opposed to taking an elevator or escalator. Activities that are regularly performed in this way are considered exercise.

Of the physiological changes that occur with advancing age, perhaps the most discerning is cardiovascular function. Beginning at the age of 25, the maximal oxygen uptake decreases at a rate of 0.4 ml/kg-1/1/min-1 each year in males and females, translating to roughly an 8%-10% decline per decade. This means that by the time individuals reach the age of 65, their rate of maximal oxygen consumption has already been reduced by nearly 40%. However, oxygen uptake declines may be abated by exercise, particularly aerobic exercise.

Physical Functioning and Health Status

Risk of disability and disease. Physical activity has been shown to improve everyday functioning for older adults. This line of research is especially important considering that, at present, 50% of older Americans aged 85 years and older require assistance in performing one or more everyday functional activities (Alzheimer's Association, 2012). Luckily, exercise interventions have provided hope in addressing this issue. Research has demonstrated that engaging in 150 to 180 minutes per week of moderate to vigorous physical activity, such as brisk walking, can decrease the relative risk of older adults losing their functional independence by up to 30% (Daly et al., 2008; Paterson & Warburton, 2010). More vigorous physical activity may further reduce risk of functional decline by an additional 30% (Paterson & Warburton, 2010). With few exceptions, research has consistently shown that clinical measures of cognitive functioning and physical performance are predictors for future falls, disability, and mortality in older adults. For example, gait speed (also referred to as walking speed) has been shown to be associated with health and physical functional status in older adults both upon initial evaluation and at a 5-year follow-up. Several researchers have recommended gait speed as a useful clinical indicator for older adults' well-being and functional abilities (Cesari et al., 2005; Guralnik et al., 2000). The benefits of physical activity have been well-demonstrated for multiple chronic conditions including diabetes mellitus, coronary artery disease, and stroke (Fried et al., 1998; Glass, de Leon, Marottoli, & Berkman, 1999). In a longitudinal study examining risk factors for disease and disability, Fried and colleagues (1998) found that regularly engaging in physical activity, regardless of intensity level, served as a protective factor for maintained overall health of older adults. At a 5-year follow-up evaluation, risk of disease and disability was more than four times higher for those older adults who had lower levels of energy expenditure (i.e., ≤ 282 kJ/week or 67.5 kcal/week), as compared to those with higher levels of energy expenditure (i.e., 7908 kJ/week or 1890 kcal/week). As compared to their baseline assessment, older adults who had lower energy expenditure and higher disease risk were more likely to report difficulty with at least two activities of daily living (e.g., tasks necessary for home management and independent living). Interestingly, physical activity was not the only significant predictor of disease and mortality. Researchers also reported that processing speed, as measured by the WAIS-R Digit Symbol subtest (Wechsler, 1981) was inversely associated with mortality; older adults with scores > 40 at baseline had nearly half the risk of mortality of those with scores < 18.

Physical functioning and neuroanatomical functioning. Results from both animal and human models have demonstrated the influential effects that physical activity has on the aging brain (Kramer et al., 2005; Churchill et al., 2002; Colcombe & Kramer, 2003). Research has shown that older individuals that regularly engage in physical activity have increased medial temporal lobe volumes (Colcombe et al., 2006; Erickson, Clapp, Ford, & Jabbari, 2006), an area that shows substantial age-related atrophy in sedentary elders. Such findings reflect a biological basis for the ability of physical activity to alter the trajectory of cognitive decline. This relationship may be linked to structural changes in the brain since increased physical activity is predictive of larger hippocampal size (Erickson et al., 2011). The hippocampus is of particular importance when considering clinical markers of cognitive decline because hippocampal atrophy is one of the earliest signs of the cognitive impairment and dementia (Jack et al., 2000). The hippocampus is located within the area of the brain known as the limbic system that is an area that primarily regulates emotions, and is known for its relation to memory, particularly long-term memory, and spatial navigation. Because hippocampal deterioration has been shown to be one cause of memory impairment and functional disability in older adults (Colcombe et al., 2006), dementia researchers have increased focus on developing interventions for older adults to minimize hippocampal atrophy. Physical activity has emerged as one such intervention, providing a low-cost, accessible treatment to improve neurocognitive functioning. One such study by Kramer et al. (2011) involved a randomized controlled trial with exercise training. Participants included 120 non-demented older adults who were randomly assigned to either an aerobic exercise group or a stretching control group. Prior to the intervention, all participants underwent MRI screening, then again at six months, and upon completion of the study. Researchers found that the exercise intervention significantly increased the size of the hippocampus over the course of one year. Thus, those in the aerobic exercise group showed increased hippocampal volume. In comparison, those in the stretching control group showed significantly reduced hippocampal volume.

Recently, the National Institute on Aging (NIA) funded a study by the Cleveland Clinic's Schey Center for Cognitive Neuroimaging seeking to examine the relationship between physical activity and hippocampal size in a sample of older adults that included persons with a genetic risk of developing Alzheimer's disease (Smith et al., 2011). Participants were 97 cognitively healthy older adults, aged 65 to 89 years. Based on the presence or absence of the apolipoprotein E (APOE) e4 gene (the strongest genetic predictor for risk of developing Alzheimer's disease) as well as self-reported levels of physical activity (low or high), participants were divided into five groups, one of which served as a control group. Intensity level of physical activity was defined based on the following: low physical activity – self-reported engagement in low-intensity activities such as walking or yoga ≤ 2 days per week; high physical activity – self-reported engagement in moderate to vigorous physical activity, such as jogging or swimming, for ≥ 3 days per week. All participants underwent neuropsychological evaluation, and performance-based functional assessment. Additionally, all participants received magnetic resonance imaging (MRI) scans for measuring hippocampal size as well as other brain features that have previously demonstrated associations with cognitive and physical functioning. The hippocampus specifically has been of particular interest in aging and cognition research. Studies have shown that reduced hippocampal volume is present is the earliest stages of AD and some other dementias (Colcombe et al., 2006). After five years of follow-up evaluations, results revealed that individuals in any of the exercise groups, regardless of intensity level, had significantly larger hippocampal size than those in the control group. Both the low- and high-intensity physical exercise groups had significantly reduced risk of developing Alzheimer's disease as compared to controls. Further, those in the high-intensity physical exercise groups demonstrated a slightly smaller risk of dementia diagnoses at follow-up as compared to those in the low-intensity physical exercise groups.

Physical activity has also been shown to increase gray matter volume in older adult samples. In 2006, Colcombe and colleagues investigated the effect of aerobic exercise on older adults' brain volume in regions commonly associated with age-related decline in both structure and functioning. They randomly assigned 79 participants, 59 older adults (60 – 79 years) and 20 younger adults (18 – 30 years) to either a cardiovascular exercise group or a nonaerobic exercise group for a period of six months. All participants were neurologically intact, and were screened for neurological defects such as dementia, multiple sclerosis, and Parkinson's disease prior to testing. The aerobic exercise group, supervised by exercise trainers, was designed to improve cardiorespiratory fitness, using an exercise intensity prescription based on baseline heart rate. Participants in the aerobic exercise group had to record their intensity levels and amount of exertion in daily exercise logs. Participants in the nonaerobic exercise group followed an identical activity schedule as those in the aerobics group did, but participated in a regimen involving whole-body stretching and toning exercises that were designed for adults aged 60 years and older. Participants in both groups attended three one-hour exercise-training sessions each week for the six-month duration of the study. Following the intervention, participants underwent post-test MRI scans in order to map gray matter, white matter, and cerebrospinal fluid. Findings revealed previously sedentary older adults that were assigned to the aerobic exercise group had significantly increased brain volume in several regions following the six-month exercise period as compared to those in the stretching control group following participation in the exercise protocol. Additionally, older adults in the aerobic exercise group showed statistically significant increased brain volume as compared to older adults in the control group. The largest changes were present in the frontal lobes. Older adults in the exercise group had significant increases in white matter volume after six months in areas of the brain associated with cognition and memory (Colcombe et al., 2006). This was one of the first studies of its kind to show how aerobic exercise specifically modified the brain structure of older adults.

Relationship Between Cognitive Functioning and Physical Functioning

Both cross-sectional and epidemiological studies have found a relationship between cognitive status and both physical functional activity (Barberger-Gateau & Fabrigoule, 1997) and posture control (Teasdale, Bard, LaRue, & Fleury, 1993) in older adults. In a cohort of cognitively normal older adults, Holtzer, Verghese, Xue, and Lipton (2006) found that performance on neuropsychological tests including Category Fluency (Lezak, 1995) and the Block Design and Digit Symbol subtests from the Wechsler Adult Intelligence Scale – Revised (Wechsler, 1981) were significant predictors of gait speed. Research has also found a positive association between higher rates of physical activity and improved cognitive functioning in older adults. Results from a 5-year evaluation of Canadian older adults demonstrated that low, moderate, and high levels of physical activity intensity were associated with lower risks of cognitive impairment. Researchers also found that moderate and high levels of physical activity were significantly related to lower risks for dementia of any type (Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001). In 2011, Ahlskog, Geda, Graff-Radford, & Petersen examined published literature related to exercise as a protective factor for cognitive aging. Using PubMed (keywords exercise and cognition) as well as manuscript bibliographies, Ahlskog and colleagues (2011) conducted meta-analyses to determine if exercise, particularly aerobic exercise, prevented cognitive impairment and reduced the risk for dementia. Results indicated that several prospective studies showed that midlife exercise significantly reduced the risk of dementia; additionally, multiple studies indicated that midlife exercise significantly reduced risk of future mild cognitive impairment.

