DISSERTATION

THE ASSOCIATIONS AMONG MEANINGFULNESS, LEISURE ACTIVITY AND COGNITIVE FUNCTIONING IN ADULTHOOD

Submitted by

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ABSTRACT

THE ASSOCIATIONS AMONG MEANINGFULNESS, LEISURE ACTIVITY AND COGNITIVE FUNCTIONING IN ADULTHOOD

There is considerable research that has shown that individuals who engage in more social, physical, and cognitive leisure activities have higher cognitive ability and performance across older adulthood (Bielak et al., 2012; Hertzog et al., 2008). However, some studies have failed to report significant associations between leisure activity engagement and cognitive functioning (Hambrick et al., 1999; Parisi, 2010). Differences in findings in the activity literature have been discussed as resulting from differences in methodological designs and inconsistency in the measurement of constructs (Bielak, 2010; Bielak & Gow, 2022). One important area of interest involves research on the psychological and contextual modifiers that influence the activity-cognition relationship. This dissertation examined the relationships between activity engagement, meaningfulness and cognition using both cross-sectional (Study 1) and longitudinal (Study 2) research designs. Eighty-one individuals aged 45- 90 years old (M_{age} = 61.26 years, *SD* = 12.18) who participated in the Recording Everyday Activities and Cognition using Tablets (REACT) study at Colorado State University were used for analysis.

In Study 1, exploratory and confirmatory factor analysis was performed on each latent construct using the following baseline assessments: Victoria Longitudinal Study Activity Questionnaire (VLS-AQ); Engagement in Meaningful Activities Survey (EMAS); and seven standardized cognitive tasks administered using paper/pencil and computerized formats. Mediation analysis was then performed using structural equation modeling to test multiple

mediation pathways linking baseline activity and meaningfulness to cognition. The results revealed a significant direct effect of meaningfulness on activity but failed to associate either meaningfulness or activity with cognitive performance at baseline.

In the short-term longitudinal analysis (Study 2), day-to-day fluctuations in activity and meaningfulness were examined using a form of ecological momentary assessment across 14-days of tablet testing. Multilevel modeling analysis allowed for within and between-person level effects to be tested in models predicting performance across three cognitive tasks (Symbol Search Task (SST), Location Dot Memory (LDM), Flip-Back Task (FBT). Study 2 results showed significant between and within-person effects of daily meaningfulness and daily activity on cognition, particularly for the SST, a measure of visual-processing speed, and for LDM, a measure of working memory. Contrary to hypothetical predictions however, the direction of the between effects were unanticipated. For meaningfulness factor 2 (MF2) and activity, negative between-person effects and positive within-person effects emerged, although for meaningfulness factor 1 (MF1) positive between-person effects were significant, but the within-person effects were nonsignificant. Similar trends emerged for LDM; there were significant negative between-person and significant positive within-person effects for MF2 and activity, but no significant effects were found for FBT performance. Unexpected within-person level effects demonstrated that associations between meaningfulness, activity and cognition functioned differently at the group (i.e., between-person level) than at the individual (i.e., within-person level). Demonstrating that on days when individuals engaged more frequently in socially meaningful activities, or had higher daily activity levels, there was a counterintuitive effect on same-day cognition.

Consideration of the psychological context of engagement is a crucial aspect in understanding the activity-cognition relationship, however further investigation of the social, physical, and cognitive aspects of the everyday environment that promote cognitive health is warranted. Although no cross-sectional support for the activity-cognition relationship was gained through Study 1, the findings revealed that subjective meaning for activity-related experiences is an important precursor associated with the selection and evaluation of leisure activity engagement. At the daily level, Study 2 showed support for the activity-cognition relationship, showing that fluctuations in daily activity and meaningfulness predicted cognitive performance at both the within and between-person level. The implications for prevention research could aid in development of personalized lifestyle and behavioral management programs that target daily lifestyle and promote engagement in personally meaningful leisure activities.

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CHAPTER 1: AN INTRODUCTION & OVERVIEW

Aging & Cognitive Health

By the year 2050, the number of older adults across the globe is expected to reach nearly 2.1 billion (*Alzheimer's Disease Facts and Figures*, 2018). The increases in life expectancy are supplemented by increases in illness, impairment, and rising healthcare costs. As the aging population increases, so do the personal, social, and economic burdens for individuals suffering from age-related illnesses like dementia (Lindenberger, 2014). Currently, an estimated 5.5 million people age 65 and older have dementia; by 2050, this will increase to nearly 13.8 million older adults (*Alzheimer's Disease Facts and Figures*, 2018). Dementia is a disease of concern because of the cognitive decline and difficulties with memory, language, and problem-solving skills that seriously threaten older adults' ability to function in their daily lives. This disease has an extensive impact on the individual and the family, and society at large, influencing both health care systems and policy initiatives (Palma et al., 2011; Plassman et al., 2007). A 2018 report by the Alzheimer’s Association of America estimated the total lifetime cost for caring for someone with dementia to be $341,840. According to the same report, by 2050, the total cost of dementia-related care in the U.S. is estimated to be more than $1.1 trillion (*Alzheimer's Disease Facts and Figures*, 2018). Given the individual, the societal, and the economic importance of reducing risk for developing dementia, looking for ways to protect cognitive health has emerged as an imperative and influential area of aging research.

Cognitive functioning is a domain that has received much attention from the aging research community due to the natural age-related changes that occur throughout the lifespan and the critical role that cognition plays in our everyday lives. Cognitive functioning refers to the efficiency and accuracy of various mental processes, such as episodic memory, verbal fluency, working memory, processing speed, and reasoning ability, which are subject to declines as a function of age (Bäckman et al., 2000).

There is significant variability in cognitive ability levels among older adults, and impairment is not always inevitable. This variability can be credited to genetic, environmental, and lifestyle factors, which can be modified. Although some age-related negative changes in cognitive functioning may not be preventable, others may be alleviated by influencing certain aspects of an individual's environment and promoting behavioral changes that optimize mental health. It is crucial to explore how modifiable lifestyle factors, such as participation in cognitively stimulating physical and social activity, impacts cognition by delaying or preventing the rate of cognitive decline across adulthood (Hartley et al., 2017; Stine-Morrow et al., 2008). The motivation behind studying the relations between lifestyle and cognitive function is driven by the need to identify potential lifestyle factors that can attenuate the amount and degree of cognitive changes as a function of age. Given the limited treatment options for reversing late-life functional disability and dementia and the high emotional and financial burdens placed on family caregivers and the U.S. health care system, this research is fundamental (Wilson et al., 2007). Much of the literature now focuses on identifying risk and protective lifestyle factors, such as activity engagement, that promote healthy cognitive development in adulthood, and contribute to successful aging.

Cognitive Risk and Protective Factors. To fully understand the complexities of preventing cognitive decline, a life-course perspective should be taken that examines physical and environmental factors (e.g., stress, diet, physical activity, education, nutrition, and occupational exposures), as well as health and medical conditions (e.g., medications, brain injuries, cardiovascular health, mental illness, and genetic factors). This list is not exhaustive, and other research areas, like resiliency frameworks, are relevant to cognitive risk and protective factors. This discussion will focus on modifiable lifestyle factors, specifically, engagement in cognitively stimulating physical and social leisure activities.

Risk factors that contribute to cognitive decline in older adults include sedentary behaviors or low physical activity and social isolation (James et al., 2011; Vance et al., 2005). However, leading an intellectually stimulating, physically active, and socially engaged lifestyle may enhance cognitive functioning (Schaie, 1983). Findings from one of the largest and significant longitudinal studies of aging, the Seattle Longitudinal Study (Schaie, 1983), showed that this relationship is likely a result of using cognitive skills needed to perform daily activities, especially activities that are cognitively demanding, resulting in either the maintenance or even enhancement of cognitive skills. Following these discoveries, numerous studies examining the extent to which older adults' everyday lifestyles may buffer against age-related declines in cognitive performance have emerged (Salthouse, 2006). Research suggests that participation in three types of leisure (cognitive, physical, or social) activity is associated with developing a variety of favorable activity-cognition relationships (Small et al., 2012). Examples of these favorable associations include reports by Hertzog and colleagues (2008), which identified patterns of cognitively stimulating activities that promote the preservation of cognitive ability in normal healthy aging adults (Hartley et al., 2017; Lövden et al., 2010). Moreover, individuals who engage more frequently in cognitively stimulating leisure and social activities have a reduced risk for age-related cognitive decline (Mitchell et al., 2012; Paggi et al., 2016). Thus, the trajectory of cognitive decline may be influenced by modifying specific behavior patterns and promoting engagement in stimulating cognitive, physical, and social activities.

Identifying risk and protective factors, such as leisure activity engagement, that contribute to successful aging is incredibly important and will aid in the development of evidence-based programs aiming to reduce or delay age-related cognitive decline, thereby enhancing the proportion of older individuals that age successfully. The following sections present theories that have been used to explain successful aging and the importance of activity engagement for maintaining cognitive health.

Theories of Successful Aging. Over the past few decades, several lines of research have attempted to define and predict successful aging, with formal models emerging in the 1970s and 1980s. Various definitions have been proposed to define the term successful aging; these variations differ based on the field of research and the functional domains being evaluated (Phelan & Larson, 2002). According to Rowe and Kahn (1987), successful aging is multidimensional and encompasses three distinct domains: a) avoidance of disease and disability, b) maintenance of high cognitive and physical functioning, and c) sustained engagement in social and productive activities. These theorists maintain that functional capacity includes physical, cognitive, and social functioning (Rowe & Kahn, 1987; 1997).

Two common approaches for defining successful aging, described by Bowling and Dieppe (2005), are psychosocial and biomedical. The biomedical model focuses on maintaining mental functioning and the absence of disease, whereas psychosocial models focus on life satisfaction, social participation, and psychological functioning (Bowling & Dieppe, 2005). The MacArthur studies of successful aging are the most well-known and widely published biomedical studies of successful aging, and reports were based on a three-site longitudinal study of community-dwelling elderly U.S. adults (Albert et al., 1995; Seeman et al., 1994). The MacArthur Network on Successful Aging operationalized successful aging as a biomedical model, highlighting the role of maintaining physical and psychological well-being and maximizing effective functioning throughout later adulthood (Rowe & Kahn, 1997). Further, many predictors of risks for cognitive functioning and activity levels appear to be potentially modifiable, either by individual behavior change or changes in their immediate environment (Rowe & Kahn, 1997). Some investigators have broadened the model to include more psychosocial elements, yet interdisciplinary models are still rare, and Rowe and Kahn's model is still the most widely used approach.

In terms of psychosocial approaches, three major theories that describe how people develop in old age have been applied to the study of successful aging, including activity theory (Lemon et al., 1972), disengagement theory (Cumming et al., 1960), and continuity theory (Atchley, 1993). Although both activity and disengagement theories have historical significance in aging research, they have faced strong criticisms because they were originally proposed. Unlike activity theory and disengagement theory, which gave opposing recommendations for successful aging, based on either the maintenance of activity and social interactions with increasing age (i.e., activity theory), or lack thereof (i.e., disengagement theory) (Havighurst, 1963), continuity theory predicts that people will show bias towards what they perceive as continuous. Applied to activities, continuity theory states that adults gradually develop stable activity patterns across the lifespan and engage in thoughts and behaviors designed to maintain and preserve these patterns generally. Continuity theory proposes that in making adaptive choices, middle-aged and older adults attempt to protect and maintain existing psychological and social practices by applying familiar knowledge, skills, and strategies (Atchley, 1993). One of the significant ideas in continuity theory is that, in adapting to aging, people attempt to maintain and preserve patterns of thought and behavior that they believe are important adaptive and developmental skills. Another major component of continuity theory is that people select and develop ideas, relationships, environments, and activities based on what defines an optimal developmental trajectory.

Despite the agreement on the importance of continued activity across the lifespan, how and why patterns of engagement change across the lifespan has received relatively little attention from empirical research. Baltes (1990) proposed the Selection, Optimization, and Compensation (SOC; Baltes & Baltes, 1990; Freund & Baltes, 1998) model to explain changes in activity engagement across adulthood. According to this model, successful aging occurs through adaptation, focusing primarily on selecting appropriate leisure and social activities (Adams et al., 2010). The SOC model focuses on maintaining everyday competence in activities- selecting and optimizing activity choices, for which the individual feels a high level of competence or functioning although compensating for other areas that may be less strong. The critical concept of SOC describes a general process of adaptation that individuals engage in across the lifespan that is essential for achieving high levels of functioning (Baltes & Baltes, 1990). Although these theories attempt to describe how and why certain individuals age successfully, they do not explain why engagement in certain types of leisure activity is related to cognition.

Activity & Cognition

In addition to living in the absence of disease or disability and maintaining a high level of cognitive and physical functioning, the Rowe and Khan model of successful aging also requires individuals to maintain an active lifestyle (1997). Activity engagement plays a crucial role in structuring our lives and can both affect and be affected by the major components of Rowe and Khan's model of successful aging (1997). Although research studies have consistently shown that individuals who engage in more complex and stimulating cognitive activities have a lower risk for disease and disability in later life (Krell-Roesch et al., 2017; Livingston et al., 2017; Njar et al., 2019; Scarmeas et al., 2001), various types of activity seem to impact reduction in dementia risk differentially. Furthermore, the protective benefits of different forms of activity engagement may manifest slowly and often over different periods.

