Individual and Partner Exercise Status and Cognitive Function in Older Adults

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Abstract

The present study used a linear mixed model analytic approach to assess the association between a combined respondent and spousal exercise score and cognitive outcomes of older adult respondents drawn from a nationally representative dataset, The Health and Retirement Study. Informed by the Scaffolding Theory of Aging and Cognition (STAC), the present study sought to understand the role of both an individual and their spouse's aerobic physical activity in an individual's cognitive outcomes and trajectories. Utilizing longitudinal survey data collected across twelve years (N=3,189), the combined exercise status of a married couple was found to be a significant predictor of cognitive outcomes; when an interaction between time and couple exercise status was included in the model, this was also found to be a significant predictor of four specific cognitive outcomes. The highest cognitive benefit was identified among individuals where both they and their partner participated in the recommended amount of aerobic physical activity, suggesting an additive effect. These findings and their implications are discussed further.

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General Audience Abstract

The present study explores how the combined exercise behaviors of a married older adult couple may predict the cognitive outcomes of one partner. Data was analyzed across twelve years and included married individuals between the ages of 65 and 95. Findings showed that the combined couple exercise status predicted outcomes in cognitive function of the respondent. Additionally, the interaction between time and the couple exercise status significantly predicted cognitive outcomes. The addition of a spouse's aerobic physical activity was beneficial to the cognitive outcomes of their partner. The cognitive benefit was highest among couples where both partners participated in aerobic physical activity. These findings and their implications are discussed further.

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Chapter 1: Introduction

Decline in certain cognitive functions is a normative part of the aging process, but there are considerable individual differences in cognitive changes across older adults (Spreng & Turner, 2019). Aging can lead to cognitive decline in domains like executive processing; this may impede an individual's ability to live independently in older age (Park & Reuter-Lorenz, 2009). Furthermore, developed nations across the world are experiencing increases in their elderly populations (Freedman & Kasper, 2019). Given that this means a greater number of individuals may be experiencing cognitive decline, preventative measures to lessen cognitive decline and maintain independence are important for individuals, practitioners, and policy makers.

The need for physical activity is important throughout the lifespan; it helps to maintain independent living, reduce disability, and improve quality of life in older adults (Sun et al., 2013). Physical activity has proven to be a promising intervention for maintaining general brain health and cognitive functioning (Erickson et al., 2015). Aerobic physical activity has been linked to improvement in executive functioning, even in populations that are already healthy; for example, research has found that working memory may be improved following aerobic exercise (Guiney & Machado, 2013). Understanding how physical activity can best serve as a preventative measure for cognitive decline will be helpful in reducing morbidity and elongating healthy years (Fried, 2016).

Maintaining cognitive function, or minimizing decline, throughout the life course requires individuals to take part in healthy behaviors, like physical activity, that have proven to stave off Alzheimer's disease, dementia, and cognitive functioning declines (De la Rosa et al., 2020). The benefits of physical activity are usually measured on the effects within an individual, although it is possible that benefits could expand to close others in one social network, like spouses. The family unit and social networks have been identified as important means of intervention and influence for physical activity behaviors; it is possible that there are additive cognitive effects when social interaction and exercise are combined (Wong & Hsieh, 2019).

Purpose

Changes in cognitive function throughout aging may include declines in problem-solving skills, memory, speed of processing, global cognition, language, and executive functioning (Klimova et al., 2017; Yang et al., 2021). Evidence suggests that these declines may be lessened through interventions including nutritional changes (Dominguez & Barbagallo, 2018), cognitive training (Butler et al., 2018), and creative therapies (i.e., art or music therapies) (Klimova et al., 2017). Exercise programs in particular are often recommended as a means to prevent or delay disability and cognitive decline in later life, serving as a protective mechanism for the brain (De la Rosa et al., 2019; Liu et al., 2014). This study looked at the cognitive outcomes of individuals' exercise habits in combination with their spouses' exercise behaviors to understand if it is more beneficial for cognition if both partners participate in aerobic activity, rather than just the individual or their spouse alone. This study focused solely on the cognition of the respondent, but future work may wish to include cognitive outcomes of both partners.

Spouses, and families, play a role in the health behaviors and outcomes of one another (Anderson-Bill et al., 2011; Wong & Hsieh, 2019). For example, the education level of an individual and their spouse influences their combined self-rated health; these findings highlight the potential of shared resources within a marriage to produce better health outcomes (Brown et al., 2014). Spouses tend to influence one another (Cobb et al., 2016), so studying their behavior in tandem may offer insight into the role of interpersonal relationships. Information is also available to support the cognitive and physical benefits of physical activity for individuals who meet certain physical activity guidelines (Erickson et al., 2019). Less is known regarding the possible benefits that a spouse's aerobic activity could have on the cognitive outcomes of their partner, regardless of that partner's aerobic activity status.

There are both modifiable and non-modifiable risk factors that older adults may face; non-modifiable factors consist of variables like race and ethnicity, gender, age, and genetics (Klimova et al., 2017). It is suggested that about “60% of general cognitive ability is of a genetic origin” (Klimova et al., 2017, pg. 903). While this represents substantial portions of variance in cognitive function, modifiable risk factors help maintain cognitive functioning even in the presence of non-modifiable risk factors; these include physical activity, lifestyle, education, and health conditions like diabetes (Klimova et al., 2017).

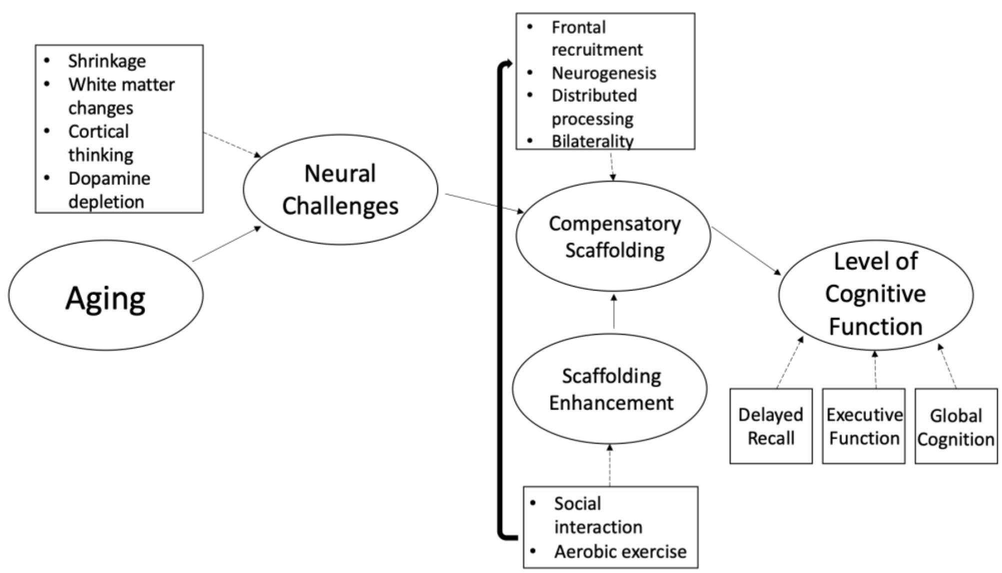
The present study had two primary objectives: (a) assess whether there is a significant difference in cognition among older adult respondents in a relationship where both spouses, one spouse, or neither spouse engage in aerobic activity that meets the Physical Activity Guidelines, and (b) discern whether there is an interaction between the combined partner exercise status and change in cognitive function over time. To contextualize the results of this study, the Scaffolding Theory of Aging and Cognition (STAC) was used as a theoretical framework. This theory provides an explanation for how aging may lead to structural and functional changes in the brain that affect cognitive functioning while considering scaffolding and cognitive enhancements that may mitigate age-related changes. This theory is discussed in further detail below.

Theoretical Framework: Scaffolding Theory of Aging and Cognition

The Scaffolding Theory of Aging and Cognition (STAC) provides the guiding theoretical framework for this research. STAC provides a powerful explanatory model for how aging leads to changes in the level of cognitive functioning including functional and structural issues in the brain while integrating scaffolding and cognitive enhancements that can buff the effects of age-related changes. The original model (see Appendix A) was slightly modified to integrate into the current study (see Figure 1).

Figure 1

Modified STAC Model Focused on Aerobic Exercise and Social Interaction (modified from STAC model proposed by Park and Reuter-Lorenz, 2009)



Adapted from "How Does it STAC Up? Revisiting the Scaffolding Theory of Aging and Cognition" by P. Reuter-Lorenz and D. Park, 2014, *Neuropsychology Review,* (https://doi.org/10.1007/s11065-014-9270-9).

The model illustrates how aging is associated with neural challenges which are described as structural changes that occur in the brain with aging; these may include volume loss, white matter changes, cortical thinning, and dopamine depletion (Reuter-Lorenz & Park, 2014). These neural challenges may directly influence cognitive functioning but may also be mediated by compensatory scaffolding. Compensatory scaffolding describes the brain's ability to counteract the negative effects of functional and neural decline through compensation utilizing other parts of the brain; this may include frontal recruitment, neurogenesis, distributed processing, and bilaterality (Reuter-Lorenz & Park, 2014). Frontal recruitment describes higher level cognitive executive-processes performed by the frontal lobes (Nocera et al., 2017); greater frontal recruitment is often associated with better cognitive performance. Neurogenesis describes the "proliferation, survival, and differentiation of neural precursor cells into mature neurons or glia that are integrated into the rest of the brain structure"; this provides the brain with the ability to adapt and change when necessary (Goh & Park, 2009, pg. 6). In older adults, the process of neurogenesis declines and synaptic plasticity is used to adapt and function (Boldrini et al., 2018; Villeda & Wyss-Coray, 2013). Distributed processing refers to more diversified processing across more neural areas (Goh & Park, 2009), and is often associated with better cognitive performance. Bilaterality is the recruitment of both the left and right brain of older adults on tasks where younger counterparts have lateralized activity; bilateral recruitment is often associated with improved cognitive performance (Reuter-Lorenz & Park, 2014).

Scaffolding enhancement includes both social interaction and aerobic exercise. Scaffolding is a process that protects cognitive functioning of the brain and attempts to absolve some of the cognitive decline that is often associated with normal aging (Goh & Park, 2009; Park & Reuter-Lorenz, 2009). Just as scaffolding on a structure supports the integrity of a building, the idea of scaffolding within the STAC model is that it provides support for cognition during aging. Scaffolding enhancement occurs when a challenge is presented and helps to optimize performance (Park & Reuter-Lorenz, 2009). Social interaction and aerobic exercise are linked to components of scaffolding enhancement; social support and physical activity impact these processes and contribute positively to cognitive abilities (Amieva et al., 2010; Bherer, 2015).