Aerobic exercise has been associated with improved cognitive functioning in older adults (Colcombe & Kramer, 2003; Kramer et al., 1990). With limited exceptions, research findings have demonstrated that older adults who engaged in aerobic exercise for substantial periods of their lives were faster to respond to auditory stimuli and visual stimuli and more quickly discriminated between different stimuli as compared to older adults who were primarily sedentary for a significant period of their lives. (Clarkson-Smith & Hartley, 1989). Cardiovascular exercise appears to have the biggest impact on higher order cognitive domains, with exercisers outperforming non-exercises on tasks measuring working memory, task switching, inhibitory control and managing conflicting instructions, vigilance monitoring, and fluid intelligence (Clarkson-Smith & Hartley, 1989; Colcombe et al., 2006; Colcombe & Kramer, 2003; Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005). However, not all researchers have found notable differences in the performance of exercisers versus non-exercisers on similar tasks. For instance, increased levels of cardiovascular exercise did not result in remarkable differences between exercisers and non-exercisers on tasks assessing simple and choice reaction time, short-term memory, digit span, and somatosensory thresholds (Clarkson-Smith & Hartley, 1990; van Boxtel, Martin, Langerak, Houx, & Jolles, 1996).

Physical activity may not only reduce risk of cognitive decline, but may also slow the rate of reduced cognitive speed associated with the normal aging process (Larsen et al., 2006). There is growing empirical support for the efficaciousness of physical activity in maintaining functional neuroanatomy and cognitive functioning of older adults. In an attempt to simultaneously examine the relationship between physical activity, neuroanatomical functioning, and cognitive proficiency, researchers recently explored the extent to which cardiorespiratory exercise indirectly affected frequency of forgetting in older persons based on its effects on hippocampal size and spatial working memory (Szabo et al., 2011). Prior research stated that poor spatial working memory was associated with compromised hippocampal volume, and researchers were interested in determining the protective effect of higher levels of aerobic exercise in preserving hippocampal functioning and volume. Path analyses were used to examine this relationship in a sample of 158 older adults. Results supported their hypotheses, showing a direct effect of cardiorespiratory fitness on hippocampal volume that in turn, was significantly related to spatial memory. Although greater spatial memory accuracy was not associated with lower frequencies of forgetting, hippocampal volume did have a direct effect on frequency of forgetting (Szabo et al., 2011).

Albert and colleagues (1995) explored ways in which cognitive changes were influenced by various psychosocial variables including physical activity. Using a linear structural relations modeling technique (LISREL) to examine longitudinal data of nearly 2,000 community-dwelling older adults who, at baseline, were between the ages of 70 and 79 years, researchers intended to test the capability of an a priori model of predicting cognitive changes in older adults over the course of a 2- to 2.5-year period. Using an exploratory-confirmatory design, the model analyzed the effect of 22 demographic, physical, and psychosocial variables as predictors of a composite factor of cognition that included tests of language, higher order decision making, and visuospatial ability. In concordance with findings from previous research, education and income were strong predictors of cognition function at both the initial evaluation and at a 2.5-year follow-up evaluation. Interestingly, cognitive vitality was strongly predicted by level of general physical activity and measures of cardiorespiratory fitness.

Researchers recently explored the association between cognition (measured via a general mental status screening) and physical activity (evaluated based on self-reports of walking distance and total expended kilocalories per week) in a sample of 5,925 older women living in the community (Ford, et al., 2010). When compared to women who walked one mile per week or less, women who walked regularly demonstrated better performance on several measures of cognitive functioning. Previous research reported differences in the rate of maximum oxygen uptake decline between sedentary older adults and those who regularly exercised. Older women who walked at a moderately intense pace for more than 150 minutes per week had only one-half the rate of decline in oxygen consumption as women of the same age who were sedentary. Further findings of the same study reported that males and females between the ages of 65 and 75 who were properly trained in physical exercise had maximal oxygen consumption rates that were equal to or higher than individuals under the age of 65 who had primarily sedentary lifestyles (Nieman et al., 1990).

Previous research has demonstrated the interrelated nature of cognitive and physical functioning (Scherr et al., 1988). Yet it remains unclear how cognitive performance influences different physical ability over time, and vice versa. Surprisingly, the association between many observed cognitive measures/domains and functional status is statistically “weak,” albeit significant (Royall et al., 2007). For example, individuals with greater self-reported disability on Activities of Daily Living (ADLs) scored significantly lower than lose with less disability on tests of immediate memory, delayed memory, attention, and orientation (Scherr et al., 1988). In the same way that decreased cognitive abilities share a strong correlation with physical disability and functional limitations, strong cognitive performance is positively related to improved physical function and performance. Older adults with higher baseline cognitive performance had a significantly decreased likelihood of physical performance decline at a 2-year follow-up. Furthermore, these same older adults also had a significant increased likelihood of improved physical performance at follow-up. Although the association between physical performance and cognitive functioning is strongest at later stages of dementia, there is increasing evidence that these factors interact at the earliest stages of impairment. This suggests that an existing relationship between these two factors exists notwithstanding presence of cognitive deficit.

The aforementioned findings are demonstrative of the beneficial influences of physical functioning on cognition. However, several limitations exist within the existing literature concerning their relationship. One such limitation is the extent to which the relationship between cognition and physical exercise is affected by the covariate nature of demographic characteristics. Another limitation is that many of the cross-sectional nature of the many of existing studies. Although longitudinal studies are gaining presence in the literature, much of what we know about cognition and exercise comes from cross-sectional research and thus is limited about their generalizability. One of the limitations in the literature exploring the association between physical ability and cognitive functioning is the discrepancy across studies in the operationalization and assessment of physical functioning. Some studies relied on self-report measures of physical ability, others used informant-based reports of activities of daily living, some utilized the pulmonary measure of maximal oxygen consumption during aerobic exercise (VO_2max), and recent research has even begun to use body mass index (BMI) as a global indicator of physical fitness (Ho et al., 2010). Also, inconsistent terminology to describe varying types of physical activity (e.g., functional ability, physical exercise, strength training, physical fitness, etc.) limit the global delineation of research findings and hinder efforts to draw associations between physical activity research and cognitive efficiency in the elderly population. It is unclear the amount of variance in functional status that can be explicitly attributed to cognitive functioning independent of major non-cognitive covariates (e.g., age, gender, education). Few researchers have explored the relationship between cognitive functioning and basic physical functional status, and have instead focused on complex physical activity such as activities of daily living or high-intensity physical activity like aerobic exercise. This raises questions about the association between cognition and rudimentary physical activity rather than cognitive function and physical activity and/or level and frequency.

Such limitations highlight the need for future research to explore longitudinal changes in cognition and functioning. First, it will be important to formally operationalize physical activity and physical functional status. Additionally, researchers should consider the extent to which demographic variables influence cognitive functioning and physical functional status. Researchers should also ways to increase the consistent utility of validated physical ability assessments, and determine possible ways for generalist psychologists to assess cognitive functioning and physical functional status in everyday clinical settings in ways that are cost-effective, timely, simplistic, and beneficial to their clinical practice. Improving upon our understanding of the relationship between cognition and physical functioning would assist in predicting the onset of cognitive impairment, and has tremendous implications for interventions to slow, delay, and possibly even prevent progression to these devastating dementia disorders.

Additionally, much of the research to date has examined the association between functional status and cognition in samples of demented older adults, yet little research examines the relationship in the absence of pathology. Thus little is known about the strength of the association or unique correlates of the relationship between these two factors in the absence of cognitive decline. It would be reasonable to assume that a relationship between cognition and function exists prior to deficits and declines. Thus, it is possible that a relatively strong association between function and cognition would exist in a sample of healthy community-dwelling older adults. One latent factor that may be contributing to the relationship between cognitive functioning and physical performance is mental energy and/or motivational processes.

Previously examined in occupational therapy and vocational psychology research, motivational processes relate to the level of expended cognitive energy that is necessary for completing various tasks, both cognitive and/or physical. In other words, mental effort measures how hard a person "tries" to both actively process presented information and successfully carry out intended behaviors. Mental effort is the cognitive capacity that is actually allocated to accommodate the demands imposed by the tasks. This is similar to Sweller's (1988) theory of cognitive load which describes the energy needed for the learning process, which includes encoding of information, transferring short term knowledge into long-term memories, accommodating new information into preexisting schemas, etc. This is different from mental effort because cognitive load specifically refers to the process of learning, and does not account for processing of information in general. Unlike cognitive load, mental effort is the necessary energy needed to process information without learning and creating new cognitive constructs, and relies heavily on working memory and visuospatial processing. It is comprised of three primary characteristics: perceived demand characteristics, perceived self-efficacy, and depth of information processing.

Statement of the Problem

The literature on cognition and physical functioning in older adults suggests several important findings. As part of the normal aging process, older adults demonstrate decreased performance across various cognitive domains including attention, processing speed, various levels of memory abilities, and inhibition. Older adults are likely to perform more poorly than younger adults on measures of perceptual speed, working memory, tracking, decision making, explicit memory, and task-switching. Cognitive decline sufficient enough to impede independence or the ability to carry out functional tasks may be indicative of an age-related disorder known as dementia, with the most common type of dementia being Alzheimer's disease. Understanding the relationship between basic cognitive functioning and rudimentary physical activity in the elderly population may enhance clinicians' ability to provide earlier detection of risk for conversion to cognitive impairment or physical disability. This will serve to improve prevention measures, while also improving older adults' quality of life and well-being. A stronger understanding of the association between basic cognition and rudimentary physical functioning in healthy, non-pathological older adults will serve to benefit not only the research literature, but also clinicians and health professionals. We are reaching a new chapter in our field, where assessments such as these are no longer unique to academic or clinical research settings. Mental health professionals have not widely adopted the use of performance-based measures to evaluate the physical activity of older adults. Perhaps clinicians do not view functional status assessments as a necessary component for mental health treatment. Others may perceive functional tests as measures requiring substantial space, excess administration time, special equipment, or the need to be performed by personnel with special training. However, many functional assessments require little more than a stopwatch, a chair, and a hallway, and can be completed in less than 15 minutes. Uncovering the ways in which physical functioning can be assessed in typical practice settings so as to enhance treatment for older adults will only serve to benefit the field. Much of the research to date has examined the association between functional status and cognition in samples of demented older adults. Few investigations have explored the relationship between cognition and function in healthy older adults. Research has shown the apparent protective effect that physical activity, particularly aerobic exercise, has on cognition. The present study evaluated the relationship between a cognition factor and a physical performance factor in a sample of physically healthy, non-demented community-dwelling older adults. The study used archival data collected as part of an ongoing examination of healthy aging at the University of Kansas Alzheimer's Disease Center. Data collection was funded by the National Institutes of Health Grant P30 AG035982. Confirmatory factor analyses (CFA) in a structural equation modeling (SEM) format was used to examine model fit for two one-factor models representing the latent constructs of cognitive speed and physical functional speed. A two-factor measurement model then evaluated the relationship between the two latent constructs. Multiple indicators multiple causes (MIMIC) modeling was used in order to examine the effects of covariates on the factor structures of a cognition and physical functioning factor. This approach involved multiple steps: the creation of a measurement model to define the relationship between a cognition factor and a physical performance factor and their respective indicators; creation of a structural model specifying the relationship between both factors; and examination of final model that includes three covariates (age, sex, education) into the model structure. After reviewing model fit information and modification indices, the researcher selected to use Differential Item Functioning (DIF) to examine direct effects of covariates on specific indicators. Model fit and factor loadings was then re-examined in order to determine if direct paths between covariates and select indicators improved overall model fit.