Several lines of research suggest that a more widely enriched (i.e., diverse) lifestyle may ward off cognitive decline more effectively. Schooler's (1984) environmental complexity hypothesis speculates that a person's environment includes both stimulus and demand characteristics that contribute to the cognitive complexity of their environment (Schooler, 1990; Schooler et al., 1999). The existence of more diverse and varied environmental stimuli requires individuals to make more challenging and complex decisions; this, in turn, creates a more cognitively stimulating environment. If the cognitive effort is rewarding from a complex environment, individuals will become more motivated to develop their cognitive skills and apply these cognitive resources across different situations and contexts, thereby improving cognitive functioning. Accordingly, it is expected that individuals who engage in activities that require greater cognitive skills and challenges will show greater maintenance or improvements in cognitive abilities. Individuals exposed to less complex and stimulating environments requiring minimal cognitive effort would not be expected to offer these same protective effects. From this perspective, it seems possible that different engagement patterns in everyday leisure activities may be associated with different trajectories of cognitive change in adulthood.

According to La Rue (2010), diverse lifestyles that combine cognitively stimulating exercise with physical activity and significant social interaction give the best odds for preserving cognitive functioning. Karp and colleagues (2006) supported this idea, following a sample of healthy Swedish adults for nearly a decade. Findings showed that active individuals on two or three of the leisure dimensions (physical, cognitive, and social) had the lowest risk of developing dementia, compared to active individuals on only one essential dimension. Therefore, lifestyles that combine cognitively stimulating activities with physical activities and rich social networks may provide the best chance for maintaining cognitive functioning in old age. Models of cognitive optimization support this argument, suggesting that activities that incorporate complexity, novelty, and diversity are critical in supporting cognitive health throughout adulthood (Carlson et al., 2012; Moreau & Conway, 2014). A recent review of the physical activity literature by Tomporowski and Pesce (2019) noted that multicomponent intervention programs that emphasize the integration of physical and mental activity produced the most substantial evidence in favor of cognition. Cognitive gains were most prominent in studies that emphasized complex, novel, and various engagement in multiple forms of leisure. These authors stressed the importance of skill acquisition as a common mechanism driving the cognitive benefits that resulted from sustained engagement in mentally stimulating forms of complex physical activity (Tomporowski & Pesce, 2019; Diamond and Ling, 2016). According to the skill-acquisition hypothesis, a variety of complex, movement-based activities can elicit cognitive improvements; the learning of certain forms of karate, Tai Chi, and social dance may exemplify ideal intervention conditions and social contexts that favor cognitive ability (Witte et al., 2016; Müller et al., 2017). Physical activity and aerobic exercise represented only one form of conceptualized complex, movement-based activity, and interventions that involved skill learning in socially diverse and cooperative settings were more favorable for cognition (Best, 2012; Moreau et al., 2015; Tomporowski & Pesce, 2019)

Although the social and physical environments provide a range of available leisure activities and recreational opportunities, it is the individual who, because of their own experiences, cognitive ability, social encounters, and personality, determines what activities to engage in and why (Iso-Ahola, 1993). Theories of social psychology and research on leisure and recreation help clarify the relation between activity and cognition by considering the social dimensions and constructs that influence activity engagement. According to social psychologist Iso-Ahola (1993), individuals desire to seek out activities in line with their social norms, expectations, and roles and retreat from interpersonal situations that are not in line with these social ideals. The seek-retreat model considers the underlying, socially motivating factors that determine the type and frequency of leisure activity participation. Taken together, these theories emphasize the importance of considering context (e.g., type of activity, level of cognitive demand), as well as environmental characteristics (e.g., available cognitive resources, level of complexity, social constructs) when evaluating the relationship between activity and cognition.

"Use it or Lose it." One primary framework that has guided much research examining the effects of activity on cognition is the "use it or lose it" or engagement hypothesis (Hultsch et al., 1999). According to the framework, activity engagement may prevent declines in cognitive performance when adults repeatedly perform cognitively stimulating tasks across various settings, contexts, and social roles (Fratiglioni et al., 2004; Small et al., 2007; Wang et al., 2002). Hultsch et al. (1999) stated: "Individuals who engage in activities that make significant loads on their cognitive skills will show greater maintenance or improvement of their abilities than individuals who are exposed to less complex environments with minimal cognitive loads" (p. 246). For example, in terms of physical activity, exercises that are more frequently practiced and involve cognitive or social stimulation seem to benefit cognitive performance more than other forms of physical activity that are infrequent or lack social involvement (LaRue, 2010). This “use it or lose it” framework provides a conceptual aphorism through which theoretical and mechanistic pathways have formed (Stine-Morrow et al., 2020).

Cognitive Reserve. Another related theory that must be applied to the association between activity-cognition is the cognitive reserve hypothesis (Fratiglioni & Wang, 2007; Kramer et al., 2004; Stern, 2002). Cognitive reserve operates under the supposition that our external environments and activity can influence neural processing and synaptic organization by allowing neurological processes to increase efficiency, becoming more adaptive and plastic (La Rue, 2010; Scarmeas & Stern, 2003; Stern, 2002). This hypothesis indicates that engagement in mentally stimulating activities helps build additional neuronal resources or cognitive strategies and that these tools may protect against aging-related cognitive declines. In one study that assessed participation in various leisure activities in non-demented elders, researchers found that individuals who engaged in more leisure activities had 38% less risk of developing dementia (Scarmeas et al., 2001). A great majority of papers studying the effects of education, occupation, premorbid I.Q., and mental activities found significant protective effects of all these lifetime exposures against the expression of disease pathology, according to one literature review (Valenzuela & Sachdev, 2005). The implications of these findings are that cognitive, social, and physical leisure activities aid in the development of greater cognitive reserve capacity and protect against disease pathology. Neuroimaging studies have supported these claims, demonstrating that sustained engagement in complex, mentally challenging activities enhanced neural efficiency (McDonough et al., 2015).

Other Considerations. However, most empirical evidence has come from carefully controlled laboratory settings, complicating the generalizability to everyday, real-world activities (Bielak et al., 2017). Understanding ecological opportunities and constraints within an individual's everyday environment may be critical in refining the "use it or lose it" hypothesis. The assessment of activity interventions in a naturalistic setting may provide unique contextual information describing real-world conditions that facilitate engagement in mentally stimulating activities. Researchers have stressed the important differences between naturalistic and laboratory settings, highlighting a need to examine how cognitive skills are acquired through everyday activity participation.

Researchers need to try and disentangle the respective influences of physical, social, and cognitive activities on cognition as these effects likely operate via different pathways (Karp et al., 2006). These mechanisms may function simultaneously, present lagged effects, or depend on certain, shared features of the activity type (Bielak, 2010; Bielak & Gow, 2022; Christensen et al., 1996; La Rue, 2010; Verghese et al., 2003). As some researchers have pointed out, mental activity seems to increase cognitive reserve via compensatory mechanisms, thereby decreasing dementia risk, whereas more physical forms of activity seem to exert their effects via cardiovascular mediated processes (Bielak & Gow, 2022). Adding to the complexity of these dynamics, studies exploring the activity-cognition relationship have produced inconsistent results. The following literature review presents studies that have supported the engagement hypothesis and those that have failed to provide evidence. The pathways hypothesized to link different forms of leisure activity to various cognition domains are discussed, and the frequent inconsistencies across studies are explained.

Literature Review

This review focuses on cross-sectional and longitudinal research studies investigating the relationship between different forms of leisure activity (e.g., physical, social, cognitive) and cognitive performance. Most studies reviewed here focus on older adulthood (ages 65 years and older), with a few widening the age range to include middle-aged individuals (ages 40-65). Potential pathways underlying the observed associations are discussed for each domain of activity.

Physical Activity & Cognition. Research has consistently demonstrated that physical activity can decrease the risk of disease and disability and is associated with maintaining cognitive functioning in older adults (Albert et al., 1995; Colcombe & Kramer, 2003; Kramer et al., 2006; Tomporowski & Pesce, 2019). Other research has indicated that the amount of physical activity is negatively related to cognitive decline. Anstey and Christensen (2000) showed that more physically active individuals experienced less decline in cognitive performance than others who were less physically active. A study by Kramer and colleagues (2006) demonstrated that routine aerobic exercise positively influenced older adults' cognitive functioning, especially executive functioning. Other research has shown that more frequent engagement in strenuous physical activity is associated with better response accuracy and faster response times on executive functioning tasks (Bugg et al., 2006; Hillman et al., 2006). Other studies have agreed on findings that showed favorable executive functioning effects, especially for activities that involved complex physical or aerobic movement (Moreau et al., 2015; Newson & Kemps, 2006; Roth et al., 2003). Spirduso and colleagues (2008) proposed a model highlighting various pathways through which physical exercise and aerobic activity are linked to favorable cognitive outcomes. In this model, the path from activity to cognition likely operates directly and indirectly via mediating factors such as health status, physical functioning, and available psychological resources (Spirduso et al., 2008).

The strength of the relationship between exercise and cognition has been suggested to be influenced by moderators such as age, education, and social support (Tomporowski & Pesce, 2019). Another study indicated that within-person differences in psychosocial support mediated the relationship between physical activity and cognitive functioning (Robitaille et al., 2014). Often engagement in physical activity or exercise includes some forms of social involvement, for example, exercising in groups or performing physical activities in the presence of other individuals, such as at a health club or gym. One potential pathway linking physical activity and cognition is skill acquisition (Bielak & Gow, 2022; Tomporowski & Pesce, 2019). Combined physical and cognitive exercise creates an enriched environment that can boost the potential for neurogenesis in adults and increase neural recruitment, promoting cognition (Erickson et al., 2012; Kempermann et al., 2002). As suggested in a recent review by Tomporowski and Pesce (2019), cognitive benefits were greater when activities had several components or included mental engagement. Activities such as dancing, boxing, yoga, or tai-chi are physical, movement-based activities that enable skill development through socialization and strategic thinking (Tomporowski & Pesce, 2019). Neuroimaging studies have explored brain activation patterns in response to dance training (Rehfeld et al., 2018). Compared to other conventional forms of physical exercise, dancing was associated with increased brain volume in areas such as the cingulate cortex and increased levels of BDNF in blood plasma. Regarding cognition, both the dancing and conventional exercise groups showed improvements in attention and spatial memory. However, no significant group differences emerged (Rehfeld et al., 2018).

Using data from four longitudinal studies of aging, Lindwall et al. (2012) examined the relationship between physical activity and cognition and found that higher baseline physical activity was associated with less decline in verbal fluency. However, this effect was specific to only one type of activity (e.g., physical) predicting only one cognitive outcome (e.g., verbal fluency). The authors discussed several measurement distinctions between the studies and pointed out that the evidence for the association between baseline physical activity and cognitive change in performance was relatively weak across other cognitive domains (Lindwall et al., 2012). Most outcomes measured across the four studies showed no relationship of baseline levels of activity predicting cognitive change. Furthermore, the authors concluded that the significance of physical activity in predicting verbal fluency performance might have been due to the advanced age of the sample. Lindwall et al. (2012) also suggested that the beneficial effects of physical activity on cognition may be limited to specific fluid cognitive domains (e.g., verbal fluency) and may not generalize to other areas of executive functioning. Other authors have explored the role of intraindividual change in activity on cognitive performance, noting that cognitive trajectories depend upon both within- and between-person differences in physical activity (Robitaille et al., 2014).

A growing number of animal and human studies suggest that physical exercise may directly affect the brain substrates that support cognition. In mice, stimulating environments and physical exercise have promoted neurogenesis in the dentate gyrus and increased neuronal plasticity (van Praag et al., 2005). In human studies, aerobic exercise programs increased cerebral blood flow in the dentate gyrus, which was correlated with higher memory performance (Coelho et al., 2013; Cotman et al., 2007). Benefits have also been described as reduced age-related atrophy in gray and white matter volumes in the prefrontal cortex and hippocampus following engagement in physical activity and exercise intervention programs (Gow et al., 2012; Kramer et al., 2018; Pereira et al., 2007).

Other mechanisms for brain plasticity and compensation other than neurogenesis have been proposed to explain the relationship between increased physical activity and cognitive ability; these include increased synaptic branching and a range of neurochemical effects that support cognitive functioning (Bruckner, 2004; Sachdev & Valenzuela, 2009). At the molecular level, the brain-derived neurotrophic factor (BDNF), which plays a role in neuronal growth and protein development, has been shown to increase in response to moderate-intensity physical activity (Coelho et al., 2013; Szuhany et al., 2015). Numerous studies have reported anti-inflammatory and anti-oxidative effects following engagement in physical activity and cognitive intervention (Di Benedetto et al., 2017). For example, decreased neuroinflammation directly and indirectly affects cognition (Cotman et al., 2011). Although the neurochemical pathways linking physical activity to the brain remain an exciting avenue for future research, further mechanistic studies are needed to explain how molecular effects relate to changes in brain structure and cognition function. The literature reviewed here on the mechanisms responsible for the consequences of physical activity on cognitive performance demonstrates a highly complex, multifaceted, and bi-directional relationship that is mediated by changes in psychological, behavioral, and physiological functioning (Lindwall et al., 2012).

Social Activity & Cognition. Like physical activity, social activity has also been related to a decreased risk of disability and attenuated cognitive decline (Cohn-Schwartz, 2020; Seeman, 1996; Wang et al., 2002). A study by Vance et al. (2005) reported increased participation in leisure activities within a social context or group, such as bowling and cycling, was associated with higher cognitive performance. Similarly, Tang et al. (2018) reported that participation in more mental and social activities was associated with better cognitive functioning and, a higher frequency of religious activity was related to better working memory. Activities that promote social connectedness, integration and reduce social isolation are favorable for cognitive health and promote physical functioning in older adults (James et al., 2011). Lövden and colleagues (2005) demonstrated that individuals who participated in more social activities (e.g., sports, hobbies, playing games, attending cultural events, visiting friends and family) performed better on cognitive assessments than individuals with less social participation. In this study, the protective factors of increased social participation over two years enhanced perceptual speed. Similarly, research has shown that activities such as volunteering, which encompass both mental and social engagement, resulted in increased cortical and hippocampal volumes and reduced cortical amyloid in healthy aging adults (Carlson et al., 2015; Donovan et al., 2016).