Cognitive function in aging is associated with normative decline in delayed recall, executive functioning, and global cognition (Chen et al., 2018). These declines affect a range of abilities including working memory, inhibition, cognitive control, and speed of processing (Park & Reuter-Lorenz, 2009). Changes in brain structure and functioning influence changes in cognition among older adults (Reuter-Lorenz & Park, 2014).

Literature Review

Physical inactivity has been associated with elevated risks of chronic conditions and mortality (Richards et al., 2017). Those who participate in regular physical activity achieve improved functional ability in activities of daily living, delayed age-related changes, and extended longevity (Adrieieva et al., 2019). According to some observational research studies following older adult participants anywhere from one to twelve years, strong evidence indicates that higher levels of physical activity are associated with lower rates of dementia (including from Alzheimer's Disease) and cognitive decline more generally (Erickson et al., 2019). This is important because the prevalence of dementia sharply increases as one ages, rising from 2.6% in those aged 65-69 to 43.1% in those 90 and older (Legdeur, 2018). Additionally, physical activity reduces risk of depression, anxiety, improves sleep, helps maintain healthy weight, lowers the risk for cardiovascular disease and diabetes, and strengthens bones and muscles (CDC, 2021).

To lessen age-related decline in cognitive function, it may be useful to investigate how physical activity behaviors occur among married couples. Intervention at the family level has been shown to increase adherence to physical activity programs (Osuka et al., 2017), but health declines within an individual have also been linked to health declines in their spouse (Vitaliano et al., 2011). However, it is not entirely clear if having a spouse who engages in healthy lifestyle behaviors is associated with better health outcomes for their partner.

Public Health Implications

Physical health and cognitive health have significant implications for public health more generally, given that Alzheimer's disease cost the United States $355 billion in 2020; this among is expected to rise to $1.1 trillion by the year 2050 (Alzheimer's Association, 2021). One in three seniors in the United States dies with Alzheimer's or dementia, making this a prevalent health issue (Alzheimer's Association, 2021). Increasing physical activity can help to lessen the burden on social care and healthcare by allowing healthy aging in older adults (Sun et al., 2013). Lowering the prevalence of neurodegenerative diseases may positively affect the economy, mental health, and physical health at a societal level. Many studies that have been conducted focus on subsets of the population like cancer patients and their spouses, couples of a specific race, or those with arthritis. While this information is beneficial to those populations, to determine whether it may generalize to society at large, it is necessary to conduct large-scale longitudinal studies that examine the health benefits of physical activity among older adult spousal pairs.

Physical Activity Guidelines for Americans

The U.S. Department of Health and Human Services (HHS) outlined Physical Activity Guidelines for Americans (PAG) for the first time in 2008, and again ten years later in 2018

(Second Edition Physical Activity Guidelines for Americans, 2018). Because the HRS does not include guidelines congruent with the Physical Activity Guidelines, the measures were based off of other work that has created variables for this purpose. This is still a relevant benchmark to use given that the primary change to the newest version of the guidelines does not impact the variables utilized in this study (the newest version of the guidelines no longer has a ten-minute minimum for exercise to be counted) (Second Edition Physical Activity Guidelines for Americans, 2018).

Despite the benefits of physical exercise on cognitive health and physical health more generally, Perusse et al. (1989) found that only about 20% of Americans were meeting recommendations suggested to achieve cardiovascular benefits. The CDC suggests that the percentage of Americans who meet both the guidelines for strength, which was added by the HHS in the 2018 second edition, and aerobic activity combined is 23.2%, less than a fourth of the United States population. Comparing findings from Perusse (1989) to the current CDC estimates highlights that physical activity behaviors of Americans have not increased substantially over the last thirty years. Older adults are less likely to meet physical activity guidelines relative to younger population cohorts (Office of Disease Prevention and Health Promotion, 2021).

Spousal Effects on Individual Health Outcomes

While this study is not examining spousal dyads per se, it is important to understand the role a spouse may play in their partner’s behavior change. Few studies have examined the concordance of physical activity habits between spouses. It is possible for the health problems of one spouse to “spillover” to their partner (Litzelman et al., 2016). Some studies have called for the use of assessments that measure outcomes of the participants’ spouses to understand possible spillover effects (Cobb et al., 2016). Given the potential for spillover effects, it is also possible that positive health outcomes may have a beneficial effect on partner health. For example, multiple studies have found that weight loss treatments may have a positive weight loss influence even among spouses who did not partake in the same treatment as their partner (Gorin et al., 2008; Schierberl Scherr et al., 2013). Spouses also have a higher likelihood of complying with physical activity guidelines if their partner also met them (Cobb et al., 2016). Furthermore, emotional distress and cognitive impairment in one spouse has been found to affect these outcomes in the other spouse (Lee et al., 2012). However, these studies have not frequently examined spousal health behaviors and their partner's cognitive functioning.

Physical activity interventions involving both partners may increase both partner's exercise behaviors, given that health behavior changes often co-occur within couples (Richards et al., 2017). One study found that spouses who attended an exercise program together were significantly more likely to adhere to the program than unmarried singles; additionally, half of the participants who left the program cited a lack of spousal support or family responsibility as their reason (Wallace et al., 1995). Analyzing exercise behaviors across closely connected members within a social network, such as a spousal pair, will be beneficial in creating interventions that target barriers to adoption and utilize social support.

Given that over half of the United States population over 18 is married (Fry & Parker, 2021), it is important to consider how spousal relationships may play a role in health behaviors. Those who are married tend to be in better health and have longer lives than those who are not married (Umberson et al., 2018). The benefits of marriage include a healthier lifestyle, better health overall, healthier diet, not smoking, and a lower mortality rate than single or divorced individuals (Ayotte et al., 2013). Some longitudinal studies have linked better physical activity habits of one spouse with higher physical activity levels in their partner (Richards et al., 2017). Furthermore, associations have been discovered between self-efficacy, perceived social support, and physical activity of husbands and wives (Ayotte, 2007); spouses serve as an external motivator to behavior change (Mcphee et al., 2016). Interdependence often forms in close relationships, like that of spouses, and may result in some shared behaviors (Richards et al., 2017). Physical activity outcomes may be positively *or* negatively affected within close relationships (Anderson-Bill et al., 2011). Thus, healthy lifestyle habits within one partner may have the potential to positively influence healthy changes in their spouse as well (Cobb et al., 2016).

Oftentimes, physical activity is observed and measured solely based on the individual. However, life changes and challenges are often experienced as a couple and therefore affect both spouses. Spouses may influence one another's behavior and lifestyle choices through demands, requests, or rewards; within these social demand's, women tend to have more influence over their spouse's health behaviors than men do (Umberson et al., 2018).

There are gender differences in a heterosexual spousal dyad that may play a role in the health behaviors of spouses. Women tend to fulfill the caregiver role more often and have closer social ties to friends and family (Wong & Hsieh, 2016). Women tend to have more influence than men in the health behaviors and lifestyle habits of their spouses (Umberson et al., 2018). Regardless of the gender differences, research suggests that spousal support is a key factor in a healthy lifestyle (Anderson-Bill et al., 2011). Extant literature has considered the influence of a spouse on their partner's involvement in healthy lifestyle behaviors, like physical activity; less work has been done to understand if the behavior of one spouse can positively influence the outcomes, specifically cognition, of the other partner.

Aging and Cognition

Some level of neural and cognitive decline is a normative part of the aging process (Klimova et al., 2017); these changes may include a decline in the number of dopaminergic receptors, shrinking of brain structures, less density of white matter, the destruction of neurofibrillary tangles and plaques, memory deficiencies, problems with executive processing, and declines in processing speed (Reuter-Lorenz & Park, 2014; Park & Reuter-Lorenz, 2009). Changes in brain volume often occur in the hippocampus and prefrontal regions in older adults; some researchers suggest this may account for changes in memory and executive function often associated with aging (Bherer, 2015).

These declines in brain health cognition are associated with normal aging, but participation in physical activity, even among those who are frailer, has been shown to have ample cognitive and physical benefits (McPhee et al., 2016). While cognitive decline may be a typical part of the aging process, it may be possible to change the trajectory of this decline through physical activity interventions (Nilsson et al., 2022). The percentage of older adults in the population is continuing to grow in most developed countries; maintaining cognitive function will help these individuals live independently for longer and maintain communication and social ties (Klimova et al., 2017; Murman, 2015).

Cognition tends to decline as one gets older; these declines may inhibit the processing speed to make decisions, executive cognitive functioning, and working memory (Murman, 2015). Less change is observed in areas of cognition involving vocabulary, general knowledge, and unconscious learning (Mather, 2010). Learning new skills and cognitive training can be beneficial in maintaining cognition (Klimova et al., 2017). Some cognitive skills are more age sensitive than others like working memory, processes related to executive control, and episodic memory (Bherer, 2015).

Physical Activity and Cognition

Healthy lifestyle factors, including physical activity, avoiding exposure to neurotoxins, and cognitive stimulation decrease rates of cognitive decline and even delay the onset of symptoms related to age-associated diseases (Murman, 2015). A substantial body of research suggests that physical activity has neuroprotective effects on the brain in later life (Kramer et al., 2006; Phillips et al., 2015). Physical activity is a relatively accessible, low-cost preventative measure that can be used to lessen cognitive decline and the onset of neurodegenerative diseases, especially in older adults (Kämpfen & Maurer, 2016). Preventing cognitive decline may also help increase autonomy and independent living in older age (Altieri et al., 2021); some health benefits likely linked to cognitive functioning from physical activity include better functional brain connectivity, higher-level memory and executive function, and more efficient brain activity (Erickson et al., 2015).

One study reported significant differences in aging between groups who completed physical activity versus those who did not; the group that did not participate in physical activity experienced accelerated biological aging (Andrieieva et al., 2019). Physical activity delays the onset of cognitive declines linked to dementia as well as normal aging and can be an effective intervention even if cognitive decline has started (Hertzog et al., 2008).