Research Questions and Hypotheses

The purpose of the current study was to determine the relationships between cognitive functioning and physical performance functional status in a sample of community dwelling older adults. The following research questions and hypotheses guide this study.

Research Question 1. What proportion of variance in cognitive functioning is uniquely accounted for by selected cognitive measures?

- **Hypothesis 1a:** Stroop Color Naming, Digit Symbol, Block Design, and Category Fluency-Animals will significantly load on a cognitive functioning factor.
- **Hypothesis 1b:** Cognitive functioning, as a first order factor, will demonstrate good model fit based on χ^2, RMSEA. RSMR, CFI, and TLI.

Research Question 2: What proportion of variance in physical performance is uniquely accounted for by objective functional assessments?

- **Hypothesis 2a:** Timed Up and Go, Five Times Sit to Stand Test, Walk 50 Feet, Pick Up a Penny, and Step Test will significantly load on a physical performance factor.
- **Hypothesis 2b.** Physical performance, as a first order factor, will demonstrate good model fit based on χ^2, RMSEA. RSMR, CFI, and TLI.

Research Question 3: What is the relationship between cognitive speed and functional speed?

- **Hypothesis 3a:** A two-factor model consisting of a cognitive functioning factor and a physical performance factor will demonstrate strong model fit.
- **Hypothesis 3b:** A statistically significant correlation will be specified among a cognitive functioning factor and a physical performance factor.

Research Question 4: How do covariates affect the relationship (i.e., model fit) between cognition and physical performance?

- **Hypothesis 4a:** After adjusting for covariates of age, sex, and years of education, the two-factor model fit will be strong.
- **Hypothesis 4b:** After adjusting for covariates, the correlation between cognition and physical performance will be significant.

Chapter III

Methods

Using retrospective data of physically and cognitively healthy older adults, the present study examined the model fit of two one-factor models based on nine chosen proxies, four representing cognitive speed and five representing physical functional speed. One goal of the study was to demonstrate the chosen proxies for cognitive speed and physical functional speed significantly loaded on their chosen latent constructs. Also examined was the structural fit for a two-factor model representing the latent constructs of cognitive speed and physical functional speed. Specifically, the author was interested in the strength of the relationship between both constructs in the two-factor model. Other goals were to examine the effect of covariates on model fit of the two-factor model, and explore what covariates would potentially affect the relationship between cognitive speed and physical functional speed. This chapter describes the participant selection, measures of cognitive functioning and physical performance, statistical procedures, fit indices, research questions, and hypotheses.

Participants

Data included in the present study were collected and shared through funding by the University of Kansas Alzheimer's Disease Center (KU ADC) National Institutes of Health Grant (P30 AG035982). The present study utilized retrospective data collected between 2011 and 2015 from the University of Kansas Alzheimer's Disease Center (KU ADC). KU ADC is funded by the National Institute on Aging and adheres to National Alzheimer's Coordinating Center (NACC) procedures for clinical evaluation, clinical diagnosis, and neuropsychological assessments methods (Morris et al., 2006). Procedures were approved in compliance with the ethical standards from KU Medical Center Institutional Review Board. All participants provided written informed consent for their clinical assessment data to be included in the NACC database for future research. Longitudinal data from 229 cases of normal control participants were initially screened. Only participants who, at baseline, were aged 60 years or older were included in the present study. Participants aged 59 years and younger were excluded from this study. Eligible participants were cognitively healthy (Clinical Dementia Rating [CDR] = 0) at the time of their first clinical evaluation, and also at a 1-year and 2-year follow-up evaluation through February 27, 2015. Although only baseline scores are included in the present analysis, the likelihood of introducing error variance as a result of subclinical cognitive decline was minimized by including only participants whose cognitive status did not decline at the 1- and 2-year follow-up. Exclusion criteria were based on recommendations by Hughes, Berg, Danziger, Coben, and Martin (1982). Exclusion criteria included the following: baseline diagnoses of neurologic diseases impairing cognition; current or previous diagnostic history of diabetes mellitus; clinically significant depression lasting more than two months (i.e., Geriatric Depression Scale [GDS; Yesavage et al., 1983] scores ≥ 6 - 7); severe psychiatric disturbances; history of alcohol and/or substance abuse; diagnosed learning disabilities; severe head injury; and/or recent history of cerebrovascular disease. Individuals who required legal representative to consent to participation in empirical research studies were also excluded. Out of 229 cases reviewed, 119 met inclusion criteria. Participants included in this study were community-dwelling men and women who, at baseline, were aged 60 to 93 years.

Evaluation included the Clinical Dementia Rating (CDR; Morris, 1993) – a semi-structured interview of the participant and a study partner to determine presence or absence as well as severity of dementia. The study partner, commonly a spouse or close relative, was an individual whom shared a close relationship with the study participant, and was familiar with the participant's everyday functioning in areas such as basic hygiene, financial management, and driving and directional navigation. These allowed researchers to gain informant-based information on participants' functioning. The CDR evaluates cognitive functioning in each of 6 domains (memory and orientation, judgment, problem solving, performance in community affairs, home and hobbies, and personal care) without reference to psychometric performance or results of previous evaluations. CDR scores range from 0 to 3 and interpretation is as follows: score of 0 indicates no dementia; 0.5 very mild dementia; 1 mild dementia; 2 moderate dementia; 3 severe dementia. This method of diagnostic classification follows recommendations of Morris et al. (2001) and Storandt et al. (2006). The CDR has high interrater reliability (Burke et al., 1988) and has a diagnostic predictive accuracy (93%) for autopsy-confirmed AD (Berg et al., 1998). Additionally, these methods have been shown to be accurate in identifying the subset of persons meeting diagnostic criteria for mild cognitive impairment (MCI) who have early-stage AD (Morris et al., 2001; Berg et al., 1998). For the purpose of the proposed study, only individuals with CDR scores of 0 at baseline were included in the analysis.

Measures

Neuropsychological battery. At baseline and annual follow-up evaluations, all participants had extensive neuropsychological assessment. The neuropsychology test battery used as part of annual evaluations is part of the National Alzheimer's Coordinating Center's Uniform Data Set (NACC UDS; Morris et al., 2006; Weintraub et al., 2009) administered by all 51 Alzheimer's Disease Centers across the country. Trained psychometrists administered assessments following standardized instructions for administration and scoring Weintraub et al., 2009). The UDS test battery is comprised of measures to assess basic attention, verbal recall, executive functioning, processing speed, working memory, semantic memory, and verbal fluency. A full description of these tests can be found in Weintraub et al. (2009). The KU ADC supplements the UDS battery with additional tests including the Buschke Free and Cued Selective Reminding Test (Buschke, 1973), Stroop Color Word Test (Stroop, 1935), the Block Design and Letter-Number Sequencing subtests from the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III: Wechsler, 1997), and the Digit Symbol subtest from the Wechsler Adult Intelligence Scale – Revised (WAIS-R: Wechsler, 1981). The tests included in the battery were specifically selected due to their sensitivity to age-related cognitive changes (Ivnik et al., 1997; Ivnik, Malec, Smith, Tangalos, & Petersen, 1996; Ivnik et al., 1992; Lucas et al., 2005) and their ability to accurately predict progression from mild cognitive impairment to dementia. Of the tests included in the UDS neuropsychological test battery, particular interest for the present study was four select tasks. These measures have previously demonstrated high validity concerning older persons' cognitive functioning as well as high sensitivity about cognitive decline. Digit Symbol (subtest of the Wechsler Adult Intelligence Scale –Revised; WAIS-R: Wechsler, 1981) was used as a measure of processing speed and graphomotor tracking. Block Design (subtest of the Wechsler Adult Intelligence Scale, 3rd Edition [WAIS-III: Wechsler, 1997) assessed visuo-constructional ability and visuospatial perception. Category Fluency – Animals (Lezak, 1995) assessed semantic fluency, semantic memory, and word list generation. The Stroop Color-Word Test – Color Naming (Stroop, 1935) assessed basic attention, processing speed, and executive functioning.

Digit Symbol. This WAIS-R (Wechsler, 1981) subtest measures processing speed, cognitive flexibility, attention, concentration, motivation, short-term visual memory, learning ability, and visual motor coordination (Groth-Marnat, 2003; Sattler and Ryan, 2009). This task requires copying symbols to numbers with which they are paired. The key consists of boxes with

9 digit-symbol pairs where a numeral from 1 to 9 is displayed in the upper part and a symbol in the lower part, and each number has its own symbol. The test stimuli display boxes containing a number in the top part with an empty space below each number. Individuals are instructed write the paired symbol below the number with which they were paired. A total score is derived from the total number of correctly paired digits and symbols within a 90-second time limit. Digit Symbol has adequate test-retest reliability coefficients ≥ .84 (Range = .84 - .89) for the four age groups retested during standardization of the scale (i.e., 16 to 29 years, 30 to 54 years, 55 to 69 years, and 70 to 90 years (Ryan, Sattler, & Lopez, 2009). Digit Symbol appears to assess for individuals' ability to learn number-symbol combinations and the ability to build associations in a quick and accurate manner.