The maintenance of cognitive function through social integration and the positive associations between other leisure and recreational activities have been cited in other studies as well (Barnes et al., 2004; Donovan et al., 2016; Giles et al., 2012; Kim et al., 2019; Newson & Kemps, 2006; Scarmeas et al. 2001; Wang et al., 2002). The psychological mechanisms potentially responsible for these social influences on cognitive ability include indirect pathways via social and emotional support. Evidence has shown that the relationship between higher levels of social support and better cognitive performance is partially mediated by hippocampal volume (Kim et al., 2019). These findings emphasize the interconnectivity between psychological changes and changes in structural brain processing. Another study found that individuals who reported lower social and emotional support and higher loneliness had a higher amyloid burden, a neural protein indicative of dementia (Donovan et al., 2016).

Although the evidence is strong supporting physical activity and cognitive stimulation positively affecting cognitive health, less research has examined the specific mechanisms that underlie social activity and cognitive health, and the physiological explanation for this relationship is not entirely understood (Bielak, 2010; Hughes, 2010; James et al., 2011). According to some social psychologists, this relationship may be attributed to improved coping processes and stress regulation (Coleman & Iso-Ahola, 1993). Studies showed that engagement with an extensive social network and higher reports of emotional support from these social relationships was associated with better cognitive performance in adulthood (Giles et al., 2012; Gow et al., 2012; Holtzman et al., 2004; Seeman et al., 2001). Forms of social engagement may benefit cognition indirectly by increasing self-efficacy, improving psychological well-being, and decreasing stress (Brown et al., 2016; Carlson et al., 2009; Fratiglioni et al., 2000; Giles et al., 2012; Kramer et al., 2004; Paillard-Borg et al., 2009; Scarmeas et al. 2001). Social relationships seem to serve as a protective factor for immune system health, and studies showed that participation in social activities might protect against cognitive decline by influencing engagement in physical activity and promoting mental health (Brown et al., 2016; Cohn-Schwartz, 2020). Although social activity is a crucial component of maintaining an active lifestyle, it is also heavily intertwined with an individual's cognitive and physical functioning (Brown et al., 2016; Cohn-Schwartz, 2020). Individuals who lead a more socially active lifestyle may also participate in more cognitively stimulating activities, possibly due to social motivations and increased opportunities for intellectual engagement (Small et al., 2012). These arguments highlight the need further to disentangle the relative mechanisms responsible for these social processes and clarify the interactivity of social engagement across other activity domains.

Cognitive Activity & Cognition. Recently, from a public perspective, there has been growing interest in cognitive activity, more than physical and social activity, as a means of maintaining cognitive functioning with age. Mainstream media and industry advertisements continue to promote products that target cognitive performance through brain training platforms (e.g., CogniFit, BrainHQ, Lumosity). Although citing mostly associational research from the literature that has reported positive associations between increased cognitive activity and reduced risk for developing aging-related illness. For example, more frequent engagement in cognitive activities (i.e., listening to the radio, reading, writing, playing game) has been positively associated with decreased risk for developing Alzheimer's disease (Wilson et al., 2002; Wang et al., 2002; Scarmeas et al., 2001; Verhese et al., 2003). Engagement in cognitive activity has also been shown to reduce the risk for dementia in older adults (Larson et al., 2006; Wang et al., 2002), and has been associated with improvements in performance across several cognitive different cognitive domains (e.g., working memory, episodic memory, processing speed) (Ghisletta et al., 2006). Unfortunately, these platforms typically fail to acknowledge other experimental research that is less favorable in supporting these claims, leading to confusion on the effectiveness of their products, which lack in evidence-based support. A broader discussion of the literature on this topic across multiple study designs is warranted, including all research not just cases in which studies reported significant observational associations.

Generally, cross-sectional studies have reported that greater levels of participation in intellectually stimulating activities are associated with higher levels of cognitive performance on a wide range of cognitive tasks and that this relationship became stronger with age (Hultsch et al., 1993). For example, a study by Christensen et al. (1996) found that higher levels of participation in cognitively stimulating activities, such as reading the newspaper, predicted better memory, fluid, and crystallized cognitive abilities. Another study found that a higher frequency of engagement in Sudoku or similar puzzle activities was significantly positively associated with grammatical reasoning, spatial working memory, and episodic memory scores (Ferreira et al., 2016). Similarly, Tang and colleagues (2018) showed that participation in more cognitive activities such as reading, playing games was associated with better episodic memory, working memory, and executive functioning. In line with the "Use it or Lose it" paradigm, engagement in cognitive activities may be a way to maintain cognitive functioning in adulthood, however not all cross-sectional research has reported these favorable associations (Hambrick et al., 1999). A study by Hambrick and colleagues (1999) showed no differences in reasoning ability between individuals who frequently engaged in crossword puzzles compared to those who spent less time participating in this intellectual activity. One possible explanation for these differential findings may be due domain-specific effects of cognitive activity on cognition.

Longitudinally, Ghisletta et al. (2006) supported the engagement hypothesis, showing that higher levels of participation in activities such as reading, playing chess, and completing crossword puzzles were associated with a more gradual decline in perceptual speed across the 5-year testing period. Other longitudinal research in support of the engagement hypothesis found that frequent (daily/ weekly) engagement in mental, social, or productive activities was related to decreased incidence of dementia (Wang et al., 2002), especially for persons aged 65 and older (Larson et al., 2006). Similarly, other longitudinal research has reported that individuals with higher leisure activity participation at baseline also had higher concurrent cognitive ability (Bielak et al., 2012), yet there was no association with cognitive change over the 8-year follow-up period. Using data from four longitudinal studies, Mitchell et al. (2012) showed significant associations between baseline level of activity and status of cognitive ability. However, baseline cognitive training at an earlier age did not predict the rate of cognitive decline later in life, with follow-ups ranging from 8 to 21 years across the four studies (Mitchell et al., 2012). A more recent study by Staff et al. (2018) revealed that although typical intellectual activity engagement in adulthood was associated with higher levels of cognitive ability, it had no effect on the trajectory of cognitive change over time. According to the authors, these results indicated that engagement in cognitively stimulating activities might not protect an individual from decline but allow them to increase the threshold from which reduction occurs (Staff et al., 2018).

Although the mechanism through which cognitive activity is believed to influence cognition is still unclear, multiple pathways have been suggested. The idea of neural plasticity provides a basis for understanding the different hypothesized mechanisms. According to this concept, the brain is both structurally and functionally malleable or capable of change (Phillips, 2017). The neurocognitive mechanisms through which daily activity engagement, work, and social/ leisure activity relate to cognition are complex and involve transfer-related processes and other more generalized mechanisms. The transfer approach can be applied to explain how an active and socially integrated lifestyle broadly promotes better cognitive ability. However, this only applies to the extent to which cognitive skills trained transfer to the demands of everyday activity involvement (Hertzog, 2009). These transferred processes would be expected to produce very specific effects on lifestyle engagement or cognition. In contrast, more generalized mechanisms alternatively explain how exposure to novel stimulating activities or mentally challenging tasks would be thought to produce more general effects on cognitive functioning (Stine-Morro et al., 2020). Another pathway used to conceptualize the activity-cognitive relationship is through motivation. Motivational pathways may operate individually or in conjunction with neurocognitive mechanisms. According to this perspective, neurocognitive pathways are likely to depend upon sustained engagement and, therefore must encompass dispositional (e.g., personality) and contextual factors (e.g., self-efficacy, meaningfulness, socioemotional stability) (Stine-Morrow et al., 2020).

Studies have shown that engagement in cognitively stimulating activity may differentially activate cognitive reserve centers in the brain. Functional neuroimaging studies have been used to examine brain regions and cognitive processes that mediate cognitive reserve (Bidelman et al., 2015; Seider et al., 2016; Stern, 2002). This work has focused on understanding the brain regions involved in specific cognitive processes and whether there are differences in activation patterns with increasing age. Some investigations have indexed brain integrity (e.g., cortical thickness in gray and white matter), identifying the prefrontal cortex and the hippocampus as primary regions involved with cognitive reserve (Franzmeier et al., 2018; Vaqué-Alcázar et al., 2017). Other neuroimaging research has begun to search for substrates of a more general cognitive reserve network that might support sustaining regular cognitive performance across a broader range of cognitive tasks. A study by Chen and colleagues (2019) examined multiple areas in the Default Mode Network (DMN) and Left Frontal-parietal Network (LFP) related to complex cognition. The results showed an association between reduced DMN connectivity and higher episodic memory performance, indicating that the inhibitory processes of the brain networks resting states are one of the main routes through which proxies of cognitive reserve, such as higher education and increased engagement in intellectual stimulating activities, might exert influences on cognition (Chen et al., 2019).

Although some of the evidence reviewed thus far has alluded to supporting the engagement hypothesis, studies continually highlight methodological constraints and inconsistency across different study designs. In line with this reasoning, several longitudinal studies have failed to provide any empirical support for the relationship between baseline cognitive activity and change in cognitive performance (Aartsen et al., 2002; Gow et al., 2012c; Mitchell et al., 2012; Salthouse et al., 2002; Sturman et al., 2005). For example, Salthouse and colleagues (2002) failed to find evidence that cognitively stimulating activity mediated or moderated age-related declines in cognitive ability. In this study, an activity inventory consisting of a list of 22 items assuming to involve a range of cognitive demands was used, and participants were asked to rate how cognitively demanding they felt the activity was. These authors reported no differences in age-related declines in fluid intelligence and episodic memory between people who participated in high levels of cognitively stimulating activities and those who reported lower levels of engagement at baseline (Salthouse et al., 2002). An alternative explanation for these findings may be the limitations of assessing activity at only one-time point (e.g., baseline), which assumes that engagement is static rather than a dynamic and adaptive process (Bielak et al., 2017). More mechanistic research is needed to explore the potential mediating effects of psychosocial functioning that influence the active association between activity engagement and cognition across time.

There seems to be a complex interaction between physiological, emotional, and cognitive factors that work simultaneously to predict cognitive functioning in response to activity engagement. The combination of multiple mechanisms by which activities may impact cognitive ability is likely, such that different mechanisms may drive the relationship between various activities and cognitive domains. Pathways may overlap or operate through bi-directional feedback exchanges; as Cheng (2016) remarked, mental, social, and physical activity domains likely build their reserve capacities through different routes although arriving at the same conclusion. For example, physical activity may support more hardwiring (e.g., functional plasticity), whereas mental or social activity may facilitate better software functioning through skill acquisition and socioemotional support (Bielak & Gow, 2022; Cheng, 2016). As more studies apply the "use it or lose it" framework, there is a need for researchers to disentangle better the relative contributions of specific physical, social, and cognitive skills that characterize the complex forms of everyday leisure engagement and what the respective influences are upon different domains of cognitive function.

Comments on Study Design. Although substantial literature has emerged on this topic over the past two decades, many of the studies discussed have utilized cross-sectional research design (Arbuckle et al., 1986; Christensen et al., 1996; Erber & Szuchman, 1996; Hill et al., 1995; Hultsch et al., 1993). Due to the limitations of cross-sectional research, these observations are purely associational and cannot be used to determine or predict casual relationships among variables. Further, cross-sectional analysis does not determine whether higher activity engagement leads to better cognitive performance or vice versa. Secondly, few cross-sectional studies consider or control for possible confounders between activity and cognition, such as the social context in which activity occurs. Lastly, cross-sectional designs do not allow for researchers to observe how constructs of performance changes across time. This is particularly important for cognitive aging research as both activity engagement and cognitive functioning are dynamic processes that fluctuate in response to individual and environmental contingencies (Bielak et al., 2017).

Longitudinal analysis may offer numerous advantages in that it repeats assessment across multiple time points rather than testing at a single occasion (i.e., cross-sectional). Longitudinal study designs are now considered the gold standard for developmental and aging researchers. Broadly, in the social and behavioral sciences, longitudinal designs continue to evolve. This evolution has allowed for the expansion of conceptual and methodological conversations surrounding the assessment of change over time; emphasizing the need to identify and observe the evolving features and dynamic characteristics of the sample. For example, more studies incorporate daily activity assessments into longitudinal designs, using methods such as end-of-day testing or ecological momentary assessment where participants respond to daily surveys reporting real-time activity participation using mobile technology (Bielak & Gow, 2022). These methods are advantageous for research as they provide shorter assessment periods for activity which may result in more minor recollection errors and help to avoid potential inaccuracies in reported activity information (Bielak et al., 2017; Hatt et al., 2021).

It seems that the longitudinal associations between activity level and cognitive ability vary by age, type of activity, and the cognitive domain being evaluated (Bielak et al., 2014). One issue with longitudinal studies addressing this topic is that they often only consider activity at baseline, although cognitive outcomes may be assessed across multiple longitudinal follow-ups periods (Bielak, 2010; Bielak & Gow, 2022). Thus, fluctuations in within-person activity levels are left unaccounted for when activity is only considered at baseline. The association of activity engagement at baseline predicting cognitive ability does not address the issue of intraindividual variability, and it is essential to consider analysis that includes both group- and individual-level effects in predicting changes in cognitive performance across time (Bielak et al., 2014).