Negative cognitive outcomes are often associated with sedentary behaviors which tend to increase among older adults (Lee et al., 2017). Retirement is a transitional life event for older adults that contributes to this decreased level of movement and physical activity; leaving work likely impacts the amount of movement and cognitive stimulation that older adults are getting in their daily lives (Barnett et al., 2012). “Lack of time” is often cited as a major barrier to physical activity, but retirees tend to have more time available to participate in exercise; older adults can benefit from physical activity to promote balance and prevent falls (Kämpfen & Maurer, 2016). Reduced muscle mass, declines in cardiac function, and arterial stiffening may also be reasons for lower levels of physical activity (Nilsson et al., 2022).

Physical activity may decline in older age because older adults may transition to a nursing home or retirement home. In a review, it was reported that over 30% of residents in a nursing home have reported declines in physical activity following their entry into the assisted living environment (Volkers & Scherder, 2011). Implementing a physical activity program in a nursing or retirement home would be beneficial to the executive functioning of older adults; executive functioning is used in activities requiring organization, inhibition, response selection, and mental flexibility which are all beneficial in maintaining autonomy during aging (Hillman et al., 2013). Physical activity programs integrated into spaces for older adults may lessen frailty, improve cognition, and help to boost emotional and social networking skills (Tarazona-Santabalbina et al., 2016).

Social Interaction and Cognition

Loneliness and decreased social interaction can have a negative impact on cognitive outcomes among older adults (Volkers & Scherder, 2011). A significant proportion (24%) of older adults who live in community settings, like nursing homes or retirement homes, report feeling socially isolated (Cudjoe et al., 2020). Older adults who are lonely and sedentary tend to have lower cognitive functioning and experience a faster cognitive decline than their peers who are more socially and physically active (Evans et al., 2019). Isolation can even cause memory deficits, attention problems, difficulty with inhibitory control, slower information processing, and difficulty learning (Volkers & Scherder, 2011). Discovering methods to decrease social isolation and increase social interaction may be beneficial in maintaining cognition across the lifespan.

Cognitive performance has been found to be higher across the age spectrum among those who are more socially engaged (Ybarra et al., 2008). Social interaction itself requires cognitive resources and thus may serve as a benefit to general cognitive functioning (Ybarra et al., 2008).

A lack of social stimulation and impoverished environments may exacerbate cognitive decline; this may be more likely in an institutionalized setting where normal daily social interactions are lessened (Volkers & Scherder, 2011). Larger social network sizes are closely associated with cognitive functioning and are hypothesized to mitigate declines related to aging in cognitive functioning (Katz et al., 2020). Some longitudinal studies have linked social isolation to risk of mortality and development of chronic illnesses (Schrempft et al., 2019).

Social support and loneliness are linked to the well-being of older adults (Chen & Feely, 2014), yet social networks and friendships tend to decline in older age (Kalmijn, 2012). A spouse who has a more active social life may positively influence their partner's cognitive functioning given that this may offer more opportunities for cognitive engagement, however, there is little research exploring the effect of spousal social activity on the cognition of their partner (Wong & Hsieh, 2019).Regardless, it is clear that cognition and social interactions are closely linked and likely bidirectional; cognitive problems in one spouse tend to lead to less social interactions among both partners (Wong & Hsieh, 2019). Further longitudinal work is needed to understand how changes in social interactions over the life course within married couples affect health outcomes.

Social Interaction and Physical Activity

Participation in physical activity programs that involve a social component promotes adherence to health behaviors (Osuka et al., 2017). There is a growing body of intervention literature to examine how adherence to physical activity can be increased in social settings. Spouses may motivate their partner to return to a physical activity program or support living a healthy lifestyle (Osuka et al., 2017). Fitness programs with a social component are more successful at creating adherence given that the social component boosts the confidence of an individual to make lifestyle changes (Estabrooks et al., 2012). Physical activity programs that are group-based are more effective for some populations than others, including older adults and individuals at a higher risk for chronic disease; the group environment promotes physical activity, especially when individuals are working together towards a common goal (Harden et al., 2015). While the research suggests that spouses engaging in physical activity together promotes adherence (Osuka et al., 2017), there is less literature about spouses who may both participate in exercise but not necessarily at the same time or in the same environment.

Social isolation contributes to decline in physical activity across all age groups; consequently, individuals who feel socially isolated are prone to more sedentary time (Schrempft et al., 2019). Social engagement and physical activity are viable lifestyle factors for maintaining cognitive functioning, health, and quality of life during aging (Dause & Kirby, 2018). Combining social interaction, which is beneficial for preserving cognitive functioning, with physical activity, which is also beneficial for cognitive health, may offer an additive effect on cognition.

Aerobic Activity in Older Adults

The present investigation utilizes The Health and Retirement Study (discussed in more detail within the methods section in Chapter 2). The Health and Retirement Study includes information regarding light, moderate, and vigorous aerobic activity. There is not a measure of strength training, potentially because this study began over a decade before the Physical Activity Guidelines First Edition was published. This study will examine the impacts of aerobic activity, rather than strength training, on cognitive outcomes. It is possible that the individuals included in the analysis are still participating in strength training, but there is not a separate measure for this behavior. Aerobic training may be a valuable activity in promoting cognitive health among older adults, as it increases brain volume and greatly benefits cardiovascular health (Bouaziz et al., 2017)

Regular participation in aerobic activity has been associated with cognitive benefits (Gonzales et al., 2013), less cognitive decline (Legdeur et al., 2018), maintaining executive functioning (Netz, 2019), and providing cardiovascular and musculoskeletal benefits (Lee et al., 2017), which in turn may improve independence and have an additional indirect positive effect on cognition. Aerobic fitness serves as a biological basis for the maintenance of cognitive function and the central nervous system (Colcombe et al., 2006). One additional positive feature is that aerobic activity may be more accessible for all populations because no equipment is needed compared to strength training.

A systematic review assessing the benefits of aerobic training programs, specifically in older adults, found percentage increases on measures of general and specific cognitive functioning ranging from 4.0% to 34.0% and increases one's measures of quality of life ranging from 17.1% to 178.0% (Bouaziz et al., 2017). Evidence suggests that aerobic activity may reduce hypertension and increase glucose metabolism control, functional outcomes, cardiorespiratory fitness, cognition, and quality of life in older adults (Bouaziz et al., 2017).

Decline in cognitive functioning can be a normal part of the aging process, but interventions may slow this decline (Klimova et al., 2017). Given that the aging population continues to grow, there is an urgent need for preventative measures to slow cognitive decline; fortunately, lifestyle factors such as exercise and cognitively engaging environments have proven to be beneficial in slowing cognitive decline (Dause & Kirby, 2019). Exercise, as well as social interaction (Ybarra et al., 2008), helps to maintain individual cognition (De la Rosa et al., 2020), but little work exists to understand if being in a relationship where one’s partner also exercises is beneficial or provides an additive effect on their partner’s health outcomes.

Other Demographic Factors Linked to Cognition in Older Adults

The covariates included in this study were gender, years of education, race, and age. These covariates were included because they impact cognitive outcomes (Ikegami et al., 2019; Kremen et al., 2019). Gender differences in cognition begin in early school years and continue throughout the lifecourse (Parsons et al., 2005). Evidence suggests that those who are more highly educated perform better on measures of cognition throughout the lifespan relative to their counterparts who have lower educational attainment (Lenehan et al., 2015). There are racial differences in cognition across different groups with Hispanic and non-Hispanic Black individuals having lower cognitive outcomes than non-Hispanic white individuals across all age groups (Díaz-Venegas et al., 2016).

Research Question and Hypotheses

Research Question: Does an individual as well as their spouse’s exercise status impact cognitive function within the individual during aging, and does the individual and their spouse’s combined exercise status impact cognition more than the effect of an individual's exercise status alone?

Hypothesis 1: An individual who exercises, and whose spouse also exercises, will have better cognitive function relative to: 1) an individual whose spouse does not exercise, 2) an individual who does not exercise, and 3) an individual who does not exercise and whose spouse does not exercise.

Hypothesis 2: An individual who exercises, and whose spouse also exercises, will have less decline in cognitive functioning *over time* relative to: 1) an individual whose spouse does not exercise, 2) an individual who does not exercise, and 3) an individual who does not exercise and whose spouse does not exercise.

Conclusion

Physical inactivity in individuals has a negative effect on chronic conditions, cognition, mental health, and physical health (Erickson et al., 2019; Richards et al., 2017). Some decline in cognitive functioning is expected in older adults as they may be less active, experience less cognitive stimulation, and have general declines in brain structures (Klimova et al., 2017). Modifying as many risk factors as possible, like physical activity and lifestyle, may be helpful in mitigating cognitive decline and maintaining healthy life years (Klimova et al., 2017). Spouses play an important role in behavior change and health problems from one spouse may negatively affect the other spouse (Litzelman et al., 2016). Therefore, physical activity should serve as an intervention and incorporate both spouses when possible.

Chapter 2: Manuscript

Abstract

Objectives: Physical activity may lead to both health and cognitive benefits during aging. The present study had two primary objectives: (a) assess whether there is a significant difference in cognition among older adult respondents in a relationship where both spouses, one spouse, or neither spouse engage in aerobic activity that meets the Physical Activity Guidelines for Americans (2008), and (b) examine whether there is an interaction between the combined partner exercise status and change in cognitive function over time.

Methods: To conceptualize physical activity behavior between spousal pairs, a couple exercise status score was created using data drawn from The Health and Retirement Study. This score combines respondent and spousal exercise behaviors into a summary measure that includes whether only the respondent, only the spouse, neither partner, or both partners participate in physical activity. To understand the effects of the interaction between time and couple exercise score on cognitive function, a linear mixed model, or linear mixed-effects model, was used. Basic demographic variables were included as covariates in all analyses.

Results: Before adding the interaction term, four models each found a significant main effect of the couple exercise score on four separate cognitive outcome measures. The interaction between time and couple exercise score was added in a secondary model for each cognitive outcome measure and was significant across all models.

Discussion: Respondents who were members of couples where neither partner participated in aerobic physical activity had both the lowest cognitive baseline scores as

well as the steepest declines in cognitive function over time. Conversely, the highest baseline cognitive outcomes and least decline over time was observed in couples where both partners participated in aerobic physical activity. It is possible that a spouse's exercise status has an additive effect on the cognitive outcomes of their partner; this may have significant implications for lifestyle interventions designed to improve cognitive functioning in older adults.