Stroop Color Naming. This is one of three trials comprising the Stroop Color Word Test (SCWT: Stroop, 1935), one of the most well-validated measures of attentional selection (MacLeod, 1992). It requires individuals to read a series of colors, words, and color-words from three separate 8 ½ x 11" cards with a preset time of forty-five seconds for each trial. The Stroop Test consists of three parameters: naming colors of boxes (Color Naming), reading words written in black ink (Word Reading), and naming the color of ink in which the word is written rather than reading the word itself (Interference). Individuals are asked to complete the task for each respective condition as quickly as possible. For each condition, number of correct responses within in the 45-second time limit is recorded. The Stroop test assesses the ease with which individuals can shift their processing capabilities to conform to changing demands. Changes in performance on Stroop Color Naming have been shown to be evident at the earliest stages of cognitive impairment (Spieler et al., 1996), and are thus commonly used as part of neuropsychological test batteries for older adults.

Category Fluency – Animals. This test is widely used as a measure of language processing and semantic memory (Lezak, 1995). Participants are required to orally generate as many responses as they can for respectively given categories within a 60-second time limit. Each category is performed in a separate trial, and scores are based on total number of correct responses within the time limit. Performance on category fluency tasks demonstrates individuals' ability to retrieve words quickly and accurately based on a semantic category (i.e. animals, fruits, vegetables, musical instruments). Research has shown that, when compared to healthy controls, individuals with compromised integrity of brain structures crucial to the capacity for semantic knowledge tend to display poorer performance on category fluency tasks (Henry & Crawford, 2004). Research has shown that dementia patients are more likely to generate fewer exemplars than control participants on the category fluency tasks, and are also more likely to display errors of perseveration (same word said twice or more) and intrusion (incorrect category responses) in their answers (Cerhan et al., 2002). The ability of category fluency to discriminate between normal and pathological aging provides explanation for its common use in neuropsychological test batteries during neuropsychological evaluation of older adults. Due to its brief administration time, many suggest using category fluency as a brief cognitive screening measure. Educational level and has been shown to have a significant effect on performance on category fluency tasks (Crossley, D'Arcy, & Rawson, 1997). Brickman et al. (2005) found age effects on category fluency tasks, with the number of exemplars declining significantly across normal age span.

Block Design. This WAIS-III (Wechsler, 1997) subtest is a commonly used test to assess nonverbal reasoning and visuospatial organization. Successful completion involves nonverbal concept formation and reasons simultaneous processing, visuospatial ability, and learning (Carroll, 1993; Groth-Marnat, 2003). Block Design is commonly used as part of cognitive battery assessments, because its complexity and ability to assess multiple factors of cognition including visuo-perceptual reasoning, visuo-motor coordination, analysis and synthesis, and attention (Sattler and Ryan, 2009). During this task, subjects are instructed to reproduce designs using six-sided blocks: two sides have red surfaces, two sides have white surfaces, and two sides divided diagonally into half red and half white. Total score is the number of correctly assembled designs within a time limit. Block Design demonstrates adequate test-retest reliability (r = .87), with reliability coefficients across all groups ≥ .80 (Range =.80 - .91). Cross-sectional data indicate a graduate yet significant decline in performance from early to late adulthood (Wechsler, 1981). However, longitudinal examination showed that older adults with advanced education maintained mean-level performance on the Block Design task (McArdle et al., 2000), thus demonstrating the protective effect of education on Block Design performance.

Assessment of physical functioning. Many of the assessments selected to assess physical functional speed were from the Physical Performance Test (Reuben & Siu, 1990) which assesses older persons' strength, mobility, dexterity, and stamina through direct observation of performance on timed tasks such as writing a sentence, picking up a penny off the floor, and putting on and taking off a coat. These tasks intended to assess physical functioning abilities required for carrying out activities of daily living with varying in degree of difficulty. The PPT is a reliable and valid measure of physical functional status in older adults, and correlates well with degree of disability, mortality, and loss of independence (Reuben & Siu, 1990).

Sit-to-Stand Test (FTSST or 5XSST). The Sit-to-Stand Test is an objective functional assessment of lower body strength, transitional movements, balance, and fall risk. Studies examining test-retest reliability of the FTSST in community-dwelling older adults demonstrated adequate (.89; Tiedemann, Shimada, Sherrington, Murray, and Lord, 2008) to excellent (.96;

Bohannaon, 2006) reliability coefficients. This activity assesses the ability of a person to stand up from a standard straight-backed chair without using his/her arms. While seated, individuals are instructed to fold their arms across their chest and then stand up from the chair without using their arms. Scores range from 0 to 4, (0=normal; 1=slow, or may need more than one attempt; 2= pushes themselves up from arms of seat; 3=tends to fall back and may require more than one attempt, but can arise without needing assistance; 4=unable to arise without assistance).

Self-Paced Step Test. This is an effective tool for testing older adults' physical fitness, and assesses the ability to step up and down using a set of two standard steps (each with a rise of approximately 7-9 inches) 20 times at a pace similar to that which a person would normally climb stairs. Prior to beginning the activity, participants are fitted with heart rate monitor, and are then escorted by an examiner to a standard staircase with railing. The examiner then demonstrates climbing 2 stairs, putting both feet on the second stair before descending backwards and placing both feet on the ground. The participant is then asked to practice this 10 times. After practicing, participants are allowed to sit and rest until their heart rate is within 5 beats of a normal resting rate. Examiners then instruct participants to ascend and descend two steps at a normal pace for 20 repetitions. Participants are scored based on their ability to complete the task in its entirety. The self-paced step test was originally developed for the Step Test Exercise Prescription (STEP; Petrella, Koval, Cunningham, & Paterson, 2001) program, a brief, low-cost, and easy to use clinical tool for assessing older adults' maximal aerobic capacity (VO2 max) as well as predicting risk of disease and functional decline. The Self-Paced Step test is useful because it requires few resources, is adaptable for use in an individual or group setting, and can be delivered by physicians, allied health professionals, research assistants, or nurses. Additionally, because so few resources are needed, the Self-Paced Step Test can be implemented in a wide variety of clinical and community settings (e.g., hospitals, nursing homes, private practice offices, and counseling centers), thus reducing health professionals' burden of finding suitable environments to perform functional assessment evaluations.

Timed Up-And-Go. The test is a simple, well-established measure of dynamic balance, agility, lower extremity functioning, mobility, and multi-tasking ability (TUG; Shumway-Cook, Brauer, & Woollacott, 2000). It requires individuals to stand up from a seated position in a chair, walk 8 feet at a comfortable yet quickened pace, turn around, walk back to the chair and sit back down. Two trials are performed, and the best time of the two trials is recorded. Scores are based on the number of seconds required to get up from a seated position, walk 8 feet, turn, and return to a seated position. Poor TUG performance has been shown to correlate with slow gait speed, poor balance and functional indices (Podsiadlo & Richardson, 1991). Furthermore, researchers have demonstrated the value of TUG performance in predicting global health decline (Viccaro, Perera, & Studenski, 2011), inability to perform activities of daily living (Viccaro et al., 2011), incidental and recurrent falls (Lin et al., 2004; Viccaro et al., 2011), and nursing home placement (Nikolaus et al., 1996).

Walking is reliant on cognitive processes including attention, visuospatial processing, and executive function. In addition to assessing persons' walking ability, the TUG test also measures additional components of physical performance including turning and transferring from a sitting to a standing position, and researchers and clinicians alike are realizing that their original considerations for the TUG test are actually much more complex than what was once thought. The TUG test is useful in comparing physical performance with cognitive functioning, and previous cross-sectional research has demonstrated strong correlations between TUG performance and cognitive functioning, specifically concerning executive function (Wennie

Huang et al., 2010). The TUG test was selected for the present study due to its well-established reputation as a valid measure of physical functioning as well as its previously demonstrated association with various components of cognition.

Walk 50 Feet. This task from the PPT (Reuben & Siu, 1990) is a commonly used assessment for measuring walking ability as well as capacity to change and maintain body motion. Participants are assessed based on their capacity to walk short distances (in this case, 50 feet; other common distances include 8 feet, 13 meters, and 150 feet) as quickly as they can without over-exerting themselves. Longitudinal research has demonstrated that slower gait speeds can serve as identifiers for a high risk of poor health-related outcomes in older adults. Older adults with slower gait speeds (< 2 feet/second) had a 1.5-fold increase in risk of falls as compared to those who had normal gait speeds (Cesari et al., 2005).

Pick Up a Penny. This PPT (Reuben & Siu, 1990) task is a performance-based measure of multiple dimensions of physical functioning, activities of daily living, and balance. During the assessment, the examiner places a penny on the ground approximately 12 inches from the subject's dominant foot. The examiner then asks the subject, on the command "Go", to pick up the penny from the floor and then stand up. Subjects are scored based on the number of seconds until standing erect with a penny in hand. Longer time to complete this task has been associated with degree of disability, early mortality, and loss of independence (Brown, 2000). Additionally, Pick up a Penny also predicted fall risk and nursing home placement at a 5-year follow-up evaluation (Guralnil et al., 2000).

Statistical Procedures

Descriptive statistics were computed using SPSS Version 19 (IBM Corp., 2011). Confirmatory Factor Analyses (CFA) within a Structural Equation Modeling (SEM) format and

Multiple Indicators Multiple Causes (MIMIC) modeling were conducted using Mplus Version 7 (Muthén & Muthén, 2007) and maximum likelihood estimation. Missing data were managed with full information maximum likelihood (FIML), which analyzes all available information in order to estimate parameters. For both latent factors, factor means were set to zero and variance set to one in order to achieve model identification.

Two primary steps were used for the analysis. First, a measurement model was established in order to individually represent cognition and physical function based on their respective indicators. The "Cognition" factor was measured using the following measures: Block Design, Category Fluency – Animals, Stroop Color Naming, and Digit Symbol. The "Physical Function" factor was assessed using the following 5 measures: the Self-Paced Step Test, Up and Go, Pick up a Penny, Walk 50 feet, and Chair Rise. The structure of the cognitive factor based on the four cognitive measures outlined above and the structure of the physical function factor based on the five functional measures outlined above were first examined individually in order to establish good model fit. Next, a CFA was performed in order to establish the validity of a model correlating the two latent factors so as to examine the interrelation association between cognition and physical function prior to the addition of covariates.