Furthermore, especially in cognitive aging research, prior cognitive ability may confound longitudinal associations between activity and cognition. Therefore, prior performance should be accounted for, however in reality, this can be difficult to achieve as few studies have data that can account for prior performance across the lifespan. One such study was a cohort analysis conducted by Gow and colleagues (2012), which showed that the association between leisure activities earlier in life and level of cognitive ability several decades later was not significant after controlling for cognitive ability at age 50. Furthermore, there were no associations between baseline leisure activity level and cognitive change between ages 60 and 80 (Gow et al., 2012c). Extending from this, in 2014, the same authors showed no associations between leisure activity (level or change) and change in cognitive ability at ages 75, 80, and 85 (Gow et al., 2014).

The longitudinal studies described throughout this section may test two different classes of hypotheses explaining the relationship between activity and cognition functions: differential preservation and preserved differentiation (Salthouse, 2006). The first idea, differential preservation, states that an individual's level of activity changes the rate of their cognitive decline (Bielak et al., 2014). For example, individuals who are constantly engaged in mentally stimulating activity show slower decline rates over time. In contrast, preserved differentiation theorizes that activity improves an individual's cognitive ability to a higher degree than inactive individuals. The differences between individuals are then preserved, but there are no differences in the rate of change in cognition over time. In this case, individuals who have had higher levels of activity engagement and cognitive functioning throughout their lifetime are those who will maintain higher levels of performance as they age. Studies have shown support for the theory of preserved differentiation (e.g., Bielak et al., 2014; Finkel et al., 2007), but there has been some disagreement in the literature on the existence of differential preservation (Potter et al., 2008; Schooler, 2007; Salthouse, 2006; Salthouse et al., 2002). This debate over causality is central to understanding how activities and cognitive ability change in conjunction with one another over time.

Although the idea that various lifestyle activities may be protective against cognitive decline in later life has received much attention in the literature, some doubt remains about the nature of this relationship. Drawing conclusions about the nature and directionality of the activity-cognition relationship and how it changes over time has been challenged by differences in study design and methodological approaches used across studies (see Bielak & Gow, 2022 for review). Two major factors contributing to this confusion include (1) differing approaches for how to conceptualize activity and limited definitions of what constitutes leisure engagement and,

(2) inconsistency in assessment approaches and the timing of measurement in relation to current cognitive ability as well as projected change in cognitive performance over time (Bielak, 2010; Bielak & Gow, 2022; Hertzog & Hultsch, 1999; Mackinnon et al., 2003; Salthouse, 2006).

CHAPTER 2: BACKGROUND & STUDY PURPOSE

Background

Understanding how aging adults spend their days provides essential insight into one of the fastest-growing segments of the population. By studying how older individuals spend their time, researchers can better understand the similarities and differences in activity patterns and individual motivations, goals, and personal beliefs regarding activity participation and successful aging. Generally, research supports a multidimensional and individualized view of aging, which is heterogeneous and reflects lifelong activity patterns, as well as personal preferences and gender roles. According to continuity theory (Atchley, 1989), across the lifespan, adults gradually develop regular habits of activity, suggesting that in making adaptive choices, middle-aged and older adults attempt to preserve and maintain existing psychological and social patterns by applying familiar knowledge, skills, and strategies (Agahi et al., 2006; Atchley, 1993). Taking a lifespan developmental perspective, the SOC model (Baltes & Baltes, 1990; Freund & Baltes, 1998) suggests that when selecting appropriate leisure and social activities, adults tend to choose and optimize activity choices where they feel a high level of competence or functioning although compensating for other areas that may be less strong. The critical concept of SOC describes a general process of adaptation that individuals engage in across the lifespan that is essential for achieving high levels of functioning (Baltes & Baltes, 1990; Hertzog & House, 1991).

Although both theories explain why changes in activity engagement occur throughout adulthood, what constitutes an activity is much more elusive, contributing to the difficulty in measuring this construct. Differing definitions and classifications of what constitutes a leisure activity limit the consistency of used assessments across studies. To evaluate the activity-cognition relationship more rigorously, clear, and concise depictions of activity are needed.

Interestingly, there is still no consensus in the current literature on defining activity engagement, and there is even greater diversity in how it is measured.

Defining Activity Engagement. Activity refers nontechnically to what people do throughout their day (Kelly & Kelly, 1994). Activity is a process of engagement. It is not simply something people do to pass the time, but rather a measurable behavior that can serve as an essential predictor of lifestyle engagement (Katz, 2000). There are different forms of activity referred to in the gerontology literature, including physical activity or movement, activity in the pursuit of everyday interests, and activity that involves social participation (Katz, 2000). Further distinctions have been made between leisure pursuits of activity and those that are occupationally specific. Most research broadly defines leisure activity as the pursuit of a range of tasks and activities outside of the work or occupational environment (Fallahpour et al., 2016).

When conceptualizing leisure activity, it is necessary to consider that leisure is inherently associated with lifestyle and highly subjective. According to the social psychology literature, leisure is characterized in the following ways: as specific types of activity (e.g., attending a concert); as time, free from obligations (e.g., the amount of time not spent working); as meaningful and satisfying experience (e.g., helping others, relaxation); or as some combination of the three (Kloeher et al., 2011). Leisure is a challenging concept to define, and there is no universal definition of what constitutes a leisure activity. Descriptions of leisure and measurement approaches will differ based on the field of research and the nature of the question or problem of interest. Differences about what leisure is and what circumstances contribute to activity engagement have resulted in the need for researchers to become familiar with a wide variety of theories and information. According to some, the terms "leisure," "recreation," and "free time" are often used interchangeably in the literature. Thus, leisure research involves the broad study or time-use activities or behaviors and their associated experiences (Barnett, 1988). According to social psychologist Iso-Ahola (1980), leisure can be defined simply or comprehensively, either objectively or subjectively. Objectively, leisure activity can be defined as time spent outside of work (Neulinger, 1974). Subjectively, leisure refers to a state of mind and involves an individual's perception and inference of the quantity and quality of their activities (Iso-Ahola, 1980a).

Regarding aging, lifespan theorists have implied that leisure behavior plays a differential role at various points throughout human development (Gould, 1975; Levinson, 1978). DeCarlo (1974) studied the relationship between leisure and recreational activity engagement and successful aging. This study found that continued participation in recreational activities throughout the entire life span was characteristic of individuals who aged more successfully (i.e., without disease, illness, or significant functional impairments); these individuals tended to live longer than those who were not able to maintain an optimal level of arousal through leisure activity engagement as they aged. Although it may seem that leisure participation generally decreases with age (Parisi et al., 2017), the importance of leisure activities remains relatively stable. Some evidence suggests that leisure engagement plays a vital role in problem-solving as individuals develop through different stages or seasons of life (Gould, 1975; Levinson, 1978). Because individuals change and evolve their leisure activity repertoire throughout various stages of life, what is considered "optimal" for an individual is determined mainly by the social, cognitive, and physical nature of their environment.

Leisure activities are distinct from functional activities of daily living. They can vary widely, including inherently physical, social, or cognitively engaging activities, such as visiting friends and family and participating in clubs, classes, or other types of organized events (Parisi et al., 2017). It has been well documented that leisure participation is typically social (Coleman & Iso-Ahola, 1993). Thus, there is a social dimension to activity participation, in the sense that social norms, expectations, and roles all function to influence the types of activities chosen for engagement (Braudel, 1992; Hanson & Hanson, 1993). According to Iso-Ahola's (1984, 1990) model of leisure motivation, one important dimension is the desire to seek and escape interpersonal situations or "retreat." Following this line of reason, an important characteristic or function of leisure activity is that it serves as a route for individuals to develop friendships and social connections. These researchers believe that the social nature of leisure activity positively affects health because of the development of social support systems and self-determination, which provide stress-buffering effects (Coleman & Iso-Ahola, 1993).

Time-use studies show that older adults are resoundingly active in all forms of leisure activity (physical, social, cognitive) compared to what stereotypical views of aging might portray (Klumb & Baltes, 1999; Lawton, Moss, & Fulcomer, 1987; Szanton et al., 2015). A typical day for an older individual represents a unit of time embedded in a larger physical and social context. Based on specific patterns of individual preferences, these unique social and physical environments create opportunities and restrictions for participation in certain activities (Singleton, Forbes, & Agwani, 1993). Hanson and Hanson (1993) suggested that both time and space, at the most basic level, influence activity participation, and thus a person's day not only consists of the nature and diversity of activity but also perspectives of acceptable time use, individual social preferences, and the spatial context of the activity.

According to the literature on occupational therapy, the use of terms like activity and occupation has fluctuated significantly over the past several decades as different lines of research have emerged (Christiansen et al., 2005). The model of human occupation (MOHO) presumes that activity participation is influenced by the dynamic relationship between person-occupation-environment (Kielhofner, 2008). Based on this framework, occupations incorporate many things that people do to occupy their time, including self-care activities, physical work, and pleasurable leisure activities. Engaging in occupational activities gives a sense of meaning, helps individuals connect and, leads to skill acquisition (Fallahpour et al., 2016). According to Townsend and Polatajko (2007), occupations are groups of activities and ritual tasks of everyday life, organized and given value and meaning by individuals and their social and economic communities (Townsend & Polatajko, 2007). Therefore, leisure activity participation can be conceptualized under the giant umbrella of occupations and thus has become a focus of occupational therapy and occupational science literature (Law, 2002). According to Kielhofner (2008), the MOHO provides a theoretical basis for conceptualizing leisure activity engagement linked to the relationship between activity participation and risk for late-life cognitive decline found in prior research (Fallahpour et al., 2016).

Extending the framework provided by the MOHO, Baum et al. (2015) proposed the Person-Environment-Occupation-Performance (PEOP) model which involves three components: (1) characteristics of the person (e.g., physiological, psychological, motor, cognitive or spiritual; (2) features of the environment (e.g., cultural, social support, physical and natural environments, assistive technology); and (3) characteristics of the activity, task, or role (Baum et al., 2015). This model states that when people are performing occupations (i.e., work-related activities or leisure engagements), they are also inherently interacting with their environment, producing a reciprocal relationship. The consequence of this interchange is that changes can influence the goals and intentions that affect a person's occupational performance in their environment. The application of the PEOP model appears throughout the occupational therapy and rehabilitation literature. It is considered a client-centered approach that aims to improve occupational performance by promoting optimal fit between individual leisure needs and the occupational environment (Baum et al., 2015).

People naturally change over time, as do their leisure needs, motivations, and recreational pursuits. However, research has often assumed that leisure and occupation are static processes. Future research must acknowledge that leisure is a dynamic and changing process that occurs at the individual level and in response to persons, places, situations, and conditions. Finally, the choice of leisure activities is highly subjective, and as such, psychological values must be considered to determine what the relative strength of forces such as cognitive functioning might have on our interpretation of leisure experiences and how these processes change over time and influence the risk of cognitive decline (Fallahpour et al., 2016). Thus, it is reasonable that in addition to measuring both frequency and duration of activity participation, researchers should also consider environmental and contextual variables (i.e., subjective experience) in which leisure activities are embedded. Furthermore, it might be beneficial to shorten the assessment time frame for activity so that individuals can more quickly and accurately remember patterns of engagement.

Measuring Activity Engagement. Retrospective, self-reported questionnaires are the most used method for gathering information about activity engagement (Bielak, 2010). Typically, surveys ask participants to report the total frequency of participating in a list of specific activities. Some research reports use simple yes/no questionnaires to assess whether individuals engage in a particular activity. In contrast, other research has used rating scales to measure different aspects of activity, varying from the frequency, diversity, and the intensity of participation (Harper Ritchey & Dietz, 2001). For example, the Victoria Longitudinal Study

Lifestyle Activity Questionnaire (VLS-AQ) (Hultsch et al., 1993) is a survey that contains 70 activity items and asks about frequency over the past two years, with response options ranging from never to daily participation. The VLS-AQ is well-known in the cognitive aging literature (Jopp & Hertzog, 2007; Jopp & Hertzog, 2010; Hess et al., 2018). The benefits of this survey include a large number of activities (70 items) assessed, including activities that represent both general (e.g., do household repairs) and more specific (e.g., play jigsaw puzzles) forms of engagement. This survey provides detailed information about the frequency and variety of activity engagement; the VLS-AQ has also been psychometrically validated across multiple studies or aging adults (Jopp & Hertzog, 2007; Jopp and Hertzog, 2010; Hess et al., 2018). Another self-reported questionnaire, the Lifestyle Activities Questionnaire (LAQ) asks participants to rate lifestyle activity on a 6-point scale of how often, over the past year, they participated in 23 different activities (Carlson et al., 2012). These surveys have two fundamental differences; the first is that they differ in the number of activity questions asked. The second is they vary in the length of time (years) over which engagement was reported. These are just two examples that demonstrate a lack of consistency in activity measurements across studies, and there are numerous other examples of inconsistent methodologies across the activity literature (Bielak, 2017; Carlson et al., 2012; Hughes, 2010; Mackinnon et al., 2003; Schinka et al., 2005. This variability has made it tough to draw definitive conclusions, which has resulted in the unclear classifications of the types of activities that should be assessed and the characteristics under which to define them (Fallahpour et al., 2016).