Introduction

Physical activity remains important throughout the life course as a preventative measure against declining health (Mcphee et al., 2016). Continued physical activity during late adulthood helps to maintain independence, reduce disability, and improve quality of life (Sun et al., 2013). Using physical activity as an intervention for cognitive decline may help to extend healthy years of living; additionally, it is possible that the benefits of physical activity affect close others in one's social network, such as spouses. The family unit and an individual's social network may have an influence on health behaviors and have been identified as a potential means of intervention. This study seeks to understand the importance of aerobic exercise habits of both partners on the cognitive functioning of the respondent.

Literature Review

Physical Activity Benefits

Physical inactivity has been associated with elevated risks of chronic conditions and mortality (Richards et al., 2017). Those who participate in regular physical activity achieve improved functional ability in activities of daily living, delayed age-related changes, and extended longevity (Andrieieva et al., 2019). Additionally, some observational studies have provided strong evidence that higher levels of physical activity are associated with lowering rates of dementia (including Alzheimer's Disease) and cognitive decline (Erickson et al., 2019). This is increasingly important as one in three seniors in the United States dies with Alzheimer's or dementia; both also have significant public health implications and cost the nation $355 billion in 2020 (Alzheimer's Association, 2021).

Aerobic Physical Activity

Aerobic exercise is beneficial in maintaining executive functioning (Netz, 2019), providing cardiovascular and musculoskeletal benefits (Lee et al., 2017), and reducing brain atrophy (Jonasson et al., 2017). Aerobic exercise may also be more widely accessible because no equipment is needed in comparison to strength training. A systematic review considering the benefits of aerobic training, specifically in older adults, found consistent increases in cognitive functioning and quality of life (Bouaziz et al., 2017). Aerobic activity may also improve cardiovascular conditioning, decrease the risk of heart disease, lower blood pressure, better control blood sugar, increase brain volume, and improve lung function (Cleveland Clinic, 2019). Additionally, aerobic activity that boosts cardiovascular fitness has been linked to the protection of brain tissue in older adults (Colcombe et al., 2006).

Aging and Cognition

Several cognitive deficits are associated with aging; these include memory deficiencies, problems with executive functioning, and declines in processing speed (Reuter-Lorenz & Park, 2014). Executive functioning is a process necessary to planning, selective attention, working memory, mental flexibility, sustained attention, and resistance to interference (Guiney & Machado, 2013). Work comparing older brains to younger brains illustrated that the older brain was working harder than the younger brain and engaging in more compensatory processing to perform certain tasks (Park & Reuter-Lorenz, 2009).

Cognitive abilities are affected differently during aging; crystallized abilities are the result of cognitive processing done in the past consisting of cumulative skills and memories; these may include vocabulary, historical knowledge, reading comprehension, and math skills (Murman, 2015). Alternatively, fluid cognitive abilities are those that utilize cognitive processing in current time and the subject must be able to process new information (Murman, 2015). Crystallized abilities plateau from about 60 to 80 whereas fluid abilities tend to experience steady decline across the lifecourse (Salthouse, 2012).

Better aerobic endurance has been linked to improved processing speed, working memory, and inhibition in older adults (Zettel-Watson et al., 2017). Preserving cognition in older adults allows for functional independence and autonomy (Murman, 2015). Cognitive functioning is of such importance across the lifespan because it contributes to other life outcomes like decision making, living independently, and communication (Salthouse, 2012).

Spouses Effects on Individual Health Outcomes

Health problems are often experienced as a family unit (Wong & Hsieh, 2019); spouses may motivate their partner to return to physical activity or support a healthy lifestyle (Osuka et al., 2017). Those who are married tend to be in better health and have longer lives than those who are not (Umberson et al., 2018). While research suggests that spouses engaging in physical activity together promotes adherence, there is less literature available regarding spouses who may both participate in physical activity, but not at the same time or in the same setting. Because a majority of the United States population is married, many individuals are experiencing health challenges or changes as a couple (Fry & Parker, 2021); interdependence often forms in close relationships, like that of spouses, resulting in shared behaviors or risk factors (Richards et al., 2017).

Physical Activity and Cognition

Healthy lifestyle factors, including physical activity, avoiding exposure to neurotoxins, and cognitive stimulation, have been seen to decrease rates of cognitive decline and even delay the onset of symptoms related to age-associated diseases (Murman, 2015). Maintaining cognitive function may help increase autonomy in older age (Altieri et al., 2021); some health benefits likely linked to cognitive functioning from physical activity include better functional brain connectivity, higher-level memory and executive function, and more efficient brain activity (Erickson et al., 2015).

Physical activity has shown to delay the onset of cognitive decline linked to dementia and normal aging; physical activity may even improve cognition over the lifespan of older adults (Hertzog et al., 2008; Tari et al., 2019); yet physical activity may decline in older age because older adults may transition to a nursing home or retirement home. In a review, it was reported that over 30% of residents in a nursing home have reported declines in physical activity since transitioning to this setting (Volkers & Scherder, 2011). Implementing physical activity programs into settings where they may not be available for older adults may lessen frailty, improve cognition, and help to boost emotional and social networking skills (Tarazona-Santabalbina et al., 2016).

While some declines with aging are normal, physical activity participation has shown to benefit cognitive and physical outcomes (McPhee et al., 2016). Physical activity is a relatively accessible, low-cost intervention that can be implemented to lessen cognitive decline and the onset of neurodegenerative diseases and maintain health in older adults (Kämpfen & Maurer, 2016).

Theoretical Framework

The Scaffolding Theory of Aging and Cognition (STAC) provides the guiding theoretical framework for this research. STAC provides a powerful explanatory model for how aging leads to changes in the level of cognitive functioning including functional and structural issues in the brain while integrating scaffolding and cognitive enhancements that can buff the effects of age-related changes. The model was slightly modified to integrate into the current study (see Figure 1).

The model illustrates how aging is associated with neural challenges like volume loss, white matter changes, cortical thinning, and dopamine depletion (Reuter-Lorenz & Park, 2014). These neural challenges may directly influence cognitive functioning but may also be mediated by compensatory scaffolding. Compensatory scaffolding describes the brain's ability to counteract the negative effects of functional and neural decline through compensation utilizing other parts of the brain; this may include frontal recruitment, neurogenesis, distributed processing, and bilaterality (Reuter-Lorenz & Park, 2014). Frontal recruitment describes higher level cognitive executive-processes performed by the frontal lobes (Nocera et al., 2017); greater frontal recruitment is often associated with better cognitive performance. Neurogenesis describes the "proliferation, survival, and differentiation of neural precursor cells into mature neurons or glia that are integrated into the rest of the brain structure"; this provides the brain with the ability to adapt and change when necessary (Goh & Park, 2009, pg. 6). In older adults, the process of neurogenesis declines and synaptic plasticity is used to adapt and function (Boldrini et al., 2018; Villeda & Wyss-Coray, 2013). Distributed processing refers to diversified processing across more neural areas (Goh & Park, 2009), and is often associated with better cognitive performance. Bilaterality is the recruitment of both the left and right brain of older adults on tasks where younger counterparts have lateralized activity; bilateral recruitment is often associated with improved cognitive performance in older adults (Reuter-Lorenz & Park, 2014).

Scaffolding enhancement in the modified model includes both social interaction and aerobic exercise. Scaffolding is a process that protects cognitive functioning of the brain and attempts to prevent some of the cognitive decline that is often associated with normal aging (Goh & Park, 2009; Park & Reuter-Lorenz, 2009); this occurs when a challenge is presented and helps to optimize performance (Park & Reuter-Lorenz, 2009). Social interaction and aerobic exercise are linked to components of scaffolding enhancement; social support and physical activity impact these processes as well as contribute positively to cognitive abilities (Amieva et al., 2010; Bherer, 2015).

Cognitive function in aging is associated with normative decline in delayed recall, executive functioning, and global cognition (Chen et al., 2018). These declines affect a range of abilities including working memory, inhibition, cognitive control, and speed of processing (Park & Reuter-Lorenz, 2009). Changes in brain structure and functioning influence changes in cognition among older adults (Reuter-Lorenz & Park, 2014).

Methods

Data Source

The Health and Retirement Study (HRS), started in 1992, is drawn from a nationally representative sample of older adults (age 51 and older) in the United States. Respondents in the HRS are surveyed every two years; the HRS provides rich demographic, cognitive, and health data across a longitudinal sample of approximately 20,000 participants. The HRS is conducted by the University of Michigan and sponsored by the National Institute on Aging (NIA) and the U.S. Social Security Administration. This study investigated cognitive outcomes of married respondents based on their exercise habits as well as the exercise habits of their spouse. The dataset used in this project was the RAND HRS Longitudinal File that was released in 2018; at the time of analysis this is the most recent longitudinal aggregate data file released by the Health and Retirement Study and contains data from 1992-2016.

Study Sample

Data from 3,189 married respondents in the Health and Retirement Study for whom each covariate was available were analyzed using a linear mixed model approach. The HRS does not include information about individuals who cohabit together, but are unmarried or unpartnered. This study included seven waves (time points) of the HRS from 2004 to 2016. The sample was limited to those between the ages of 65 and 95 which includes young-old, middle-old, and oldest-old adults (M= 78.3, SD=6.99). The sample included 1,594 (49.98%) males and 1,595 (50.02%) females. Only individuals identifying as White/Caucasian or Black/African American on a racial self-report question were included in this study; given that the remaining self-report category, “other”, includes all other categories and thus substantial potential heterogeneity, those participants were not included. The sample consisted of 2,909 (91.2%) individuals who self-reported that they are White/Caucasian and 280 (8.8%) who self-reported that they are Black/African American. Ethnicity (Hispanic or not Hispanic) was not examined in this analysis. Individuals reported their years of education, ranging from 0 to 17+ with an average of 13.63 (SD= 2.66). Only those who had data for both their personal exercise behavior and the exercise behavior of their spouse were included. A majority (57%) of participants had all cognitive data available for all seven waves (see Table 1 for demographic information and Table 2 for correlations between variables of interest).