Multiple Indicators Multiple Causes (MIMIC) modeling (Muthén and Muthén, 1998–2012) was used to examine the effects of three covariates on the factor structures of cognition and physical function. MIMIC modeling is a unique case of SEM that consists of two parts: the first step includes a measurement model defining the relationship between a latent factor and its indicators; the second step includes a structural model that specifies the relationship between two or more latent factors; the final step incorporates additional variables that are assumed to influence the latent factors and also allow for hypothesis testing on the direction of effects between different factors. MIMIC modeling can also include direct paths between covariates and factor indicators. These direct paths represent differences in the indicators that can be attributed to the covariates after controlling for the latent factor. With the present study, MIMIC modeling simultaneously estimated: a measurement model specifying the relation between a latent cognitive construct and a latent physical performance construct (i.e., a CFA model); a regression model whereby the two latent constructs are regressed on three covariates (i.e., age, sex, and years of education); and a final model integrating “direct effects” between indicators and covariates . The presence of such direct effects indicates measurement non-invariance, also called differential item functioning (DIF), exists within the model. For instance, in the context of adjustment for sex differences in performance on Block Design, males have an increased probability of stronger performance (e.g., higher scores) than do females.

The initial MIMIC model consisted of a CFA measurement model previously established and a regression model estimating the simultaneous effects of age, sex, and years of education on factor means for the cognitive and physical performance constructs. The initial MIMIC model presumed no DIF in any of the indicator items, and it served as a baseline model for an examination of modification indices (MI). Modification indices provide information on the extent to which model fit improves through estimation of DIF effects due to age, sex, and years of education. The MIMIC model also provided information on the robustness of the relationship between cognition and physical performance in the presence of covariates, as well as any discrepancies in the cognitive factors means or physical performance factors means due to age, sex, and years of education.

Model modification indices (MI) greater than or equal to 10 were requested for the MIMIC model. Modification indices represent the expected reduction in the chi-square value if a parameter is freely estimated. MI values generally serve as suggestions for including additional paths as a way of improving goodness of model fit. Based on this, additional paths were added to the MIMIC model in order to improve overall model fit, so long as there was a theoretical justification for doing so.

Fit Indices. Model fit was evaluated based on several commonly adopted standards for estimating model fit. Conventionally speaking, a significant chi-square signifies that the observed data are consistent with the hypothesized model (Bollen & Long, 1993). The chi-square test is considered by many researchers as being overly strict in its power to detect even inconsequential deviations of a data from the proposed model, and for this reason, other model fit indices were also used in order to assess absolute, parsimonious, and/or incremental data-model fit. Based on the recommendations of Mueller and Hancock (2010), the following fit indices were used: the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA; Cudeck & Browne, 1992), the comparative fit index (CFI), and the Tucker-Lewis Index (TLI; also referred to as the non-normed fit index, NNFI). SRMR is an absolute index used to evaluate the overall discrepancy between the observed and implied covariance matrices, with SRMR scores at or below .08 indicating good model fit. The RMSEA is widely considered one of the most informative measurement tools in covariance structural modeling; it examines how well the proposed model would fit the population covariance matrix if available. RMSEA values of .05 or less represent a close fit to the data, values between .05 and .08 indicating reasonable model fit, and values up to .10 representing acceptable model fit (Cudeck & Browne, 1992). The CFI and TLI are considered incremental indices, and their values represent the comparison between the specified model and a baseline model; the baseline model is typically a null/independence model that does not specify any relations among observed variables. Both the CFI and TLI have values ranging between 0 and 1, with values below .95 suggestive of model misspecification. With a minimum target value of .95, CFI and TLI values of .95 or greater indicate adequate to excellent model fit (Mueller & Hancock, 2010). All fit statistics were simultaneously considered in order to assess the adequacy of the each of the models to the observed data.

Chapter IV

Results

Demographics

Demographics information and descriptive statistics for the sample population are presented in Table 1. Of the 119 subjects, 70.6 percent (n = 84) of the subjects were female. The sample was 95.8 percent White/Caucasian (n = 114) and 4.2 percent (n = 5) were African American. Means for age and years of education were 72.37 (SD = 7.04) years and 16.80 (SD = 72.76) years, respectively.

Analyses

Initial analyses examined the individual factor structure of cognition and physical performance. In the first model, the latent structure representing cognition was constructed using the four cognitive measures as indicators. After evaluating the measurement model, the author proceeded to test the validity of the model in the presence of three covariates (i.e., age, sex, years of education) using MIMIC modeling. MIMIC modeling is a special case of SEM and consists of a measurement model (established at the CFA stage) as well as a structural model. The structural model serves to specify the effects of covariates on factors. Through the incorporation of covariates, researchers can examine the relationship between factors while simultaneously accounting for covariate influences.

During this stage, modification indices suggested how model fit would improve with inclusion of two direct effects between the covariates and the indicators, while holding latent variables constant. A significant direct effect between a covariate and an indicator suggests differential item functioning (DIF). When DIF is present in a model, assessment score probabilities of a particular item differ between groups, despite both groups having been matched in terms of their factor loadings. In the case of the present study, women scored lower on the Block Design subtest than male participants, despite both genders having similar overall levels of cognitive functioning. Resultantly, results indicated presence of Sex DIF with the Block Design subtest. After examining modification indices, the direct path with the highest modification indices was added, allowing a comparison of this model to the simpler one that did not have direct paths.

Research Question 1. What proportion of variance in cognitive functioning is uniquely accounted for by selected cognitive measures?

- **Hypothesis 1a:** Stroop Color Naming, Digit Symbol, Block Design, and Category Fluency-Animals will significantly load on a cognitive functioning factor.
- **Hypothesis 1b:** Cognitive functioning, as a first order factor, will demonstrate good model fit based on χ^2, RMSEA. RSMR, CFI, and TLI.

The first model tested whether the cognitive measures significantly loaded on a cognitive functioning factor. As shown in Figure 1, all four cognitive tests significantly loaded on a cognitive functioning factor. The factor structure for the cognitive functioning construct demonstrated good model fit, χ^2(df = 2) = 1.80, p = .41; CFI = 1.00; TLI = 1.00; RMSEA = .00 [95% confidence interval = .00 - .18]; RSMR = .02). Hypothesis 1a and 1b were upheld.

Research Question 2: What proportion of variance in physical performance is uniquely accounted for by objective functional assessments?

- **Hypothesis 2a:** Timed Up and Go, Five Times Sit to Stand Test, Walk 50 Feet, Pick Up a Penny, and Step Test will significantly load on a physical performance factor.
- **Hypothesis 2b.** Physical performance, as a first order factor, will demonstrate good model fit based on χ^2, RMSEA. RSMR, CFI, and TLI.

In the second model, the author constructed the latent structure representing physical performance based on the five functional assessment measures. As shown in Figure 2, all five physical performance measures significantly loaded on a physical performance factor. The latent structure for physical performance demonstrated good model fit, χ^2= 9.72, df = 5, p = .08; CFI = .985; TLI = .970; RMSEA = .09 [95% confidence interval = .00 - .17]; RSMR = .03. Based on the direction of the relationship between scores and the indicator variables and their loadings, it appeared that the physical functioning factor was representative of reduced functional speed; thus, the physical functioning factor will heretofore be termed functional slowing. Hypothesis 2a and 2b were upheld.

Research Question 3: What is the relationship between cognitive speed and functional speed?

- **Hypothesis 3a:** A two-factor model consisting of a cognitive functioning factor and a physical performance factor will demonstrate strong model fit.
- **Hypothesis 3b:** There will be a statistically significant correlation between the cognitive functioning factor and physical performance factor.

In the third model, a two-factor model was constructed to examine the latent constructs of cognition and functional slowing in relation to one another. Additionally, the shared variance between cognition and functional slowing was estimated. This model served as our measurement model. The two-factor model, as presented in Figure 3, demonstrated good model fit, χ^2= 37.28, df = 26, p = .07; CFI = .97; TLI = .96; RMSEA = .06 (95% confidence interval = .00 - .10); RSMR = .05. The correlation between cognitive functioning and functional slowing was significant (r = -.48, p < .0001), indicating that individuals with higher scores on measures of cognitive functioning were likely to have faster completion times for the functional performance measures. Correlations between indicators are presented in Table 2. Hypothesis 3a and 3b were upheld.

Research Question 4: How do covariates affect the relationship (i.e., model fit) between cognition and physical performance?

- **Hypothesis 4a:** After adjusting for covariates of age, sex, and years of education, the two-factor model fit will be strong.
- **Hypothesis 4b:** After adjusting for covariates, the correlation between cognition and physical performance will be significant.

After adding covariates, model fit was worse but still acceptable, χ^2= 79.50, df = 47, p = .002; CFI = 0.93; TLI = 0.91; RMSEA = 0.08 (95% confidence interval = 0.05– 0.11); RSMR = 0.06. All factor loadings remained strong and significant, as did the correlation between cognition and physical performance, r (df) = -.38, $p < .0001$. Cognitive functioning was significantly related to age, r (df) = -0.35, $p < .0001$), indicating persons with increased age were more likely to have increased risk for cognitive slowing than individuals who were younger on cognitive functioning measures. Cognitive functioning was also related to years of education (r = .22, $p < .05$), indicating that individuals with higher levels of education had an increased likelihood of scoring higher on the cognitive functioning measures. Age demonstrated a strong correlation with functional slowing (r = .50, $p < .001$), indicating that increased age is associated with increased likelihood of longer completion time on the physical performance tasks. Sex had no significant effect on cognitive functioning (r = -.01, $p > .05$). Sex was significantly correlated with functional slowing (r = .18, $p < .05$), indicating that women were more likely to take longer to complete the functional measures than were men. Education did not significantly correlate with functional slowing (r = -.05, $p >.05$).