It has become evident in the literature that the relationship between activity and cognition may vary as a function of how an activity is defined and measured. Further, this relationship may also be influenced by the specific tests and cognitive domains being evaluated (Bielak et al., 2014). Bielak (2017) compared the Activity Characteristics Questionnaire (ACQ), a new questionnaire using activity characteristics, to two other activity assessments, the Specific Activities Questionnaire (SAQ) (Jopp & Hertzog, 2007, 2010) and the Daily Diary (DD) method where participants reported their activities every day for one week. This study compared the three types of activity assessments (e.g., ACQ, SAQ, DD) to predict cognitive ability (Bielak, 2017). Results found that each method provided unique information about how activity engagement related to cognitive functioning. In line with other existing research on cognitively stimulating activities (Verghese et al., 2006; Wang et al., 2002), each of the activity measures examined by Bielak (2017) showed that activities or characteristics of activities that were more focused on cognitive stimulation seemed to be the most significant predictors of mental performance.

Bielak (2010) described several challenges that exist in terms of creating an ideal activity assessment. In a more recent review, Bielak & Gow (2022) revisited these challenges and highlighted issues that remain. One pertinent problem is the cultural, geographic, and seasonal differences that influence typical engagement. When only a few activities are assessed, questionnaires may not fully grasp the variation in activity engagement necessary to predict cognitive outcomes (Jopp & Hertzog, 2007). Furthermore, many activity checklists indicate only culturally appropriate and commonplace activities for older individuals (Bielak, 2010; Katz, 2000). Many have failed to include activities that may be considered more cognitively demanding (Salthouse, 2006) or culturally taboo (i.e., drinking, smoking, sexual activities). Another issue is the lifespan of activity questionnaires and how to determine when activities have become outdated. For example, consider the following activity items from the VLS-AQ: writing letters, balancing a checkbook, doing arithmetic calculations. These activities may no longer be relevant given updated assistive technology such as emails, using calculators instead of performing hand-based written mathematical calculations, and the emergence of online banking (Bielak & Gow, 2022). An alternative to commonplace activity checklists, the ACQ developed by Bielak (2017) and categorized activities based on shared characteristics and similar cognitive skills required for engagement. Considering several activity dimensions and how different activities share specific features might facilitate measurement improvements and help to clarify further the relation between activity and cognition (Bielak, 2010). Furthermore, there may be added benefits for using multiple types of activity assessment, as different questionnaires seem to assess other engagement components. Lastly, as Bielak & Gow (2022) suggested, questionnaires should be continuously updated as the nature of engagement constantly shifts and becomes more integrated with technology. By providing more relevant examples (e.g., talking to friends or relatives on the phone or via video calling), activity questionnaires would ensure that the assessed items accurately reflect the evolving nature of engagement.

Other approaches for collecting activity information exist but are used much less frequently, such as interviewing to ask participants to recall what they did over a specific time frame (i.e., yesterday). Horgas et al. (1998) used an expanded time diary strategy, the Yesterday Interview (Moss & Lawton, 1982), which allowed individuals to reconstruct the previous day in rich detail. Findings importantly showed substantial variability in the amount of time spent with different activities during the day, and participant reports were coded into 44 different types of activities. Parisi (2010) used a similar method, the Daily Diary approach, which allowed participants to report their unique activity patterns using a journaling method. The downside to these techniques is that they require significantly more time to score because they involve having to code and classify activities rather than just summing up a rating scale done with survey and questionnaire formats. These examples describe different methods for measuring activity engagements across leisure and daily activity contexts; some of the limitations for each contribute to the challenge of "correctly" assessing activity.

Researchers in occupational therapy have reported similar time-use diary methods (Atler, 2014). The Daily Experiences of Pleasure, Productivity, and Restoration Profile (PPR Profile) was designed to measure occupational experiences over a 24-hour time frame and captured information about when, where, and with whom occupations occurred. These methods may inform researchers studying the activity-cognition relationship by encouraging similar profiles that assess short-term leisure activity experiences. The PPR offers a translational solution to the challenge of defining and measuring activity seen in the cognitive literature and suggests broadening the scope of subjective assessments to include contextual information in which the experience occurred (Atler et al., 2015).

Researchers have not agreed on the best way to measure activity engagement. There is still no consensus on the most effective method for collecting activity-related information, nor are there guidelines for identifying which activity dimensions should be assessed by these measures (Bielak, 2010). Consistency in obtaining activity information is necessary for researchers to correctly interpret and compare conclusions from different studies about the benefits of activity engagement on cognition in adulthood. Differences in the study design of prior research, various collection methods, and difficulty in categorizing activity information have created conceptual concerns that complicate cross-study comparisons (Menec, 2003). Finally, current knowledge does not prescribe how long individuals should engage in cognitively stimulating activities. Some research suggests that more is better and presents recommendations for a cognitively active lifestyle which includes engaging in cognitively stimulating activities several times a week or more (Cheng, 2016; Diamond & Ling, 2016; McDonough et al., 2015; Stine-Morrow et al., 2020). However, most activity assessments measure the frequency of engagement over more extended periods, leaving daily activity patterns not accounted for.

Measurement Approaches. Currently, the standard approach for assessing activity longitudinally involves long-term retrospective reporting. Although long-term assessments of activity provide information about stable patterns of engagement across the lifespan, some research has suggested that a more productive approach to measuring activity and cognition may be to assess these variables over a shorter time interval (Aartsen et al., 2002; Salthouse, 1996). Although self-report remains the standard approach for assessment, relying solely on long-term, retrospective self-reported activity information may not be adequate, given that data obtained from these methods can be incomplete or distorted (Salthouse et al., 2002). Cognitive decrements and issues often influence long-term assessments due to reliance on memory and estimation; these problems can be heightened in older adults, given age-related declines in episodic memory (Erber & Szuchman, 1996). Longer recall times (weeks, months, years) may contribute to a greater chance of incomplete or distorted self-reported activity information (Hatt et al., 2021). Under this assumption, activities reported over a shorter time frame (i.e., at the daily level) may be less susceptible to error and offer a more accurate depiction of actual engagement. When less time has elapsed between essential activity participation and assessment, there is less opportunity to forget activity-related information (Hatt et al., 2021). Hess et al. (2017) showed a significant positive correlation between daily activity reports and a 2-year retrospective questionnaire. However, each assessment seemed to capture different activity information.

Furthermore, Bielak (2017) demonstrated that daily reporting offered unique information about cognition, above and beyond what past reporting of activity at the weekly and even yearly level provided. When activities are reported immediately or shortly after they are engaged in (i.e., within the last three to four hours), they are being evaluated in a more momentary state of the experience. In doing so, the present self is perceiving and considering the experience in real-time. The temporal patterns of activity experiences can often foreshadow the development of more stable long-term attitudes towards certain types of activities (i.e., personality dispositions) (Coleman & Iso-Ahola, 1993; Iso-Ahola, 1980; Iso-Ahola & Allen, 1982;). These dispositions often influence the level and frequency of future activity engagement. They may affect the availability of certain activity-related information when reports are retrospective, especially in older adult populations.

To avoid issues with recalling accurate information, more time-sensitive approaches are needed to fully understand the effect of everyday activity on cognitive functioning, and advances in mobile technology may provide the necessary tools for assessing this relationship (Timmers et al., 2014). The emergence of daily activity assessment is increasing, either through end-of-day testing or by more recent technological advances such as ecological momentary assessment, which using smartphone technologies to assess activity in real-time (Bielak & Gow, 2022). These methods reduce recollection error, increase ecological validity by recording measurements in a naturalistic setting, and facilitate less inaccurate reporting. Finally, research has suggested that various forms of assessment capture engagement differently, providing different depictions or narrations of participation (Bielak, 2017; Hess et al., 2017). Thus, there may be added benefit of incorporating both short-term and long-term activity assessment in future research designs.

Other Dimensions of Activity Engagement. To better understand the influence of certain activities on cognitive functioning, it is necessary to consider different dimensions of activity and the frequency of engagement, such as difficulty, ability, and competence based on prior experiences and the perceived meaningfulness of activity. Studies have shown that the frequency of activity engagement in older adults can be influenced by several different variables, including physical functioning (SF-36), perceived locus of control (i.e., the extent to which an individual believes they have control over a situation), self-efficacy, motivation and social network characteristics (Rousseau et al., 2005). Measures of activity should capture both how frequently someone engages in a workout as well as the overall level of stimulation (Salthouse et al., 2002). Because the effect of an active lifestyle on cognition is based on the argument that increased stimulation leads to better cognitive performance, researchers must consider and measure activity using multidimensional approaches.

Some theorists suggest that classifying activity is not possible without considering an individual's subjective experiences (Hammel, 2004; King, 2004). Individuals tend towards experiences that offer novelty and stability; however, what constitutes an activity is based on the individual and their perceived level of arousal (Iso-Ahola, 1980). Because leisure experiences are subjective, the expression of psychological values must be considered to determine whether engagement patterns meet the individual's needs. A comprehensive review conducted by Fallahpour et al. (2016) stressed the importance of future research considering personal aspects and subjective experiences associated with leisure activity participation in adulthood. Individual characteristics such as age, gender, or physical functioning often moderate the association between activity and specific health-related outcomes.

In contrast, contextual and psychological factors may also play an intervening role, such as personal meaning, activity choice, or perceived quality of engagement (Adams et al., 2010). In the social psychology literature, research has investigated whether the assessment approach (i.e., objective versus subjective) influences the buffering effect that social support has on the relationship between life events and illness (Coleman & Iso-Ahola, 1993). Across studies, when social support was conceptualized and measured subjectively, for example, in terms of the perceived ability of support, rather than in objective terms, the buffering effect was more substantial (Barrera, 1986; Cohen & Wills; 1985; Kessler & McLeod, 1985). These and other potential mediating and moderating factors may explain why the relationship between activity participation and social or psychological outcomes exists and why subjective measurement considerations are warranted (Atchley, 1989; Lemon et al., 1972).

According to activity and continuity theories, another influential factor determining engagement may be the purpose or meaning prescribed by an individual and associated with engagement in different types of activity (Lawton, 1993; Warr et al., 2004). Activity participation frequently involves pursuing personal goals, which may add a sense of personal accomplishment that could influence cognitive performance, especially when the activities are significant and supportive of the individuals' sense of identity (Atchley, 1993). These other potential benefits of adult leisure activity engagement have not been thoroughly examined. Activity measurements have historically not included different types of psychologically relevant subjective information (e.g., meaningfulness), representing an important area for future research. Very few studies have explicitly considered an activity’s purpose or meaning within the context of psychological health, and no studies have examined this construct and its association to cognitive performance. Research examining the association between activity and cognition in adulthood will be strengthened by considering and appropriately measuring other psychological aspects of engagement, such as the meaningfulness of activity participation.

Meaningfulness of Activity. For humans, a sense of meaning occurs through the structural development of their everyday lives and involves the various ways they engage with the world (Schlick, 1987). Searching for purpose in everyday life is a fundamental motivating factor shaping our lifestyle and activity engagement. In the social psychology literature, personally meaningful activities are defined as those conducive to the feelings of self-determination and competence. Meaningful activity engagement results from intrinsic motivation, characterized by an individual's higher-order needs (Iso-Ahola, 1980). Theories of adulthood associate meaningfulness with three major developmental processes (DeGrandpre, 2000; Kaufman, 1986; Levinson, 1986; Reker & Wong, 1988). The first relies on structuring self-systems and interpreting experiences through a sense of wellbeing as individuals engage in and disengage from specific goals and commitments across the lifespan, aspects of meaning change, and the importance of engagement. How we develop self-structures in adulthood is based on various existential engagements, rearrangements, and disengagements following significant life events that influence how we interpret ourselves and our current situation (Brandtstädter, 1999; Klinger, 1977). Secondly, meaningfulness motivates self-creation; participating in novel experiences, having several hobbies, and engaging in diverse activities allows people to identify their strengths and weaknesses, learn what they enjoy doing, and promote self-efficacy (Kelly & Kelly, 1994).

Principles of commitment to our personal goals and values and intrinsic motivation can help explain why people come to find different activities meaningful and how meaning is derived from our everyday lives (Hess et al., 2017). And lastly, meaningfulness provides a sense of continuity across the lifespan. According to continuity theory (Atchley, 1993), people select and develop ideas, relationships, environments, and activities based on personal dispositions about what defines meaning in their individual lives. These notions lead to multiple definitions of activity that are both individual and social. They convey who an individual is through the activities they engage in and express our values and meaning systems (Atchley, 1989). Thus, our activities shape our meanings, and these meanings, in turn, influence what activities we engage in (Kelly & Kelly, 1994). Mattingly (1998) explored this idea and described the narrative structure of experience. This author argued that the present is a configuration of the past (which is used as a reference point or life context) and the anticipation for the future (or the storyline where one is headed). Concerning an individual's leisure activity experience, current involvement seems to rely heavily on former occasions, which then influences the future activities we choose to engage in (Mattingly, 1998).

Models and Theories of Meaning. King's (2004) model of Meaning in Life Experiences suggests three universal paths through which we acquire meaning from our everyday life experiences: through a sense of belonging (e.g., quality of social and supportive peer relationships), through doing (e.g., an obligation to personal goals and commitment to performance), and through self-understanding (e.g., establishing self-identity and understanding our place in the world). Individuals differ in the use of these routes and preferred paths for engaging with the world. For example, some people acquire meaning through the experience of a single, major life-altering event. In contrast, others find meaning through themes that emerge through multiple but less dramatic life events occurring throughout the lifespan (Lawton, 1993). Some people cultivate meaning primarily through social interactions and developing quality and supportive relationships. Others derive meaning from more task-oriented activities (e.g., sports, hobbies, work, volunteering) that eventually become fundamental life structures (Kelly & Kelly, 1994; Somner & Baumeister, 1998). These differences can be understood by drawing upon appraisal processes and inherent positive and negative emotions linked to experiences and, consequently, paths of engagement (King & Hicks, 2012; Park, 2010). Of course, environmental constraints and social, cultural, and family influences all play a role in the construction of meaning in our everyday lives. However, it was proposed by King (2004) that these three paths for how we acquire meaning from our daily lives (through a sense of belonging, through doing, through self-understanding) are fundamental and universal. They operate on mutually influencing levels of experience: the micro-level of perceived human engagement, the middle level at which people report subjective experiences, and the macro-level of understanding meaning in life (King, 2004).