Table 1

Descriptive Information for Demographic Variables

Age	**Range**	**Mean**	**SD**
	65-95	78.31	6.99
Race	**Frequency**	**Percent**	
White/ Caucasian	2909	91.20%	
Black/ African American	280	8.80%	
Years of Education	**Range**	**Mean**	**SD**
	0-17	13.63	2.66
Gender	**Frequency**	**Percent**	
Female	1594	50.02%	
Male	1595	49.98%	
Couple Exercise Status Score	**Frequency**	**Percent**	
0-Neither spouse	395	12.40%	
1- Spouse only	514	16.10%	
2-Participant only	598	18.80%	
3-Both partners	1598	50.10%	

Table 2

Correlation among Variables of Interest

Correlation Table	1.	2.	3.	4.	5.	6.	7.	8.
1. Age	-							
2. Race	-.04**	-						
3. Gender	-.17**	-.03**	-					
4. Couple Exercise Score[a]	-.05**	-.07**	-.03**	-				
5. Total Cognition Index	-.18**	-.18**	.14**	.13**	-			
6. Mental Status Index	-.07**	-.21**	-.05**	.11**	.68**	-		
7. Delayed Word Recall Test	-.22**	-.11**	.21**	.10**	.85**	.28**	-	
8. Serial 7 Test	-.05**	-.20**	-.08**	.10**	.58**	.89**	.22**	-

Note. ***p*<.01

[a] Couple Exercise Score: 0= neither partner participates in aerobic activity, 1= just the spouse participates in aerobic activity, 2= just the respondent participates in aerobic activity, 3= both partners participate in aerobic activity.

Cognition Measures

Serial 7 test is used to assess working memory (Wallace et al., 2005) and scores were recorded based on the ability of the respondent to subtract 7 from 100 and continue consecutively backwards counting by seven (Kaufmann et al., 2021). Five trials of subtraction are completed, and the respondent must remember where they previously left off without assistance from the interviewer. The test is scored by taking the total number of correct subtractions out of the five repetitions (0-5).

The Delayed Word Recall test is an additional cognition score used to assess memory (Gonzáles et al., 2008). Respondents are read a list of 10 words and then asked to repeat the words after completing other questions in the interview (Gonzáles et al., 2008). The task is scored based on how many words are recalled correctly, creating a score from 0 to 10.

The Total Cognition Index is a global cognition score comprising three items: immediate and delayed word recall from a list of ten words (0-20 points), backwards counting (0-2 points), and serial 7 subtraction (0-5 points) (McEvoy et al., 2017). The outcome is a total score ranging from 0 to 27. Higher scores represent better cognitive functioning in domains including attention, working memory, and episodic memory (McEvoy et al., 2017).

The Mental Status Index is a cumulative score used as an additional global cognitive outcome variable. The mental status score comprises a combination of other tasks asked throughout the interview with the participant. The tasks involved in the mental status score include backward counting, orientation to time, serial 7, and object naming (Nelson et al., 2013). This results in a score ranging from 0-15 tailored toward assessing knowledge, orientation, and language.

Aerobic Exercise Variable

The HRS does not contain the variables to operationalize exercise to exactly match the Physical Activity Guidelines for Americans (2008; PAG). The question asked in the survey is “How often do you participate in vigorous physical activity or sports- such as heavy housework, aerobics, running, swimming, or bicycling?”. Answer options include “everyday”, “>1 per week”, “1 per week”, 1-3 times per month”, and “never”. All of these are aerobic exercises, defined by the Cleveland Clinic (2019) as exercises that provide benefits to cardiovascular conditioning.

The Physical Activity Guidelines for Americans (2008) recommend that individuals participate in either 75 minutes of vigorous aerobic activity or 150 minutes of moderate aerobic activity combined with two days of strength training per week. Based on examples from previous research using the HRS, a binary variable was created to measure engagement in aerobic activity. Specifically, Kämpfen and Maurer's (2016) work guided the creation of a variable to determine whether an individual was participating in aerobic activity at a level that roughly met aerobic guidelines (See table 3).

Table 3

Combined Moderate and Vigorous Aerobic Activity Necessary to Meet Minimum Levels Established by Kämpfen and Maurer

		Frequency of Vigorous Aerobic Activity				
		Everyday	More than once a week	Once a week	1-3 times per month	Never
Frequency of Moderate Aerobic Activity	Everyday	*	*	*	*	*
	More than once a week	*	*	*		
	Once a week	*	*			
	1-3 times per month	*	*			
	Never	*				

Adapted from "Time to Burn (Calories)? The Impact of Retirement on Physical Activity Among Mature Americans" by F. Kämpfen & J. Maurer, 2016, *Journal of Health Economics,* (http://dx.doi.org/10.1016/j.jhealeco.2015.12.001).

Note. * indicates that the individual meets the Physical Activity Guidelines for Americans (2008) when the combined among of moderate and vigorous aerobic activity occur. For example, an individual who participates in moderate aerobic activity never, but vigorous aerobic activity everyday meets the minimum suggested levels established by Kämpfen and Maurer (and influenced by the PAG).

Once a score indicating whether the guidelines were met (1= yes, 0=no) was created, a combined score was created based on the physical activity of both an individual and their spouse. This score ranged from 0-3 where 0= neither an individual nor their spouse meeting the minimum suggested level, 1= the spouse but not the respondent meeting PAG, 2= the respondent but not the spouse meeting PAG, and 3= both the respondent and spouse meeting PAG.

Covariates Included

Age, gender, years of education, and race were the covariates included in the study. These variables have been noted to effect physical activity outcomes (Sun et al., 2013) as well as cognitive functioning during aging (Lee et al., 2022); age tends to have a negative effect on cognition, (Murman, 2015). Gender differences are present in cognitive outcomes that may begin in early school and continue throughout the lifecourse (Parsons et al., 2005). Additionally, those who are more highly educated may perform better on cognitive measures throughout the lifespan relative to those who have lower educational attainment (Lenehan et al., 2015). Finally, studies often identify racial differences in cognition. For example, Hispanic and non-Hispanic Black individuals demonstrated lower global cognition scores relative to non-Hispanic white individuals across all age groups in one recent study; however, these differences are often linked to systemic disparities in other key factors such as education and socio-economic status (Díaz-Venegas et al., 2016).

Exclusion Criteria

Two exclusion criteria were used to create a sample that was generally representative of a cognitively intact sample of older adults. Older adults who could not perform activities of daily living (ADLs) at any wave of data collection were excluded because it is assumed that they would be less likely to partake in physical activity. Independent living relies on the ability to complete ADLs; unfortunately, the addition of physical activity when difficulties with ADLs are already present has not shown to result in a significant reduction of a disability (Liu et al., 2014).

Those who have ever been diagnosed with Alzheimer's or dementia were also excluded from the study. While physical activity can be used as a therapeutic treatment for ADRD, there is currently no cure for this disease (De la Rosa et al., 2020). Additionally, while physical activity may be beneficial in reducing ADRD related symptoms, there is less of an effect after the onset of neuronal degeneration (Phillips et al., 2015). Given the pervasive effects of ADRD more generally on cognitive processes, including episodic memory and executive function, individuals with an existing diagnosis of either of these conditions were excluded from our analyses.

Statistical Methods

Linear mixed model analyses were used for this study because they allow for the representation of changes over time, consideration of both group and individual differences, and the inclusion of relevant covariates (Fieuws et al., 2007; Krueger & Tian, 2004). Furthermore, this method of analysis is especially beneficial due to its ability to handle missing data better than other approaches (Krueger & Tian, 2004). Missing data can be common in longitudinal datasets due to the extended time over which this data is collected (Krueger & Tian, 2004). In the HRS, some individuals may pass away or miss a wave of data collection. To handle the missing data, full-information maximum likelihood estimation is used based on raw data likelihood (Liu et al., 2012).

Each model included one dependent cognitive variable (Total Cognition Index, Mental Status Index Serial 7 Test, or Delayed Word Recall Test). Covariates included gender, race, age, years of education, couple exercise status score, and time. The intercepts were included in both the fixed and random effects. Two models were run for each outcome variable, one with all predictor variables excluding the interaction, and another with the interaction between couple exercise score and time added. For the purposes of brevity, only the interaction and couple exercise score outcomes were included for the second model.

Results

Total Cognition Index

Model 1 includes cognition total index as the outcome variable and gender, race, age, years of education, the couple exercise score, and time as covariates. Each of the included demographic variables (race, gender, age, years of education) are significant predictors of the total cognition index, all at $p < .001$. Time is also a significant predictor of total cognition at $p < .001$, as is couple exercise score, again at $p < .001$. Model 2 adds the interaction between couple exercise score and time, which is significant at $p < .001$, however, the main effect of couple exercise score is marginal after the addition of the interaction. All of the other variables remain significant in the second model (see Table 4 for Total Cognition Index results and Figure 2 for trajectories of cognitive performance by exercise condition).

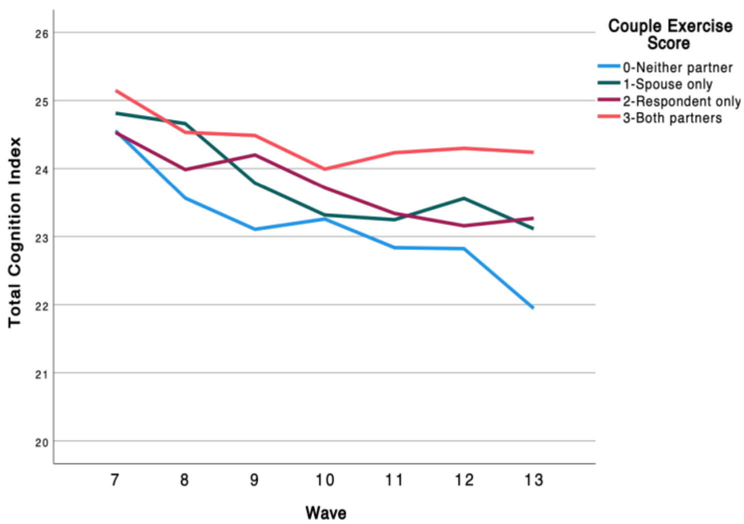
Table 4

Total Cognition Index Table of Fixed Effects

	Estimate	SE	df	t-ratio	sig
Model 1					
Intercept	21.38	0.73	3147	29.36	<.001
Race	2.04	0.18	2979	11.05	<.001
Gender	1.16	0.10	2883	11.25	<.001
Age	-0.08	0.01	3098	-9.91	<.001
Years of Education	0.56	0.02	2868	28.80	<.001
Time	-0.29	0.01	6163	-23.08	<.001
Couple Exercise Score	0.12	0.03	12326	4.16	<.001
Model 2: Interaction					
Couple Exercise Score	-0.12	0.06	5440	-1.05	0.052
Couple Exercise Score X Time	0.05	0.01	6672	4.36	<.001

Figure 2

Trajectories of Total Cognition Index Performance by Exercise Condition



Note. The figure above uses descriptive data to observe change over time in total cognition index performance based on aerobic physical activity status.