Results of differential item functioning analyses demonstrated direct effects of gender on Block Design performance. After accounting for the moderating effects of gender on Block Design as part of the larger two-factor MIMIC model, overall model fit significantly improved, χ^2= 69.02, df = 46, p = .02; CFI = 0.95; TLI = 0.94; RMSEA = 0.07 (95% confidence interval = 0.03 – 0.10); RSMR = 0.05. The correlation between cognition and functional slowing was significant ($r = -.38$, $p < .0001$). Direct effects of age on the latent construct of cognitive functioning was also observed, ($r = -0.35$, $p < .0001$), indicating that older participants performed slower on cognitive tasks than younger participants. Also affecting speed of cognitive functioning was years of education ($r = .22$, $p < .05$). Higher levels of education, as compared to less years of education, predicted faster performance on cognitive tasks. Gender did not appear to affect cognitive performance ($r = .02$, $p > .05$). Interestingly, significant gender effects in performance were observed on WAIS-III Block Design ($r = 0.25$, $p < .01$).

Age effects were also observed among latent functional slowing ($r = .50$, $p < .001$), showing an association between increased age and slower performance on measures of physical functioning. Functional performance was also affected by gender, with male participants performing functional tasks at a faster rate than the female participants did ($r = .18$, $p < .05$). Education did not significantly affect performance time on physical functional tests ($r = -.05$, $p > .05$), therefore there was no significant difference in performance time for more educated participants as compared to those with fewer years of education. Hypothesis 4a and 4b were both upheld.

Chapter V

Discussion

This chapter summarizes the main findings of the present study and offers an interpretation by reviewing the results from the factor analyses. The author then discusses how the results from the current study fit within existing research on cognition and physical performance in older adults. The limitations of the study, future directions for future research, and implications for application to professional practice are discussed.

Summary of the Findings

The present study sought to expand upon the wealth of literature examining the association between cognitive functioning and physical activity in a sample of non-demented older adults. Although much of the existing research has focused on examining this association in populations of individuals evidencing pathology, mental illness, or disability (e.g., dementia, Parkinson's disease, Major Depressive Disorder, chronic pain, schizophrenia, etc.), the author found very few articles that examined the relationship in healthy older adults. Some authors however have begun to advocate for the re-direction of empirical focus towards apparently healthy older adults (Balota et al., 2010). This is important because it will: allow for longitudinal tracking of older adults' cognition, some of whom will inevitably convert to a diagnosis of dementia; assist in identifying predictive markers for deterioration that can then be used to develop earlier interventions for underlying disease mechanisms; and increase sensitivity to preclinical markers for decline, prior to detectability (Buschke & Lipton, 2003). Understanding the pre-clinical relationship between physical and cognitive capacities allows for a richer understanding of the ways in which such factors interact with one another. This study aimed to contribute to such an understanding by examining the relationship from a structural equation-modeling lens. Another goal of the study was to provide implications for how clinicians can practically assess for cognition and physical functional status in everyday clinical settings. Thus, latent cognition and physical functional speed were assessed using well-validated, cost-effective, and time-limited measures; these measures were selected because of their ease of administration, scoring, and interpretation.

Descriptive analyses yielded several notable findings. Average years of education were significantly higher than those observed in general population. For the current study, participants averaged more than 16 years of education, the equivalence to a Bachelor's degree or higher. This is compared 2015 U.S. Census Bureau information reporting that only 49.7% of Americans aged 65 years or older had some level of college-level education, and only 26.7% of older adults had 16 years of formal education or more (Ryan & Bauman, 2016). Additionally, significant variability in participants' ages was noted, with ages spanning more than three decades (i.e., Range = 60 – 93 years). Such large age differences may have contributed to age-related cohort effects.

The author sought to study the relationship between level of cognitive functioning and physical performance status in a sample of 119 healthy, non-demented community-dwelling older adults. Correlations between indicators and covariates are presented in Table 2. As hypothesized, the indicators of cognition successfully estimated an underlying construct of cognitive functioning. Likewise, the five indicators of physical performance estimated an underlying construction of physical performance. It is interesting that the model structure of physical performance appears to be representative of functional slowing. Based on the demonstrated inverse relationship between the two latent constructs in the present study, it would be interesting to examine the same relationships in older adults evidencing cognitive decline.

Such a future endeavor may serve as being worthwhile since almost no studies have utilized physical performance measures in assessing functional abilities of older adults with dementia. Doing so may allow for an improved impression of the unique ways in which cognitive decline affects physical activity at the most basic level of functioning.

As expected, there was a significant association between functional slowing and slower performance on cognitive tasks. This supports existing evidence showing that slower functional speed predicts slower performance on cognitive measures of working memory, processing speed, and basic attention. Additionally, results of the present study demonstrate that latent cognitive functioning shared a significant relationship with latent physical performance, and that this relationship could be identified using rather common and easy-to-administer assessments of functional performance and cognition.

In terms of the clinical application, the results are remarkable. The present findings open a new window into the world of older adults' physical performance and cognitive function. The relationship between cognition and physical functioning is something that has been well-studied and presented in the literature. However, most of these studies used self-report measures of functional status, such as ADLs. The majority of those studies that used objective performance measures focused primarily on physical exercise, rather than a more foundational level of physical functioning. To examine the relationship between cognition and physical functioning at the most basic level allows for potential to more sensitively detect changes in cognition or physical functioning and better predict cognitive decline and disability.

Much of the previous research has indicated that the relationship between cognition and physical functioning is identified most strongly in populations of demented individuals (Royall et al., 2007). Very few researchers have been able to demonstrate a significant relationship between cognitive and physical functioning in healthy non-demented older adults. Further, the little research that has examined the relationship between these latent constructs has primarily done so in the context of a larger multi-factor structural model which included other latent factors such as personality traits, depression, apathy, or personal beliefs (Lam, Tam, Chiu, & Lui, 2006). Despite reducing model fit, the three covariates of age, education, and sex did not affect significance level of relationship between the two latent factors themselves or their respective indicators' factor loadings. Considering the level of motivation and mental energy expenditure required for both cognitive processing and physical performance, one could argue an underlying mediator between these two factors may be effort. This suggests that one or more underlying mechanisms are influencing the relationship between cognition and physical performance. More research needed to determine what these mechanisms might be specifically, but some have suggested that motivational processes may serve as a potential mediator (Forstmeier et al., 2012).

If motivational processes are serving as influential underlying mechanisms between cognition and physical performance, then it may be possible for clinicians to adjust clinical interventions so as to better promote motivation and motivational abilities as part of treatment objectives. This could help to empower older adults by giving them back a sense of control over their circumstances. Considering that physical activity and cognitive engagement both require individuals to put forth some amount of effort, clinicians can promote the importance of simply trying. This takes away some of the perceived burden that physical activity, particularly exercise, can have.

There have been few, if any, studies exploring associations between physical activity, physical fitness and everyday cognition using performance-based measures of both cognition and physical functioning. The present findings suggest that utilizing everyday cognition as an outcome has practical applicability in understanding how physical activity and fitness may contribute to older adults' ability to perform cognitively complex activities, beyond that which may be assessed by traditional neuropsychological measures.

At present, the field of psychology has primarily focused on mental energy as it relates to older adults' cognitive and emotional processes. Historically, mental energy and effort have been assessed using one or more of the following: (1) cognitive assessments sensitive to effort (albeit many of these assessments are specific to effort as it relates to malingering in the medico-legal context); (2) clinicians' professional impression of patients' investment in performance; and (3) self-report questionnaires about perceived degree of exerted mental effort. The latter two assessment methods largely rely on subjective impressions of internal processing and clinical impressions of whether or not the amount of patients' exerted effort are not as a result of an external incentive (as is seen in malingering cases). However, these methods are insufficient for they lack consideration of non-malingering effort. The author argues that mental effort is the underlying construct explaining this shared relationship between cognition and function. Mental effort is the hypothesized construct that assesses both physical and cognitive functioning. It is the purest way to assess effort, and can perhaps explain the association between physical functioning and cognitive functioning prior to development of pathology.

This paper adds to the body of research examining associations in older adults' level of cognitive functioning and their physical performance abilities. Better performance on cognitive tasks is associated with faster functional speed and reduced incidence rates of disability, both short- and long-term. Additionally, it extends upon previous findings by examining physical performance beyond simple self-report measures of physical activity to examine the relationship at a performance-based level. Although inclusion of covariates significantly reduced model fit, the finding that the relationship between physical performance and cognitive functioning remained significant despite inclusion of covariates suggests that the relationship between cognition and physical functioning may be more demonstrative in non-demented populations than what was previously thought.

Limitations

Although findings are informative, the present study is not without limitations. The present study marks progress in the objective comparison of cognitive functioning in relationship to physical functional status, and yet there are a number of drawbacks that should be addressed in future replications. The chosen proxies for the latent constructs of cognitive functioning and physical functional status indicator variables chosen for the present study demonstrated good model fit and adequately predicted each latent factor. However, it is possible that both factors could be better predicted using other cognitive measures. Future assessments should include other cognitive measures to determine if others might add to the sensitivity of predicting latent cognition, and also physical functional status. It would also be interesting to determine if the cognitive functioning might be predicted using objective physical functional measures as indicator variables. In other words, is it possible to assess for cognitive functioning status using measures of physical functioning? Of primary importance is establishing standardized operational definitions and measurement instruments to allow clearer interpretation of results across studies. Some of the current study limitations may be addressed in future research by utilizing objective physical activity measurement devices in combination with subjective reports done in daily dairy fashion to acquire more detailed activity information.

Due to the cross-sectional nature of the current investigation, the direction of influence between cognitive functioning and physical performance could not be determined. Thus, the temporal ordering of slowing in cognitive and physical functioning remains unknown. This also limits the ability to see how the strength of the association between cognition and physical proficiency changes over time. Future longitudinal examination of the present findings will lend considerable information that clinicians may use to increase sensitivity for identifying declines in cognitive functioning and/or physical performance. This in turn could promote the development of preventative measures for any noted declines in cognition or functional ability so as to delay or even prevent further declines. It would be interesting to compare the differences in the trajectory of the relationship between cognitive functioning and physical functional status in the healthy aging process against the trajectory of that in a population of demented older adults. Determining the point of deviation may assist in determining preclinical markers and preventative interventions in order to better treat, and also to potentially delay, deterioration of cognitive and physical disability.