This developmental theory is consistent with other social and occupational therapy sciences perspectives that suggest that our daily activities' meanings facilitate a personal sense of fulfillment through adherence to valued goals. The study of meaning in occupation is quite prominent in the occupational therapy, occupational science, and rehabilitation literature. Definitions of meaningful occupation involve the complex and dynamic association of being engaged in or "doing" activities considered valuable and personally important (Reed, 2005). According to current occupational therapy theory, occupation is generally what people do to occupy themselves. This includes self-care (e.g., looking after themselves), leisure activities, and productivity or their social and economic contributions to their community (CAOT, 2002). Although this definition does not limit classification into three categories (i.e., self-care, leisure, and productivity), this is a valuable approach for researchers. Descriptions of occupation are individualistic and dependent upon mood, goals, context, and social characteristics of the situation. According to Reed (2005), standard definitions of meaningful occupation include terms such as incredibly important, valuable, and personally significant. Because the same individual may engage in different occupational activities throughout their lives, it is difficult to give any meaning other than the subjective meaning that individuals attribute to these engagements (Kelly & Kelly, 1994).

In the occupational therapy and occupational sciences literature, meaning is framed as both global and situational. *Global* meaning refers to the more generalized facet of a person's meaning systems made up of the following individual aspects: 1) a person's fundamental assumptions about the world; 2) personally valued goals and aspirations; and 3) the subjective sense of what meaning is and what purpose it holds in a person's life (Eakman, 2015; Park & Folkman, 1997). On the other hand, *subjective* meaning refers to meaning in the context of a particular event or situation in a person's life (e.g., the onset of illness or retirement). According to these models, the meaning-making process is dynamic. It fluctuates as a response to shifts in both global and situational levels of meaning, eventually balancing out to achieve congruence and continuity (Park & Folkman, 1997).

Literature on Meaningfulness in Occupational Therapy. The application of these models of meaning has been the focus of much research in occupational therapy. According to most definitions, occupations include a wide range of daily activities that individuals participate in, including work-related activities, leisure experiences, and self-care habits (Christiansen et al., 2005). Occupational engagement provides opportunities for individuals to acquire and master skills, connect with others and is a means through which individuals can find purpose and meaning in their lives (Christiansen et al., 2005; Fallahpour et al., 2016; Law, 2002). Research on occupational therapy has made the distinction between the study of "meaning" and the study of "meaningfulness" (Ross et al., 2010). Although the concept of "meaning" may be simple to grasp, defining this construct is much more challenging. Reviewing the literature revealed two main issues that have stumped researchers examining the meaning of work: the source of meaning or where does the meaning of work come from (i.e., “meaning”), and how that work becomes meaningful, or the underlying psychological and social mechanisms (i.e., “meaningfulness”) (Ross et al., 2010). Researchers have often used these terms of meaning and meaningfulness interchangeably, contributing to the confusion about whether these constructs are the same or how they are different. According to Pratt and Ashworth (2003), when researchers refer to the "meaning of work," they commonly reference the *type* of work. When referring to the *amount* or significance attached to specific activities, this denotes "meaningfulness." According to the MOHO, all occupations are desirable for enhancing a sense of wellbeing, and research should therefore be focused on the subjective experience of engagement (Kielhofner, 2008). Outside the context of work, which represents only one classification of activities, occupations also refer to leisure and recreational pursuits that provide individuals unique opportunities for finding meaning in their everyday lives (Christiansen et al., 2005).

Given the subjective nature of meaningfulness, it is essential to consider the sociocultural context of different activities and how contextual factors impact individuals' accounts of activity participation (Rowles, 2008). Hammel (2004) explored the contribution of occupation to the experience of meaning in our everyday lives and how meaning is derived from engagement in occupational activities. Researchers have highlighted three essential aspects of activity that contribute to meaningfulness: how close the activity matches personal value systems; its ability to provide a level of competence and personal mastery; and its value within one’s larger sociocultural context (Goldberg et al., 2002; Hammel, 2004). Others suggest that occupations make life more meaningful by providing a means for social recognition, promoting personal achievement, and fostering self-actualization (Campbell et al., 1976; Lent & Brown, 2006; Rosso et al., 2010).

Rosso et al. (2010) identified four primary sources of meaning or meaningfulness in work: the self, other persons, the work context, and spiritual life. Focusing on the self as a source of meaningfulness, research can be divided into three domains of research: (1) values; (2) motivations; and (3) beliefs about work. According to self-determination theory, which follows a cognitive view of motivation, the purest form of motivation occurs when individuals experience autonomy, competence, and relatedness in their involvements (Deci & Ryan, 1985; Deci & Ryan, 2000). This cognitive view of motivation has influenced conceptions in the literature regarding the meaning of work. Research in this area has revealed that how individuals see themselves relating and orienting towards certain work-related activities plays a vital role in the meaning-making process (Rosso et al., 2010). However, meaningfulness's role in selecting an activity and its impact on cognition has yet to be explored.

Researchers have introduced the PEOP Model in occupational environments, a translational approach that highlights both intrinsic (i.e., personal) and extrinsic (i.e., physical, cultural, and social) environmental influences that affect performance in everyday activities. According to this perspective, performance involves the complex interaction between the individual, the environment in which the task, activity, or role is played out, and the meaningfulness of the experience (Eakman, 2015). This interactional approach has been described elsewhere in other bodies of literature and applied to intervention approaches. The dynamic international model of cognitive rehabilitation (Toglia, 1992) argues that cognition is the continuous production of the dynamic interaction between the individual, activity, and their environment. The type of environment (social, physical, and cultural) influences an individual's ability to process information and adapt to new incoming demands, thus mediating the activity between the individual (Toglia, 1992). Based on these theoretical foundations, it seems plausible that an interactional model, like those found in occupational therapy, occupational science, and rehabilitation research, would be fitting for and translational to the study of leisure activity engagement and its effects on cognitive performance. These models emphasize the need to consider contextual and psychological mediating factors when describing and assessing the experience of activity engagement.

Recently, occupational meaning systems have emerged to understand better and define meaningfulness and how it fosters human development and psychological health in the workplace (Wong, 2011). According to a qualitative research synthesis of eleven studies of occupation, Eakman et al. (2018) identified three common themes of meaning in occupation: *Social, Selfhood, and Pleasure*. These higher-order themes comprised 12 underlying forms of meaning or types of positive, meaningful experiences. For the *Social* theme, experiences were reflected through belonging or helping activities. In contrast, the theme of *Selfhood* was made up of activities related to mastery, self-esteem, autonomy, purpose, continuity, identity, and health and wellbeing. The theme of *Pleasure* was reflected through satisfaction, enjoyment, and stimulation. Identifying the complex structure and apparent interconnectedness of subjective occupational experiences leads to a conceptualization of meaning that is a multifaceted and dynamically changing system (Eakman et al., 2018). Occupational meaning systems have provided a framework for studying the structure of positive occupations (i.e., day-to-day activities) and specific sociocultural contexts in which changes in meaningfulness might occur (Hocking, 2009). What has not been considered is whether these systems operate outside of occupational contexts and whether this approach applies to leisure activity engagement.

In the past decade, considerable research has emerged measuring activity meaning in the occupational therapy literature. Two psychometrically sound instruments have been developed as global measures of meaning in occupation: The Engagement in Meaningful Activities Survey (EMAS) (Eakman, 2012; Goldberg et al., 2002) and the Occupational Value Instrument with Predefined Items (OVal- (Eklund et al., 2009). Using the EMAS, Eakman (2012) showed that changes in the meaningfulness of occupations were positively related to fulfilling basic psychological needs (e.g., competence, mastery) for older adults. Similarly, other studies incorporating the EMAS have confirmed that greater meaningfulness is associated with greater health and wellbeing and purpose in life (Eakman, 2012; 2016). The OVal-PD was primarily developed for clinical settings to understand the influence of perceived meaningfulness on occupational balance in people with mental illness, such as schizophrenia (Eklund et al., 2009). Both instruments have the potential to be modified as daily assessments that investigate whether unique patterns of meaning occur within specific sociocultural contexts of our everyday lives. Although these measurement tools have been psychometrically validated occupational therapy research, less is known about their fidelity in measuring leisure activities' meaningfulness.

Leisure Activity Engagement. Theories of leisure and recreational activity focus on how participation in leisure activities leads to the development of self-systems (Crawford & Godbey, 1987). Outside the context of occupational settings, the consideration and measurement of meaningfulness in *leisure* or *recreational* activities are much more limited, especially in developmental cognitive aging research. According to Kelly and Kelly (1994), leisure activities become integrated and produce meaning in our life when they are captivating to the individual, are shared with close confidantes, and support a sense of social understanding. Daily activities that are perceived with high competence seem to motivate more effortful participation and promote higher levels of positive affect, suggesting that individuals may select more enjoyable activities that match their level of ability (Agahi et al., 2010).

Furthermore, in line with models of behavioral self-regulation (Carver & Scheier, 1981) and motivation (Atkinson, 1964; Vroom, 1964), Scheier et al. (2006) proposed that valued goals are the mechanism by which individuals maintain meaningful and active life engagement. According to this perspective, behaviors occur either because they represent an immediate valued goal (e.g., socializing because it feels good to be connected to others) or because it is necessary to achieve a more meaningful and complex, higher-order goal (e.g., socializing because it promotes health and "successful aging") (Scheier et al., 2006). Thus, in contrast to work or other obligated activities, leisure activities are associated more with intrinsically motivating tasks and perceptions of freedom (Coleman & Iso-Ahola, 1993).

Commonly, leisure theories focus on specific activity types, such as social engagement, on improvements in health and wellbeing (Lawton et al., 2002; Seeman et al., 2001; Warr et al., 2004). Lawton (1993) argued the best way to classify possible leisure activities is based on the meaning of the activity, organizing activity types into three more significant categories: *experiential, social,* and *developmental.* Experiential meanings of leisure included activities that shared the following characteristics: intrinsic satisfaction, solitude, diversion, and relaxation. Social leisure activities were classified as containing social interactions, issues of social status, and community service. Lastly, developmental leisure activities were considered those that demonstrated intellectual challenge, promoted personal competence, health, and self-expression (Lawton, 1993).

Aarten et al. (2002) applied this leisure classification system in a longitudinal study that examined the extent to which cognitive functions were improved by activity or whether everyday activities were enhanced by cognitive ability. At 6-year follow-up, none of the three activity domains were associated with a change in cognitive functioning, providing little evidence in favor of beneficial effects of activity on cognition. However, the potential benefits of engaging in more meaningful leisure activities to promote cognitive health are entirely possible, given the associational effects of meaningfulness on psychological health and sustained occupational engagement (Deci & Ryan, 2000; Eakman, 2014; Eakman, 2016).

In the neurocognitive rehabilitation literature, top-down intervention approaches focus on improving the performance in everyday activities for individuals suffering from significant cognitive impairments (i.e., following traumatic brain injury or stroke) by promoting engagement in more meaningful types of activities (Skidmore, 2014). By repeatedly practicing motivating and challenging tasks and engaging in meaningful everyday activity, these neurocognitive-based interventions stimulate motivational networks in the nervous system that have been associated with learning and memory (Kleim & Jones, 2008). In addition, these rehabilitative approaches emphasize the need for instruction of metacognitive strategies; the skills help train individuals with cognitive impairments to regulate their everyday activities and monitor behavior patterns (Sohlberg & Turkstra, 2011). Using similar techniques, other research has shown cognitive improvements in memory, executive functioning, and everyday problem-solving skills following home-based care activity programs for community-dwelling older adults (Hunter & Kearney, 2018). These intervention approaches indicate that engagement in meaningful activity is a potential mechanism for preventing cognitive decline as we age. This dissertation draws from several different perspectives. The present studies incorporate theories of meaningful occupation (Eakman, 2018) and models of cognitive rehabilitation (Toglia, 1992) to explain potential mechanisms that underlie the relationship between activity and cognition. Using an interactional approach, this dissertation aimed to establish a link between meaningfulness, everyday leisure activity, and the effects on cognitive performance in healthy aging adults.

For some people, involvement in leisure activities becomes quite central to their lifestyle, and this valuing of activities is expected to heighten the influence of leisure engagement on cognition. Engagement in leisure activity as a means of self-expression implies that certain types of activity (e.g., those that are more meaningful) are being used explicitly as a mode of self-determination, thus encouraging more frequent participation (Coleman & Iso-Ahola, 1993). For example, it is possible that two people who engage in the same type of activity for the same amount of time on any given day display different patterns of cognitive performance throughout the day due to differences in the prescribed meaningfulness assigned by the individuals. It is unclear whether individuals who engage more frequently in meaningful activities will have greater cognitive performance. More research is needed that examines the role meaningfulness plays in predicting activity engagement and cognitive ability. Typically, research has paid most attention to the frequency of activity participation as a general indicator of engagement, but how certain meaningful activities are and how these subjective experiences influence our cognitive ability has not been considered. Exploring the association between meaningfulness and activity engagement in predicting cognitive performance is the primary purpose of this dissertation.