Mental Status Index

Model 1 includes mental status index as the outcome variable and gender, race, age, years of education, the couple exercise score, and time as covariates. Each of the included demographic variables (race, age, gender, years of education) are significant predictors of the mental status index, at $p < .05$. Time is also a significant predictor of mental status index at $p < .001$, as is couple exercise score at $p < .05$. After the addition of the interaction, the main effect of couple exercise score remains significant at $p < .05$. All of the other variables remain significant in the second model (see Table 5 for Mental Status Index results and Figure 3 for trajectories of mental status by exercise condition).

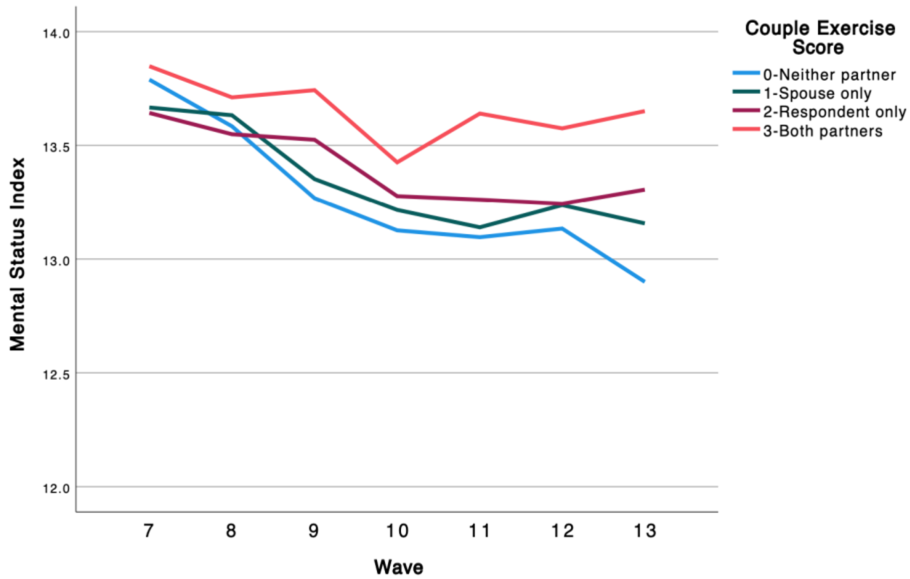
Table 5

Mental Status Index Table of Fixed Effects

	Estimate	SE	df	t-ratio	sig
Model 1					
Intercept	10.51	0.35	3110	30.40	<.001
Race	1.14	0.09	2999	12.92	<.001
Gender	-0.12	0.05	2910	-2.53	0.012
Age	-0.01	0.00	3064	-3.00	0.003
Years of Education	0.24	0.01	2897	25.48	<.001
Time	-0.09	0.01	6110	-14.99	<.001
Couple Exercise Score	0.03	0.01	12212	2.54	0.011
Model 2: Interaction					
Couple Exercise Score	-0.07	0.03	5289	-2.40	0.016
Couple Exercise Score X Time	0.02	0.01	6594	4.06	<.001

Figure 3

Trajectories of Mental Status Index Performance by Exercise Status



Note. The figure above uses descriptive data to observe change over time in mental status index performance based on aerobic physical activity status.

Serial 7 Test

Model 1 includes the serial 7 test as the outcome variable and gender, race, age, years of education, the couple exercise score, and time as covariates. Each of the included demographic variables are significant predictors of the serial 7 test, all at $p < .001$. Time is also a significant predictor of serial 7 test at $p < .001$, as is couple exercise score, again at $p < .001$. Model 2 adds the interaction between couple exercise score and time, which is significant at $p < .05$. The main effect of couple exercise score is no longer significant after the addition of the interaction. All of the other variables remain significant in the second model (see Table 6 for Serial 7 Test results and Figure 4 for trajectories of serial 7 test performance by exercise condition).

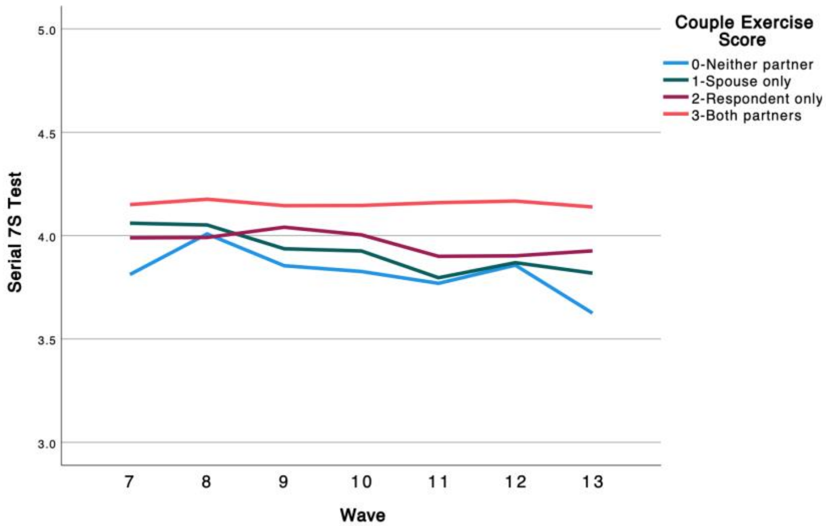
Table 6

Serial 7 Test Table of Fixed Effects

	Estimate	SE	df	t-ratio	sig
Model 1					
Intercept	1.94	0.23	3141	8.37	<.001
Race	0.88	0.06	3138	14.45	<.001
Gender	-0.20	0.03	3103	-5.82	<.001
Age	-0.01	0.00	3097	-3.51	<.001
Years of Education	0.15	0.01	3136	23.52	<.001
Time	-0.02	0.00	10313	-7.00	<.001
Couple Exercise Score	0.03	0.01	20535	3.76	<.001
Model 2: Interaction					
Couple Exercise Score	0.00	0.01	10807	-0.17	0.866
Couple Exercise Score X Time	0.01	0.00	11371	2.40	0.017

Figure 4

Trajectories of Serial 7 Test Performance by Exercise Status



Note. The figure above uses descriptive data to observe change over time in the serial 7 test performance based on aerobic physical activity status.

Delayed Word Recall Test

Model 1 includes the delayed word recall test as the outcome variable and gender, race, age, years of education, the couple exercise score, and time as covariates. Each of the included demographic variables (race, gender, age, years of education) are significant predictors of the delayed word recall test, all at $p < .001$. Time is also a significant predictor of delayed word recall at $p < .001$, as was couple exercise score, again at $p < .001$. Model 2 adds the interaction between couple exercise score and time, which is significant at $p < .05$. The main effect of couple exercise score is no longer significant after the interaction is added. All of the other variables remained significant in the second model (see Table 7 for Delayed Word Recall results and Figure 5 for trajectories of cognitive performance by exercise condition).

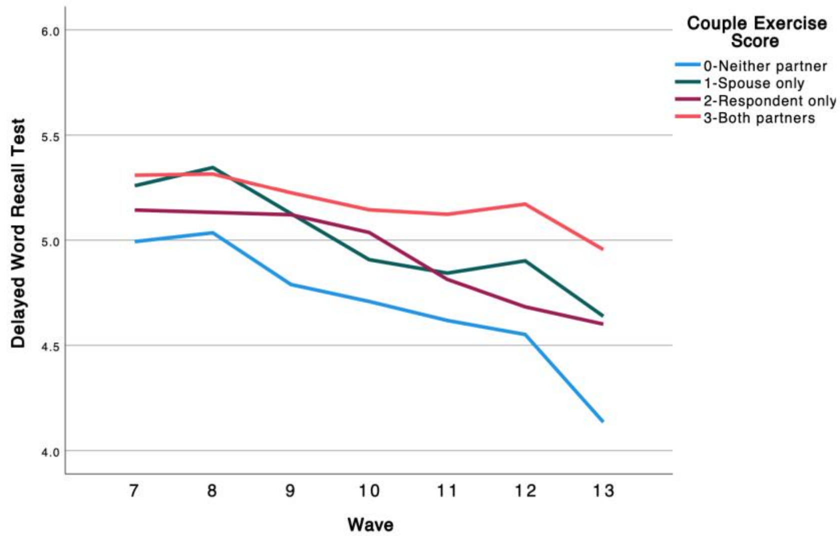
Table 7

Delayed Word Recall Test Table of Fixed Effects

	Estimate	SE	df	t-ratio	sig
Model 1					
Intercept	5.39	0.26	3192	20.67	<.001
Race	0.55	0.07	3182	7.95	<.001
Gender	0.70	0.04	3129	17.93	<.001
Age	-0.04	0.00	3120	-14.71	<.001
Years of Education	0.17	0.01	3184	22.60	<.001
Time	-0.09	0.00	10449	-18.47	<.001
Couple Exercise Score	0.04	0.01	20831	4.11	<.001
Model 2: Interaction					
Couple Exercise Score	-0.01	0.02	10680	-0.46	0.645
Couple Exercise Score X Time	0.01	0.00	11488	2.92	0.004

Figure 5

Trajectories of Delayed Word Recall Test Performance by Exercise Status



Note. The figure above uses descriptive data to observe change over time in delayed word recall test performance based on aerobic physical activity status.

Discussion

There is strong evidence that cognitive benefits are derived from physical activity, spousal exercise status, and levels of spousal support (Hong et al., 2005; Lee et al., 2012; Osuka et al., 2017). In the presence of this previous work, these findings suggest a need for further investigations to understand the additive nature of health behaviors among spousal dyads.

The addition of the interaction term in the second model of each analysis decreased, or eliminated, the significance of the couple exercise status score main effect. While the main effect of the couple exercise status score is no longer present for most of the cognition variables in the second model, this is likely because most of the variance was taken up by the interaction of couple exercise status score and time. This highlights the difference in cognitive trajectory, as a function of exercise status, over the twelve years of data analyzed in this study.

Individuals who were in a relationship where both partners participated in aerobic physical activity that met the levels established by Kämpfen and Maurer had higher cognitive outcomes and less cognitive decline when compared to other groups in the study, substantiating findings that the healthy behaviors and social support of one's spouse may positively affect their partner's health outcomes (Ayotte et al., 2013). Furthermore, findings support that the physical activity behavior of one's spouse may improve cognitive outcomes of their partner (Schierberl Scherr et al., 2013). If spouses did not influence their partner's health or cognitive outcomes, the results should be consistent across couples where both partners exercise and couples where only the respondent exercises. Additionally, cognition outcomes of the respondent were higher in couples even where only the spouse participates in aerobic activity and not the respondent.