Another limitation pertains to the retrospective nature of the data used for the present study. The data were from a sample population consisting of highly educated, Caucasian, volunteer group, Caucasian older adults who are largely representative of the non-demented older adults who regularly participate in research at NIA-supported ADCs across the country. Resultantly, the population is not representative of, and the results may not generalize to, the general population. In addition, the current participant sample is not sufficient to adequately predict the relationship between cognitive functioning and physical functional status in population of older adults from ethnic minority groups or from Spanish-speaking populations. As ADCs expand their volunteer outreach and recruit a more diverse group of volunteer participants, it will be possible to apply these findings to a community-based sample in a generalizable way.

Furthermore, findings are relevant to non-clinical elderly populations, and do not generalize well to populations with mild to severe cognitive and/or functional deficits. Although previous research has demonstrated the association between cognitive functioning and physical disability in demented older adults, research to date has yet to assess the association between these two factors using the functional assessments included in the present study. Because the objective functional measures are well-validated, can be administered by a range of different providers, require little to no equipment, and are able to be administered in a variety of different treatment and research facilities, it is quite possible that this study could be replicated in a population with individuals who have either mild cognitive impairment and/or dementia.

The sample size of the participant sample was adequate to conduct the statistical analyses, yet future studies might wish to increase sample sizes even further. Consideration of increased diversity within future sample populations would not only allow for examination of the relationship across diverse demographics, but would also allow for increased generalizability of findings. Further increasing sample size would also allow for additional options for statistical analyses without compromising validity of findings.

In conclusion, this study found that a significant relationship exists between cognitive functioning and physical functional speed, and that this relationship can be accurately assessed using easy-to-administer assessments. Cognitive functioning was assessed through the use of four brief cognitive assessments. Five physical functional measures adequately predicted overall physical functional speed. Structural equation modeling analyses suggested that cognitive performance shares a negative relationship with physical functional slowing. In other words, faster performance on cognitive assessments is associated with decreased likelihood of slowed physical performance on physical functional measures. Early assessment appears to suggest that maintained cognitive speed is associated with maintained functional speed. These findings may be useful for screening programs of older adult patients in general practice setting. This may help to identify those older adults who are more likely to experience physical or cognitive slowing in the near future, and who would likely benefit from early interventions. Considering the effort required to carry out both cognitive and functional tasks appear to be promising targets for future investigations and clinical interventions.

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Table 1

Demographics of Sample and Descriptive Statistics (N = 119)

Variable	N	%	M	SD
Sex				
Males	35	29.4		
Females	84	70.6		
Age (years)			72.37	7.04
Race/Ethnicity				
White	114	95.8		
African American	5	4.2		
Education (years)			16.80	2.757
Baseline MMSE score			29.20	1.109
Baseline GDS			.97	2.757
WAIS-III Block Design			35.25	11.04
Category Fluency – Animals			21.18	6.33
WAIS-R Digit Symbol			48.06	10.32
Stroop Color Naming			74.48	11.64
Step Test Time (seconds)	108		80.02	22.99
Timed Up-and-Go (seconds)			6.11	1.73
Chair Rise (seconds)			10.86	9.20
Walk 50 Feet (seconds)			14.26	2.51

Table 2

Correlation coefficients among indicators and covariates

1. Age	.047	-.063	-.156	-.182*	-.316**	-.110	.357**	.438**	.467**	.179	.322**
2. Education		-.363**	.179	.238**	.151	.130	.103	-.034	-.083	-.032	-.104
3. Sex			-.279**	.034	-.029	-.064	.027	-.033	.168	-.135	.236**
4. Block Design				.246**	.428**	.233*	-.055	-.215*	-.284**	-.050	-.186*
5. Category Fluency- Animals					.421**	.357**	-.145	-.079	-.214*	-.153	-.157
6. Digit Symbol						.542**	-.358**	-.353**	-.447**	-.129	-.249**
7. Stroop Color Naming							-.143	-.228*	-.219*	-.143	-.181
8. Step Test (sec.)								.437**	.572**	.516**	.577**
9. Pick Up a Penny									-.703**	.151	.568**
10. TUG (sec.)										.214*	.668**
11. Chair Rise											.039
12. Walk 50 Ft.											

* p < .01 ** p < .001

Figure 1

Single factor model structure for cognitive functioning with standardized estimates and model fit indices

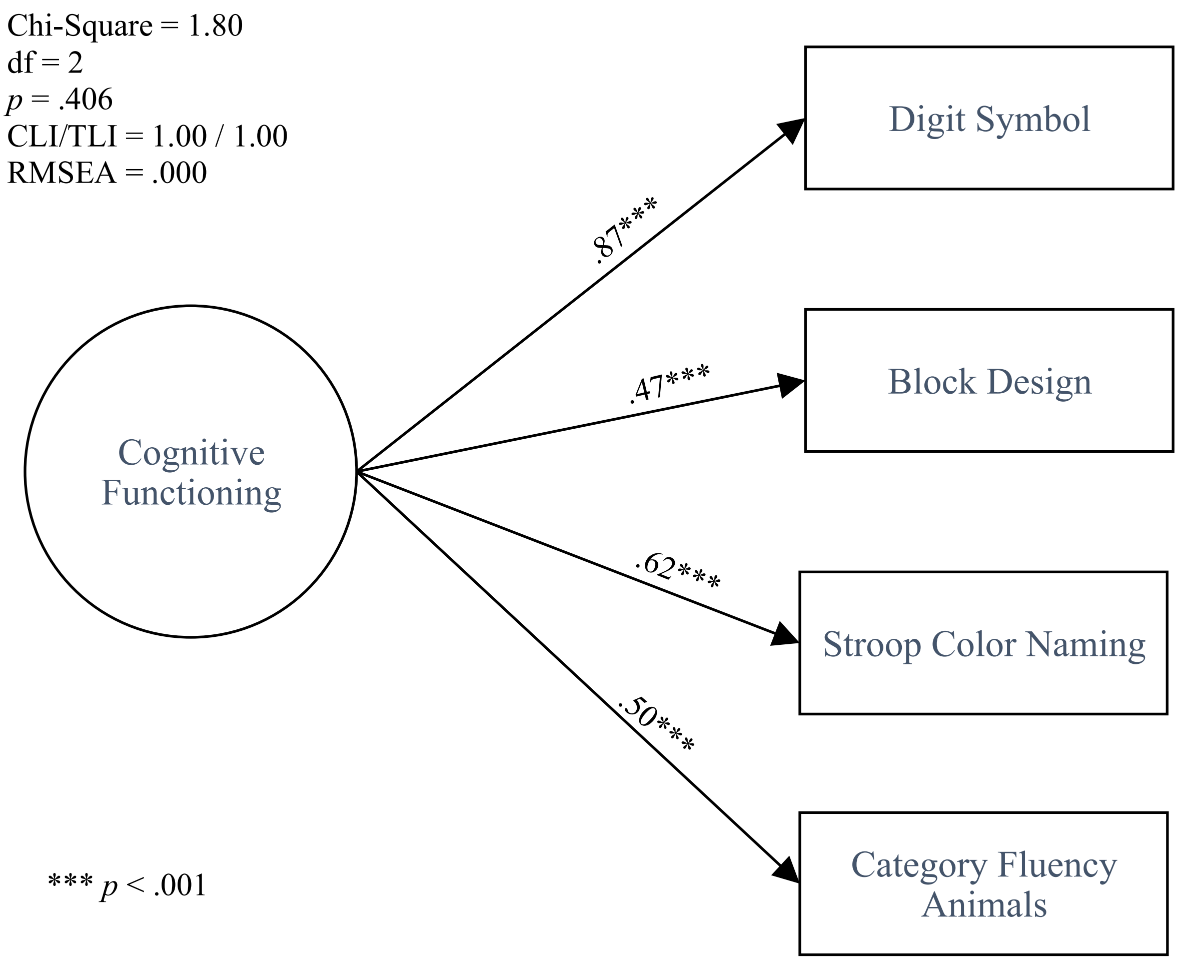

Figure 2

Single factor model structure for functional slowing with standardized estimates and model fit indices