Purpose of the Current Project

In this dissertation, the effects of meaningful leisure activity engagement on cognitive functioning were examined in a sample of healthy adults. The goals were to determine the structural and directional associations between meaningfulness, leisure activity engagement, and cognitive performance using cross-sectional (Study 1) and longitudinal research designs (Study 2). The cross-sectional mediation analyses tested two separate structural models linking activity engagement and meaningfulness to cognition via direct and indirect pathways. For Study 1, I hypothesized that a higher frequency of activity engagement and greater meaningfulness would be more strongly associated with higher cognition. Although many studies have attempted to describe the nature of the relationship between activity engagement and cognition in aging adults, this study was the first to propose the mediating role of meaningfulness on the activity-cognition relationship. In Study 2, I examined how changes in the frequency of daily meaningful activity engagement are related to changes in daily cognitive functioning across 14-days of observation. By describing this relationship over time, it is possible to determine the predictive strength of the association between daily meaningful leisure activity engagement and daily cognitive performance in both middle-aged and older adults. I hypothesized that on days when individuals engaged more frequently in meaningful activities, they would have higher cognitive performance on those same days than when less frequent meaningful engagement occurred.

Incorporating both cross-sectional and longitudinal design was appropriate for the current study because it allowed for the use of different data collection tools that expanded the depth of scientific knowledge on how meaningful leisure activity functions throughout adulthood, both structurally (Study 1) and at the daily level (Study 2), and its relative association with cognitive functioning. The benefits of cross-sectional approaches are that they allow researchers to compare many different variables simultaneously. However, this approach does not provide information about the change in relationships because it examines variables at a single moment in time. Longitudinal study designs, like cross-sectional, are often observational, however, several observations of the same individual over a certain period are collected. In the longitudinal study (Study 2), baseline cognitive performance and activity levels were recorded, and daily fluctuations from baseline were measured at both the group (between-person) and individual (within-person) levels.

In Study 1, cross-sectional mediation analysis was used to establish links or associations between the frequency of activity engagement, meaningfulness, and cognition. Then in Study 2, the longitudinal multilevel analysis determined the direction and strength of these associations at the daily level. Results from the cross-sectional study may look different than at the longitudinal level, which does not necessarily mean failure to replicate. Instead, these variables' structural and associational relations may operate differently at a single time-point than when evaluated longitudinally at the daily level.

This dissertation aimed to better understand the influence of an individual's participation in every day meaningful leisure activities on cognitive performance, both at the structural (Study 1) and daily level (Study 2). By converging models from two different paradigms: theories of occupational therapy (Eakman, 2018) and models of cognitive rehabilitation (Skidmore, 2014; Toglia, 1992), this research explored novel concepts and measurement techniques to better understand the activity-cognition relationship in a sample of healthy middle-aged and older adults. Findings from these investigations will clarify whether specific attributes of engagement (i.e., activity level and meaningfulness) are related to better cognitive ability across adulthood. This information could be beneficial for promoting healthy, active lifestyle engagement across adulthood. Identifying factors that influence cognitive health is particularly relevant for aging adults who may be experiencing subtle cognitive and functional declines. By observing patterns of fluctuations in cognitive performance and the corresponding changes in contextual patterns of activity engagement, researchers can identify behavior patterns and provide specific feedback about the types of daily engagement that may be most beneficial for improving cognitive performance. These recommendations may be based on the meaning or value that certain individuals place upon certain activities. Investigating the underpinnings and attributes of activity engagement will add to the growing scientific knowledge base regarding the influence of activity on cognition and facilitate the identification of lifestyle activities that may protect against cognitive decline and serve as targets for prevention programming in healthy aging adults. Findings may influence prevention and intervention research by further refining theoretical conceptualizations, which can contribute to developing evidence-based daily activity programs designed to promote cognitive health in aging adult populations. Ideal programs will help strengthen cognitive skills and encourage sustained engagement in stimulating leisure activities across the lifespan, resulting in an aging population that is less susceptible to cognitive decline and has a reduced risk for developing dementia.

CHAPTER 3: STUDY 1

Overview

Studies examining the extent to which modifiable lifestyle factors may slow or prevent age-related cognitive declines suggest that greater frequency of participation in cognitively stimulating physical and social activities may be associated with a variety of favorable cognitive outcomes (Salthouse, 2006; Small et al., 2012). However, little research has considered the psychological context in which activity occurs, and the intervening role that our subjective experiences have on our activity engagements (Hammel, 2004; King, 2004). More research is needed to expand conceptualizations of leisure activity to include psychological and contextual elements related to activity participation. For example, the purpose or meaning assigned by an individual and attached to or entangled with certain leisure experiences (Lawton, 1993; Warr et al., 2004). The potential influence of psychological factors, such as meaningfulness, on activity-cognition associations may help to better explain the nature of this relationship and the mechanisms underlying it (Bielak, 2010; Hertzog & Hultsch, 2007; Mackinnon et al., 2003; Salthouse, 2006).

When activities support an individual's sense of identity, they seem to have the most significant effects on health-related outcomes, suggesting that activity engagement involves motivation for pursuing goals (Locke & Latham, 2002; Rosso et al., 2010). When leisure activities are personally meaningful for an individual, they contribute to a greater sense of psychological well-being (Eakman, 2016). Meaningfulness benefits psychological health and contributes to sustained occupational engagement throughout adulthood (Eakman, 2016). Making progress towards personally relevant goals at work and leisure fosters a sense of purpose, formulates life structure, and promotes personal agency (Lent, 2013).

The meaningfulness of activity seems to amplify the positive effects associated with leisure activity engagement (Hutchinson & Kleiber, 2005). According to this line of reasoning, when actions express an individual's values (e.g., the importance of spending time with close family and friends) or allow for the expression and affirmation for one's attributes (e.g., as a helpful and caring individual), they can offer potent resources for promoting healthy cognitive development. Furthermore, engagement in personally meaningful leisure activity may offer a sense of normalcy for individuals experiencing age-related cognitive and functional declines (Warner et al., 2012). Although the effects of activity meaningfulness have been well-documented in the occupational therapy, occupational sciences, and rehabilitation research (Eakman, 2014; Eakman, 2016), little research has examined this construct in relation to leisure activity and cognitive ability (Wang et al., 2012) in healthy aging adults. By considering subjective experiences (e.g., meaningfulness) associated with activity, this study investigated whether greater meaningfulness and higher activity participation levels predicted better cognitive performance.

Evidence from cognitive rehabilitation has demonstrated that meaningfulness may be an important, contextual mechanism through which activity engagement positively influences cognition (Lawton, 1993; Skidmore, 2014; Warr et al., 2004). Meaning that the internal psychological context of the individuals' experience of engagement may mediate the relationship between activity and cognition. Occupation-based interventions may benefit cognition by involving a client-centered approach towards engagement and supporting basic psychological autonomy, competence, and belonging (King, 2004; Wong, 2011). In occupational therapy, occupational sciences, and rehabilitation literature, meaningful activity has been used as a therapeutic tool to promote psychological health & well-being. However, the directionality of effects between activity and psychological meaning on cognition is unknown. Theories suggest that there may be reciprocity between the selection of activities and the meanings we draw from them. According to theories of meaning, our actions shape our meanings, and these meanings, in turn, influence what activities we engage in (Schooler & Mulato, 2001; Atchley, 1989). It is necessary to identify the structural association between these variables to confirm whether they have mediational effects on cognition. According to research on leisure activity (Iso-Ahola & Allen, 1982; Iso-Ahola, 1986) and theories of meaning in occupation (Ross et al., 2010), it seems plausible that the meaning assigned to certain types of activities may predict the selection of our leisure engagements (Atchley, 1989; Hocking, 2009; Scheier et al., 2006). According to the SOC model (Baltes & Baltes, 1990) of adult human development, individuals select appropriate leisure activities across the lifespan to maximize levels of functioning. The SOC model focuses on maintaining everyday competence in activities- selecting and optimizing activity choices. The individual feels a high level of competence or functioning although compensating for other areas that may be less strong. I argue that the assigned meaningfulness of activity also contributes to our activity selection decisions. Perhaps activities with greater meaning would be selected more often and engaged in more frequently than less meaningful ones.

Other psychological predictors such as cognitive costs and levels of intrinsic motivation have been shown to play a role in predicting engagement in everyday activities (Ennis et al., 2014; Hess et al., 2018). As an extension of the SOC model, the Selective Engagement Theory (SET; Hess, 2014) states that engaging in demanding activities is related to the cost (i.e., subjective experience) associated with such engagement, leading to selective participation through changes in motivation. It may also be the case that engagement in meaningful activities is related to a heightened subjective experience associated with those experiences, leading individuals to more selective participation in more meaningful activities. According to the environmental complexity hypothesis, if the cognitive effort is rewarded from a complex environment, individuals will become more motivated to apply mental resources across different situations and contexts, improving cognitive performance (Schooler et al., 1999). From this perspective, meaningfulness might stimulate cognitive ability by promoting selective activity engagement and motivation (Atchley, 1989; Baltes & Baltes, 1990; Hocking, 2009; Scheier et al., 2006). By assessing meaningfulness, which presumably motivates action or involvement in leisure activity, this research represents a novel approach for exploring associations with cognition, and a potentially existential way of better defining engagement across adulthood (Wang et al., 2012).

The purpose of Study 1 was to identify the structural nature between activity engagement, meaningfulness, and cognition and to determine the predictive ordering in which these associations occurred. Two mediations models were tested in Study 1 using Structural Equation Modeling (SEM) to determine the directional effects of frequency of activity engagement and meaningfulness of activity engagement on cognition. SEM is a sophisticated analytic approach specifically for mediation models because it combines path analysis and factor analysis. This cross-sectional mediation analysis provided insight into the mechanisms responsible for higher cognitive performance and clarified the directionality of associations between three key constructs: Activity, Meaningfulness, and Cognition.

Research Questions and Hypotheses. Each mediational analysis occurred in two steps involving a separate model, using SEM as the estimation method. The goals here were first to test the association between the predictor variable and the outcome (i.e., cognition) at baseline (direct effect model), then to test for mediating effects on the association between predictor and outcome (indirect effect model). The primary purpose of this investigation was to disentangle the respective contributions of activity engagement and meaningfulness on cognition. The expectation was that all three variables would be related to one another. However, the direction of associations between predictor variables (i.e., activity and meaningfulness) is unknown. According to theories of leisure and recreation, there seems to be a reciprocal relationship between the selection of activities and the personal meaning ascribed to specific experiences (Coleman & Iso-Ahola, 1993). Further, the study of individuals' experiences of engagement through meaningful activity may advance understanding of how leisure relates to cognition. The following research questions were designed to test two different directional pathways.

Research Question 1. Does meaningfulness mediate the relationship between activity engagement and cognitive performance?

Hypothesis 1*a*. In step 1, the direct effect model was tested. I predicted that higher activity engagement would positively predict cognitive performance. This effect would emerge as a significant positive regression coefficient linking activity to cognition in the direct effect model.

Hypothesis 1*b*. In the second model (indirect effect model), meaningfulness was added to test for mediation effects. As indicated by a significant positive regression coefficient, I predicted that higher activity engagement would positively predict greater meaningfulness. I also hypothesized that greater meaningfulness would positively predict higher cognitive performance, also indicated by a positive regression coefficient. In this model, I predicted that the addition of meaningfulness as the mediator variable would reduce the direct effect between activity and cognition, demonstrating that the association between greater activity and better cognition performance was mediated by meaningfulness.

In the first scenario (RQ1), activity served as the independent predictor of cognition, and meaningfulness was tested for mediating effects on this activity-cognition relation. In line with the RQ1, consider the following situation as an example: a retired female nurse, age 63, frequently volunteers around the local community and provides help with housekeeping needs and yard work for her neighbors, in addition to being the primary caregiver to her spouse. Engagement in these activities may reflect the type of person she is, make her feel more competent, and promote a sense of social belonging. Participating in activities like volunteering, providing social assistance, and caregiving, which utilizes her preferred cognitive skills, may improve overall functioning. Thus, more frequent engagement in cognitively stimulating activities promotes greater subjective meaning surrounding those activities, which leads to gains in cognitive ability. In this example, the frequency of activity engagement predicts greater meaningfulness, leading to changes in motivation and better utilization of cognitive skills and resources that promote cognitive functioning.

However, it may also be the case that higher meaningfulness predicts a greater frequency of activity engagement. Thus, another directional scenario (RQ2) was proposed; here, the roles of predictor and mediator were switched, where meaningfulness now served as the independent predictor of cognition, and activity served as the mediator.

Research Question 2. Does activity mediate the relationship between meaningfulness and cognitive performance?

Hypothesis 2*a*. In the first step, the direct effect model was tested. I predicted a significant positive direct effect between meaningfulness and cognition, meaning that greater meaningfulness was associated with higher levels of cognitive performance.

Hypothesis 2*b*. In the second step, activity was added to test for mediation effects on the relationship between meaningfulness and cognition. I hypothesized that the regression coefficients linking meaningfulness to activity, and meaningfulness to cognition, would be significant and positive, indicating that greater meaningfulness was associated with higher levels of activity and higher levels of activity were associated with higher cognitive performance. In this model, I predicted that the addition of activity as the mediator variable would reduce the direct effect between meaningfulness and cognition, demonstrating that the association between greater meaningfulness and higher cognitive performance was mediated by the level or frequency of activity participation.