The most robust findings were observed for the global cognition measures; less robust, but still significant, findings were present for the serial 7 and delayed word recall tests. Both the serial 7 and delayed word recall tests are more domain-specific and may not provide a full assessment of an individual's cognitive abilities.

Limitations and Future Directions

While the HRS presents a large, robust dataset, it is important to note some possible limitations. Large datasets are helpful in sampling a large population (Lantz, 2013); despite this, descriptive examination of cognitive trajectories shows that the actual differences are still meaningful. The present dataset had some missing data which is to be expected; a linear mixed model analysis was used to help counteract this because this method tends to handle missing data well (Chakraborty & Gu, 2009).

Future work should also include variables that determine the role of spousal closeness and relationship quality, self-efficacy, and gender differences to better understand how these may mediate health-related outcomes. Additionally, future longitudinal studies should attempt to base their exercise measures on the most recent edition of the PAG (2018); the HRS does not match their physical activity questions to the PAG because it began prior to the publication of the First Edition of the PAG (2008).

This study only included couples who were married; future studies should consider those who cohabit with their partner, as cohabiting relationships tend to be similar to married couples (Werneck et al., 2020). Because adherence is improved when a spouse is included (Osuka et al., 2017), interventions should compare groups who participate in physical activity with their spouse versus those who do not. Training with a significant other may enhance relationships, further communication, and promote emotional and physical intimacy (Winters-Stone et al., 2021). Future studies may also explore the influence of other members within one's social network (children, friends, extended family) (Zhang et al., 2016).

Creating an intervention study would allow researchers to control the environment, better infer causality, add additional cognitive tests, and include the spouse. Additionally, it may be useful to include neural measures in future studies to provide insight into the underlying neural mechanisms present in the maintenance of cognition.

Conclusion

Findings showed that the level of aerobic activity combined between spouses was a significant predictor in cognitive outcomes and trajectories. Additionally, the interaction of time and combined exercise score of spouses was a significant predictor of the respondent's cognitive outcomes, suggesting an important change over time based on physical activity habits. This study has clear implications, such a need for further lifestyle interventions including both partners and investigations to understand how physical activity and social interaction occur among spousal dyads.

Chapter 3: Discussion

This study was conducted to understand differences in cognitive outcomes and trajectories between couples where only the individual exercises, only their spouse exercises, both partners exercise, or neither partner exercises. Two hypotheses were made at the beginning of the study:

Hypothesis 1: An individual who exercises, and whose spouse also exercises, will have better cognitive function relative to an individual whose spouse does not exercise, to an individual who does not exercise, and to an individual who does not exercise and whose spouse does not exercise.

Hypothesis 2: An individual who exercises, and whose spouse also exercises, will have less decline in cognitive functioning over time relative to an individual whose spouse does not exercise, to an individual who does not exercise, and to an individual who does not exercise and whose spouse does not exercise.

Both hypotheses were supported after conducting linear mixed model analyses and examining descriptive data. The interaction term of couple exercise score and time proved to be significant across all models, suggesting that the interaction of time and combined couple exercise status score is an important predictor of cognitive trajectory among older adults. Additionally, having a partner who also participates in aerobic physical activity served as a benefit to the respondent's cognitive outcomes, suggesting an additive effect. The highest cognitive outcomes, and least decline, were observed in the exercise group where both partners participated in aerobic physical activity.

General Discussion

There is strong evidence to suggest that cognitive benefits are derived from physical activity, spousal exercise status, and levels of spousal support (Hong et al., 2005; Lee et al., 2012; Osuka et al., 2017). In the presence of this previous research, these findings suggest a need for further investigations to understand the additive nature of health behaviors within spousal dyads.

The addition of the interaction term in the second model of each analysis decreased, or eliminated, the significance of the couple exercise status score main effect. While the main effect of the couple exercise status score is no longer present for most of the cognition variables in the second model, this is likely because most of the variance was taken up by the interaction of couple exercise status score and time. This highlights the difference in cognitive trajectory, as a function of exercise status, over the twelve years of data analyzed in this study.

Individuals who were in a relationship where both partners participated in aerobic physical activity that met the levels established by Kämpfen and Maurer had higher cognitive outcomes and less cognitive decline when compared to other groups in the study, substantiating findings that the healthy behaviors and social support of one’s spouse may positively affect their partner’s health outcomes (Ayotte et al., 2013). Furthermore, findings support that the physical activity behavior of one’s spouse may improve cognitive outcomes of their partner (Schierberl Scherr et al., 2013). If spouses did not influence their partner’s health or cognitive outcomes, the results should be consistent across couples where both partners exercise and couples where only the respondent exercises. Additionally, cognition outcomes of the respondent were higher in couples even where only the spouse participates in aerobic activity and not the respondent.

If there was no additive effect, there would be no change in the respondent's cognitive outcomes when considering the spouse's aerobic activity behaviors. Spouses tend to share risk factors with one another but identifying these may help reduce the risk of cognitive decline in spouses (Yang et al., 2021); for example, multiple studies have observed that serving as caregiver of a spouse with dementia may increase one's own likelihood of cognitive decline, possibly through the effects of chronic stress (Dassel et al., 2017; Vitaliano et al., 2011). Therefore, it is possible that spouses with higher cognitive abilities may have a beneficial effect on the cognitive performance of their partner. Across the lifespan, spouses influence each other's quality of life, mental health, physical health, and stress (Chung et al., 2009). Those with better mental health, physical health, lower stress, and better quality of life may positively impact those in their social network (Musich et al., 2018; Vogel et al., 2007), including partners.

The most robust findings were observed for the global cognition measures included in this analysis. Less robust, but still significant, findings were present for the serial 7 and delayed word recall tests. This may be because each of these tests are more domain-specific and relatively brief tasks and may not provide a full assessment of an individual's cognitive functioning; they may also be less useful among individuals with intact cognitive function who may perform better on these tasks. That being said, it is possible that there is more of an effect of a couple's physical activity on memory than executive function. Given extant research that has demonstrated links between social support and memory performance specifically (Oremus et al., 2020), this is an area for future research.

While not the focus of these analyses, patterns were observed among covariates across models. On average, Caucasian individuals performed better than African American individuals on all cognitive tests. Extant research has highlighted the gap in dementia outcomes among different racial groups and the need for interventions to improve access to economic and social resources (Garcia et al., 2017); it is likely that this is linked to systemic inequalities. To improve outcomes of intervention studies that incorporate both social support and physical activity, future work should specifically examine these programs in underrepresented populations, where stratified analyses may enable researchers to evaluate whether social support operates differently for individuals from different backgrounds (Ward et al., 2019). As expected, for every additional year of age, cognition was slightly lower. While age-related on both global cognition and specific domains has been well-established, future work could also examine the differential effects of social support and exercise between young-old and old-old adults. Years of education was one of the most robust covariates across these analyses. This is unsurprising, given that individuals who are more highly educated tend to exhibit better performance on initial cognitive tests and slower decline over time in mental status (Alley et al., 2007; Wilson et al., 2009). This is another area for future investigation, given the consistent links between education and exercise adherence (Rhodes et al., 2000). The influence of gender was inconsistent across the tests of cognition in this study. Women did better on the delayed word recall test and total cognition index, whereas men performed better on the serial 7 test. There are conflicting findings on cognitive outcomes related to gender (Garcia et al., 2017; Ibrahim et al., 2017); future studies that incorporate a greater number of cognitive tests may be better positioned to explore these differences. Furthermore, this is an important area for future investigation given that women tend to have more influence on their partner’s health behaviors than men do (Umberson et al., 2018) and often have closer social ties to friends and family (Wong & Hsieh, 2016). Across all models, there was a consistent time effect across waves on cognitive outcomes. This is consistent with literature that has found that cognition and processing speed tends to decline over time (Goh & Park, 2009; Salthouse, 2019).

Theoretical Implications

Findings from this study provide clear support for the STAC model. Both social support and exercise contribute act as scaffolding that slows cognitive decline and promotes a healthy lifestyle. Both partners participating in physical activity was a predictor of higher cognitive outcomes, suggesting that social support and physical activity serve as scaffolding enhancement activities congruent with the STAC model. To further investigate whether scaffolding enhancement activities may lead directly to compensatory scaffolding in the brain, future research should add neural measures that would enable researchers to identify bilaterality and frontal recruitment, for example. While this study did not include neural measures, the cognitive tests used do suggest that scaffolding enhancement positively impacts brain mechanisms. This study also suggests that some compensatory scaffolding is also occurring to allow older adults to account for neural declines in older age. Otherwise, it may be expected that declines in cognition would be even greater. Future studies that include neural measures may be able to further assess the impact of brain changes on the level of cognitive functioning. Additionally, future studies may wish to investigate the neural challenges presented by aging more closely.

Implications for Practice

These findings highlight a need for further intervention studies in the future, particularly those that include cognitive outcomes of both individuals within a dyad. This study found that in couples where both partners participated in aerobic activity that aligned with the levels established by Kämpfen and Maurer, cognitive outcomes were higher for the respondent compared to other individuals who had a lower combined couple exercise status score. This is applicable for not only individuals, but also doctors and health practitioners who may wish to consider the health of a family unit, or a married couple, as opposed to solely the behaviors of an individual. Recommendations should be made to patients that they include their partner, and family, in their physical activity routine when possible or encourage their spouse to also practice healthy lifestyle habits. Increased physical aerobic activity should continue to be recommended in the medical field as a preventative measure for cognitive, mental, and physical health decline (Bouaziz et al., 2016), but this may be even more effective when combined with social support. Therefore, further interventions should also include the spouse as this was found to be beneficial in this study. While the newest edition of the PAG (2018) briefly mentions the importance of social support both for maintaining physical activity habits as well as a benefit of exercising with others, future editions of the guidelines may wish to be more prescriptive in suggesting social exercise habits as the benefits are highlighted in this study. The findings from this study bolster research that the spouse may play a key role in the cognitive health of their partner (Wong & Hsieh, 2017); therefore, it may be beneficial to include them in future physical activity programs created for older adults.

Limitations

There were several limitations of the present study that should be addressed in future studies. First, significant results are often observed in larger data sets (Lantz, 2013); despite this, descriptive examination of cognitive trajectories shows that the actual differences are still meaningful (see Figures 2, 3, 4, and 5). The differences between individual cognitive trajectories where both members of a couple exercise versus those where neither do may rise to the level of clinical significance, particularly among those who may be closer to experiencing mild cognitive impairments.