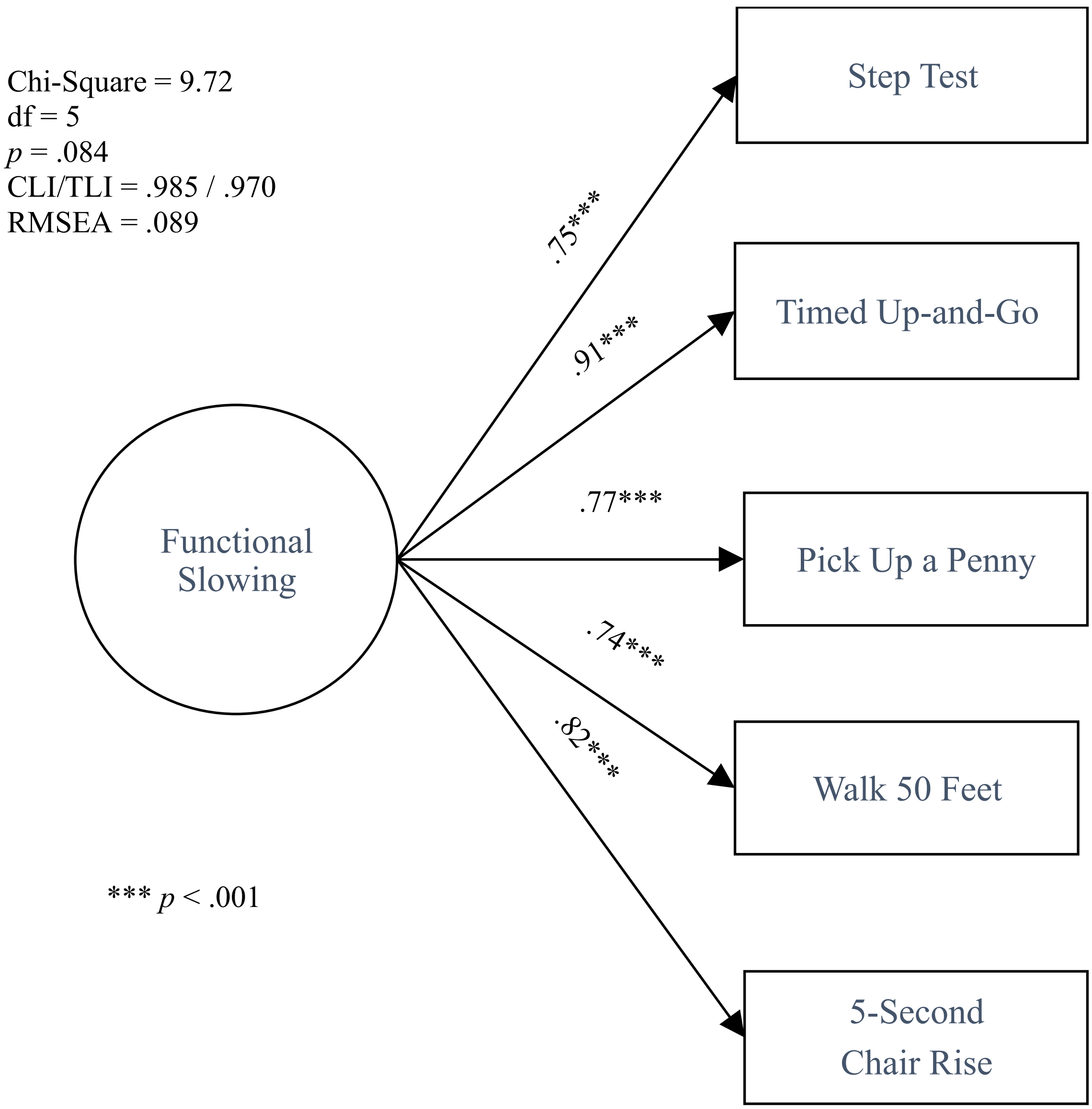

Figure 3

Two-factor confirmatory factor analysis model of cognition and functional slowing with estimates of model fit indices

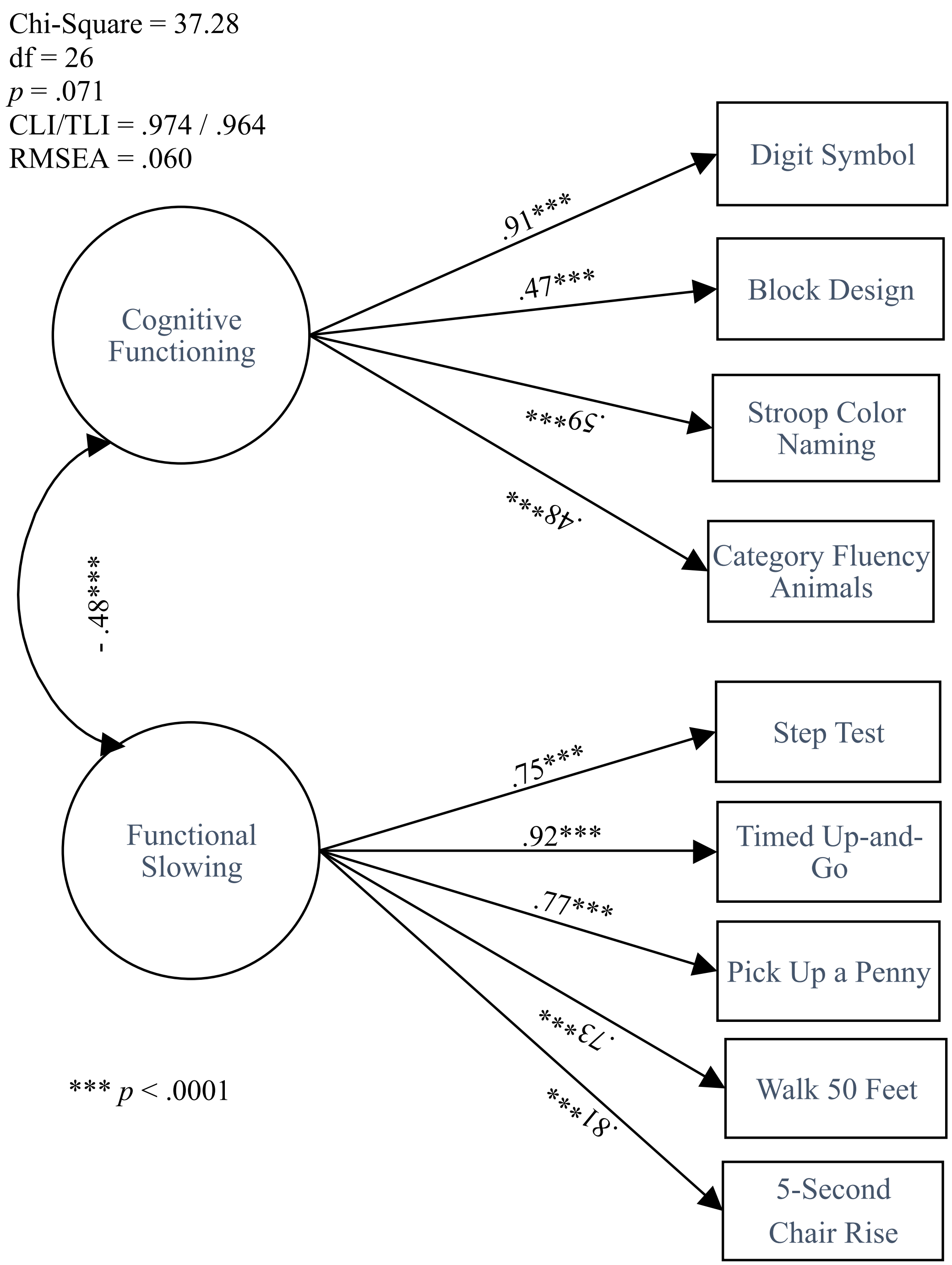

Figure 4

Two-factor model structure with standardized estimates, model fit indices, and covariates

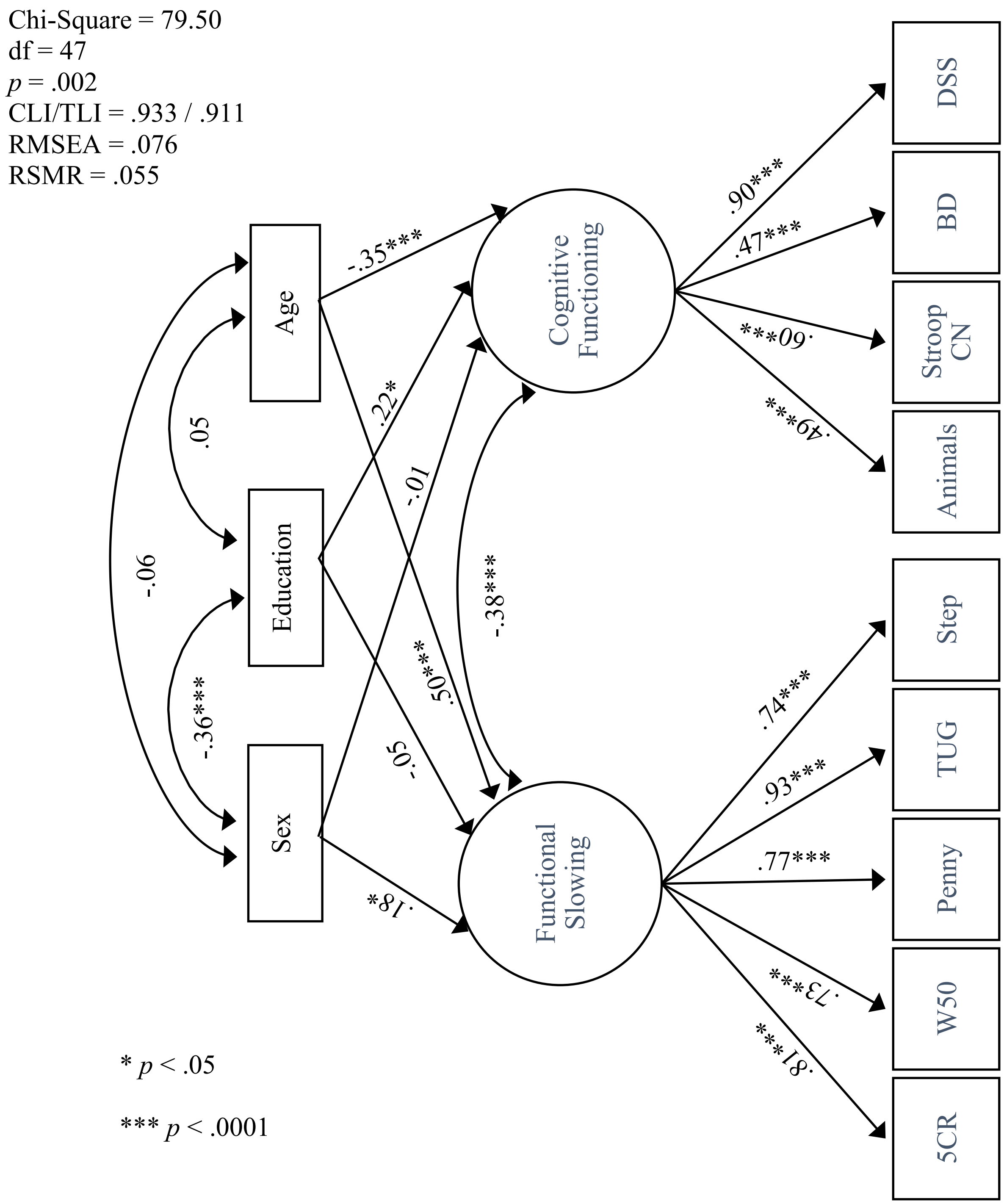

Figure 5

Second-order two-factor model structure with standardized estimates, covariates, and direct effects