There was some missing data in the HRS which is to be expected due to the longitudinal nature of this dataset; a respondent may miss a wave of data collection, leave the study, or pass away; however, linear mixed model analysis was used because this method handles missing data better than other statistical analyses (Chakraborty & Gu, 2009). Further analysis was completed to examine the attrition of individuals across the course of the study based on their physical activity status; the highest attrition rate was among the group where neither partner participated in aerobic activity and the lowest attrition was among couples where both partners participated in aerobic activity. This analysis was completed in the dataset before participants were excluded from the study on the basis of age, available data, cognitive status, and ability to complete ADLs, so the numbers are larger than the sample (see Appendix B). Future analyses may wish to examine survival effects as a function of exercise status and social support in greater detail.

The exercise recommendations in the First Edition of the PAG (2008) did not perfectly align with the physical activity questions included in the HRS. It would be beneficial for future waves of the HRS to incorporate the PAG in their questionnaires, but this presents a challenge because of the changing nature of the PAG. Additionally, the cognitive outcomes provided in the HRS are more limited in scope in comparison to other sub studies in the HRS like the Harmonized Cognitive Assessment Protocol; the tradeoff is that these studies only occur at one time point as opposed to within each wave as in the core HRS dataset examined here; thus, the HRS dataset allows for the investigation of changes over time in cognition.

The study only included couples who were married; this does leave out groups of people who may cohabit or not plan to get married. Cohabitation provides health benefits to couples similar to those who are married (Werneck et al., 2020). Additionally, there was no exploration of couples who exercise together versus those who exercise separately; this information was not contained within the HRS. Adherence is often greater among those who complete physical activity with a spouse or other member of their social network; social support is beneficial in promoting healthy lifestyle behaviors (Osuka et al., 2017). Spousal closeness was not included in the present study; some research has found that closeness is associated with cardiovascular outcomes and physical activity may improve spousal closeness (Slatcher, 2010; Wilson et al., 2020). This study only examined *spousal* physical activity behaviors; it is possible that other members of the social network (children, friends, extended family) influence physical activity outcomes and may even provide a source of motivation through healthy competition (Zhang et al., 2016). Additionally, only the cognitive outcomes of the respondent were considered in this study, but future dyadic analyses may clarify links between spouse's health behaviors.

Ethnicity was not considered as a part of the present study; minority ethnic groups are often reported as participating in less physical activity, likely because of disparities in socioeconomic status that exist among these groups (Armstrong et al., 2018). Including race as a covariate can be a controversial decision; future studies may wish to stratify race and examine outcomes across groups. Only those in the United States were used in this study because the HRS is a representative sample of this country and the guidelines used were tailored for Americans. However, it is important to add that after excluding unmarried individuals and limiting the racial groups to African American and Caucasian, this sample may no longer be representative of the U.S. population. Additionally, chronic diseases were not included in these analyses.

Future Research Directions

Future research should include further intervention studies that are longitudinal in nature and include neural measures. Intervention studies allow researchers to control the environment, better infer causality, include more cognitive tests, and observe couples who exercise together. Ample research supports social interaction as an effective physical activity intervention (Estabrooks et al., 2012). Further work should compare groups in which couples' complete physical activity together to groups who complete physical activity separate from their partner; training as a couple may enhance relationships, further communication, and promote physical and emotional intimacy (Winters-Stone et al., 2021).

The addition of neural measures may provide insight into underlying neural mechanisms through which cognition is maintained; fMRI would allow for the examination of structural and functional changes in the brain (Dorsman et al., 2020), possibly providing additional support for the STAC model. This study does use longitudinal data to assess change over time which provides the foundation for future work including neural measures. Additionally, this study did not include chronic conditions; future studies may wish to investigate how chronic conditions impact exercise status and cardiovascular health.

The role of gender and sexuality should be factors included in future studies, as this study did not specifically examine LGBTQ+ couples. Evidence is emerging that members of the LGBTQ+ community experience higher levels of stress that may lead to compromised cardiovascular health, higher BMIs, and increased tobacco use (Caceres et al., 2020); future intervention studies are highly important among this population. Additionally, the present study only included individuals in the United States; future cross-cultural work may provide insight into differences in physical activity behavior and social support across different nationalities.

Future studies should include multimodal interventions that combine improvements in behaviors like diet, physical activity, and sleep; for example, some studies found that multimodal interventions had small effects on falls as well as quality of life, functional, and physical outcomes (Baker et al., 2007). These interventions would be beneficial among populations who may be at risk for, but do not yet have, ADRD; one of the main protective measures for ADRD is physical activity (Brini et al., 2018). The current study focused on older adults, but future work should consider those in midlife, as this is a critical time for intervention and prevention (Mishra et al., 2022).

Future studies may consider other individuals who play a role in an individual's physical activity behaviors; other members of the social network should also be included (Zhang et al., 2016). For example, one study found that individuals who had more supportive, larger social networks were more likely to be physically active; additionally, having physical activity facilities was beneficial in improving physical activity habits, but not among those who are socially isolated (Josey & Moore, 2018), suggesting a need for more community-based, social physical activity programs for older adults.

The Physical Activity Guidelines for Americans recommends specific doses of physical activity to achieve health benefits; but these guidelines also promote “move more, sit less” (Second Edition Physical Activity Guidelines for Americans, 2018), suggesting that any increase in physical activity is beneficial to health relative to a sedentary lifestyle. Additionally, many of the studies included above consider physical activity as a predictor of cognition, yet they do not cite evidence-based guidelines in their analyses. Practitioners and researchers should consider using evidence-based recommendations for physical activity moving forward while also emphasizing that even small amounts of physical activity may be helpful to maintaining a healthy lifestyle and cognition during aging. Future work should examine dose-response effects of physical activity on cognition in a social context.

Conclusion

This study sought to understand how health behaviors, specifically aerobic physical activity, of both an individual and their spouse affected the cognitive outcomes of one partner. Findings showed that the combined aerobic activity of a spousal pair was a significant predictor in cognitive outcomes. Additionally, the interaction of time and combined exercise score of a couple was a significant predictor of cognitive outcomes. This study has clear implications, such as a need for further lifestyle interventions that include both partners. It also highlights the importance of physical activity among older adults, and potentially in a social context, on cognition. While causal inference in the present study is limited due to the nature of the dataset, this work highlights a need for further investigation of physical activity and social interaction. This study reinforces the extent to which a spouse may affect their partner's health behaviors, and the meaningful impact this may have in cognitive performance during aging.

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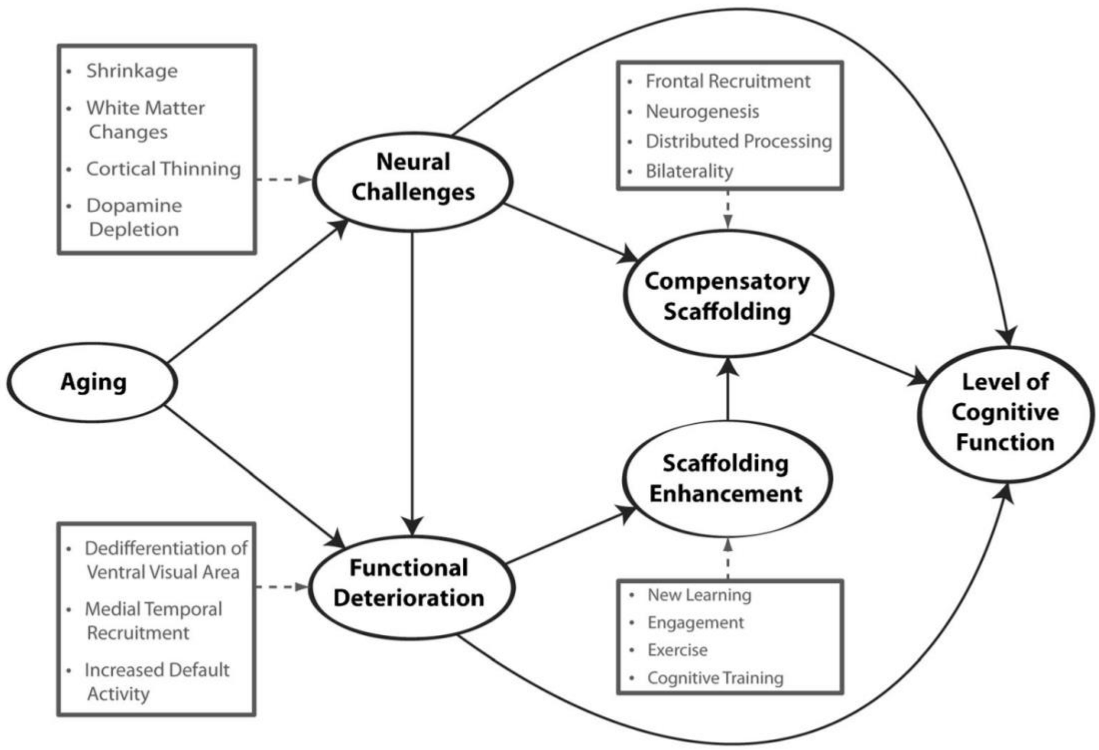
Appendix A: Scaffolding Theory of Aging and Cognition (STAC)



From "How Does it STAC Up? Revisiting the Scaffolding Theory of Aging and Cognition" by P. Reuter-Lorenz and D. Park, 2014, *Neuropsychology Review*, (https://doi.org/10.1007/s11065-014-9270-9).

Appendix B: HRS Attrition by Couple Exercise Score

Exercise Score	Wave 7	Wave 13	Percentage Remaining
0- Neither partner	11862	5246	44.23%
1- Spouse only	3914	2354	60.14%
2- Participant only	2285	1366	59.78%
3- Both partners	2068	1389	67.17%
Total	20129	10355	51.44%

Note. The above table represents the percentage of Wave 7 respondents who remained in the study in Wave 13.

The highest attrition was among couples where neither participated in aerobic physical activity. The lowest attrition was among those where both partners participated in aerobic physical activity. There was essentially no difference in attrition between couples where only the participant or only the spouse participated in aerobic physical activity. The biggest difference in attrition was between couples where neither partner completes aerobic physical activity or both partners complete aerobic exercise.

It is important to note that the reason for attrition is unknown in the context of this study. Further studies should be completed to assess survival rates among those who participated in physical activity versus those who did not.