As justification for the second directional scenario (RQ2), consider the following situation as an example: the same retired female nurse, age 63, has always enjoyed helping others and providing care for those around her because it makes her feel more valued and accomplished. Given these preferences, she frequently volunteers around the community, aids her neighbors, and serves as her spouse's primary caregiver. Her intrinsic motivation to help others promotes greater meaningfulness. This increases her selection of certain social activities, creating a more stimulating environment and improving her cognitive skills. If the RQ2 scenario is correct, then the subjective experience (i.e., meaningfulness) would predict the selection and frequency of activity participation, leading to greater cognitive ability.

Methods

Data for this analysis was collected between 2016-2018 and taken from the Recording Everyday Activities and Cognition using Tablets (REACT) study conducted at Colorado State University (CSU). The REACT study examined cognition and activity via questionnaires and used a momentary format that supplied participants with mobile tablets to record activity patterns and assess ambulatory cognitive performance. In this cross-sectional analysis (Study 1), baseline scores were analyzed to determine the structural associations between activity, meaningfulness, and cognition at baseline (before the 14-days of tablet testing). In Study 2, the daily momentary data was longitudinally analyzed to assess changes in daily performance across time. Methods specific to Study 2 will be described in the next chapter.

Participants. The targeted age group was both men and women aged 40 years and older. Recruitment occurred via a variety of sources, including existing databases of older adults who were permitted to be contacted for future research studies; IRB approved advertisements on listservs and via university newsletters (e.g., CSU's Society for Senior Scholars; CSU's Source) and advertisements at various community locations where fliers were posted. To meet inclusion criteria, participants had to be English-speaking adults aged 40 years or older, not have a clinical diagnosis of dementia, or suffer from any significant visual or hearing impairment. Participants were also required to wake regularly between the hours of 4 -10 am to fit into one of six beeping schedules for the tablet prompts.

Of the 100 adults who participated in the REACT study, only 81 individuals completed all study parts. The enrolled participants who did not complete the study dropped out after the first or second testing session (n = 19); reasons for discontinuing the study were cited as time constraints, occupational interferences, and other personal reasons that limited availability adheres study procedures. There were 59 females and 22 males, and the mean age was 61.26 years (SD = 12.18), ranging from 41 to 94 years old. Within the sample, 92.6% of the participants were Caucasian, 54.3% were married, and 71.6% reported living with others. For educational attainment, 13.6% reported having a high school diploma (n = 11), and 49.4% reported having some college-level education (e.g., technical, associate's, bachelor's degree). The average years of education for the entire sample was 17.35 years (SD = 2.79). There were 29 participants (35.8%) who reported graduate-level education. For marital status, many participants were either married (n = 44) or separated/divorced (n = 22). And only 18.5% of the sample reported being single or widowed (n = 15). Most participants reported living with others (71.6%) rather than alone (n = 22), and 64.2% of the sample was not yet retired, although the remaining 29 participants reported either complete or partial retirement. Nearly 75% reported household incomes higher than $50,000. The mean income reported was 3.45 (SD = 1.54), which was coded at five levels: 1 = Less than $25,000; 2 = $26,000 to $50,000; 3 = $51,000 to $75,000; 4 = $76,000 to $100,000; 5 = More than $100,000. Most participants (n = 77) reported good, very good, or excellent health status. The mean health status was 3.75 (SD = .70), which was coded at four levels: 1 = Fair; 2 = Good; 3 = Very Good; 4 = Excellent.

Procedure. All participants went through the following testing schedule: baseline testing session, 2nd testing session, 14-days of tablet testing (completing daily surveys and cognitive exercises), and a final feedback session. All testing sessions occurred on campus in the Behavioral Sciences Building and were conducted by a trained Healthy Cognitive Aging Lab member. The baseline session was scheduled when the participant was available to a) return 2-3 days later to complete the 2nd testing session; and b) complete the tablet portion of the study for the following two weeks. The Institutional Review Board approved all study procedures at Colorado State University.

The first session (baseline) was conducted in a small group setting and took approximately two hours to complete. Participants were first asked to read the consent form and sign if they agreed to participate in the study. Next, participants completed a series of questionnaires and surveys that collected basic demographic and health information, a general activity questionnaire, and other questionnaires about personality and meaningful activity. The participants were then instructed on how to use the tablets and answer surveys on the tablets. After the baseline session, participants took the tablet home for 2-3 days of practice and then returned to the lab for the 2nd testing session. At the beginning of the 2nd session, the tester checked the data from the tablet to make sure data was being correctly recorded and to ensure the participant was answering the surveys and completing the cognitive exercises. Any problems with the tablet or questions that the participant had about answering the surveys were addressed. The tester then administered a series of cognitive tests. This session took approximately an hour to complete, and the tablet was then returned to the participant to complete the two-week tablet testing period. After two weeks, participants returned their tablets to the lab and completed a brief feedback questionnaire, which took approximately 15 minutes.

No compensation was directly provided for participation; instead, a drawing for 10 Samsung Galaxy Tablets, worth approximately $150 each, and 20 $50 Amazon gift cards, occurred after study completion. Each participant who completed the study received one entry into the drawing; if they achieved at least 90% compliance in completing the daily survey over the two weeks, they received an additional entry.

Measures. At the baseline session, a trained research assistant administered questionnaires to measure activity[1] and meaningfulness[2]. Cognitive testing[3] took place during the 2nd session. Only data from baseline and the 2nd session were used for analysis in Study 1. The baseline instruments used to measure each key constructs in Study 1 are reported in the footnotes

[1] To measure Activity, the Victoria Longitudinal Study Activity Questionnaire (VLS-AQ) was used.
[2] To measure Meaningfulness, the Engagement in Meaningful Activities Survey (EMAS) was used.
[3] Cognitive testing involved seven tasks (Coding Symbol Digit, Opposites, Letter Sets, Letter Number Sequencing, Trail Making Test, Visual Puzzles, Explicit Memory).

below. The next chapter will describe the measures relevant to Study 2; here, the focus remained on presenting methodological information specific to the cross-sectional analysis (i.e., Study 1).

Activity Assessment. The Victoria Longitudinal Study Activity Questionnaire (VLS-AQ; Hultsch et al., 1993) was originally developed to assess participation across multiple activities. Originally, the VLS-AQ included 70 short activity descriptions. Individuals indicated the frequency of each activity on a 9-point Likert-type scale. Response options included: 0 = never, 1 = less than once a year, 2 = about once a year, 3 = 2 or 3 times a year, 4 = about once a month, 5 = 2 or 3 times a month, 6 = about once a week, 7 = 2 or 3 times a week, and 8 = daily. Hultsch et al. (1999) used factor analysis on the questionnaire items categorizing them into the following activity factors: Physical, Social, Self-Maintenance, Passive Information Processing, Integrative Information Processing, and Novel Information Processing. Using this factor structure, intellectually stimulating activities such as doing crossword puzzles and reading, was shown to be predictive of rates of cognitive decline in older adults (Hultsch et al., 1999). Jopp and Hertzog (2007) extended the original questionnaire by adding 12 new items, including seven physical and five social activities. The new physical activity items were aerobics (e.g., cardiovascular exercise, fitness training, workout), flexibility training (e.g., stretching, yoga, tai chi), weightlifting, strength training or calisthenics, walking (e.g., around the block, in the mall, in lieu of driving), swimming, bicycling, dancing (e.g., swing, ballroom, jazz, country). The new social activities were talking to a friend on the phone, go out with a friend, attend a party, attend an organized social event (e.g., at the senior center, fraternity events, church social groups), and engage in political activities (e.g., neighborhood organization, environmental club). Researchers showed that a general activity factor predicted cognition and self-rated memory function in an older adult sample (Jopp & Hertzog, 2007). Then, Jopp and Hertzog (2010) used exploratory and confirmatory factor analysis to examine the VLS-AQ once again; item reduction identified 23 items for removal, and the remaining 57 items were included in the final analysis (Jopp & Hertzog, 2010). Authors found an 11-factor structure of the VLS-AQ that organized items into the following factors: Physical, Crafts, Games, TV, Social Private, Social Public, Religious, Travel, Experiential, Developmental, and Technology. The abbreviated version of the VLS-AQ was used for the present study, based on the Jopp and Hertzog (2010) factor analysis (see Appendix A), this questionnaire included 57 activity items. Participants were instructed to indicate how often they engaged in each activity over the past two years. Response options indicated the frequency of participation on the 9-point Likert scale mentioned above. For older adults, Jopp and Hertzog (2010) reported Cronbach's alpha for the eleven activity categories ranging from .15 (Travel) to .78 (Craft) in one sample and .38 (Experiential) to .81 (Craft) in another sample.

Meaningful Engagement. The Engagement in Meaningful Activities Survey (EMAS; (Goldberg, 2002; Eakman, 2012) is an occupational instrument created to address constituents of meaningful engagement and assess aspects of activity meaning (Eakman, 2012; Hammel, 2004). The EMAS is a 12-item survey that has established validity as a tool for assessing activity meaning (Eakman et al., 2010b; Eakman, 2012). Each of the 12 items begins with the phrase, "The activities I do…" and includes, respectively, help me take care of myself (e.g., keep clean, budget my money), reflect the kind of person I am, express my creativity, help me achieve something which gives me a sense of accomplishment, contribute to my feeling competence, are valued by other people, help other people, give me pleasure, give me a feeling of control, help me express my values, give me a sense of satisfaction, and have just the right amount of challenge (see Appendix B). The scaling for the EMAS in the present study was as follows: 1 =

rarely, 2 = sometimes, 3 = usually, 4 = always, based on recommendations by Eakman (2012). This scaling was altered from an earlier five response version that included never as an option (e.g., 1 = never to 5 = always; Goldberg et al., 2002). This scale has been used in community and institutional dwelling older adult populations to demonstrate that greater meaningfulness is associated with greater health, well-being, and life satisfaction (Eakman et al., 2010a; Eakman et al., 2010b; Eakman, 2016). In occupational therapy sciences, the EMAS has been related to measures of meaning and purpose in life and basic psychological needs (e.g., competence, self-esteem, mastery), thus supporting its criterion-related and convergent validity (Eakman et al., 2018). Previous factor analytical research (Eakman et al., 2010a) has found that the EMAS forms into two separable yet related factors: Social-Experiential Component (SEC), which included items reflecting pleasure, satisfaction, control, just-right challenge, and expression of personal values; and the Personal Competence Component (PCC), which included activity meanings related to personal experience with competence or achieving accomplishment, expression of the self, and personal creativity. This two-factor model of the EMAS has also been validated by other researchers, using a Spanish version of the survey (Prat et al., 2019). The Eakman (2018) study reported a person reliability index of 0.85, indicating good measurement reliability in the sample.

Cognitive Functioning. To measure cognitive performance in Study 1, cognitive testing was conducted, using both computerized and paper and pencil forms.

Coding Symbol Digit Task (Wechsler, 2008a). For this task, research personnel first explained the instructions and then gave a brief demonstration. The instructions indicated boxes at the top of the page; each box had a number in the top part and a unique mark in the bottom part. Participants were given the form and instructed they would have 90 seconds to fill in as many boxes as possible with the correct symbol that matched the number in each box. Research assistants used the coding scoring template to count the total number of correct responses and record this value to score this task. The outcome measure for this task was the total number of correctly written symbols. This task served as a measure of visual processing speed and short-term visual memory.

Letter Sets (Ekstrom et al., 1976). For this task, participants were instructed that one letter set did not follow the same pattern or rule as the other four-letter sets and to draw an X through the one letter set that was unlike the others. Each set contained four letters. Participants were allowed seven minutes to complete this test. To score this task, the tester marked each correctly identified item, and then the total correct number was recorded. The outcome score for this task was the total number of correct responses. This task measured reasoning ability.

Opposites Test (Wechsler, 1939). Participants were given the testing sheet and asked to think of words that were the opposite or nearly the opposite in meaning to the given word. Participants were given five minutes to complete this test and provide (up to six) opposite words for each of the four words listed (calm, wrong, fair, awkward). Testers were given an example list of acceptable words, and scores were totaled, and the total number of correctly written opposite words out of 24. This task measured verbal fluency.

Letter-Number Sequencing (Wechsler, 1939). Each test item included three trials. The tester read each trial at a rate of one number or letter per second for each sequence, and then the participant was asked to repeat back starting with the numbers first, followed by the letters in alphabetical order. The first few trials started with simple two letter-number set combinations and then progressed to more complicated sequences. The task was discontinued if the participant scored a 0 on all three trials of an item set. Credit was given if all the numbers and letters were recalled in the correct sequence, even if the letters were recalled before the numbers. The longest sequence of letter-number combinations, where participants correctly identified each letter-number trial, was recorded as the final score. This task measured attention, and the ability to manipulate and reorder information in working memory.

Trail Making Test (TMT) (Reitan, 1992). Both Parts A and B of the TMT were administered. For Part A, participants were given the form and the administrator demonstrated that they were supposed to start at the number 1 and draw a line from 1 to 2, 2 to 3, etc. until they reached the circle marked "end." The administrator used a stopwatch to time the participant's score and record the number of near misses and the total time it took to complete the task. For Part B, the same process was followed, except this time the form had numbers and letters, and participants were asked to draw a line from 1 to A, A to 2, 2 to B, B to 3, 3 to C, and so on, in order, until they reached the stopping point. A stopwatch was used to record the time for participants to complete the task as well as record any near misses in the process. Part A measured visual-processing speed and Part B measured executive functioning, as it required attention and task-switching. the TMT difference score was used as an outcome and was derived from subtracting the RT on Part A from the RT on Part B.

Visual Puzzles (Wechsler, 2008a). The WAIS-V Visual Puzzle Administration book was used, and participants were shown a demonstration, and then several practice items were completed. This visual task required participants to view a completed puzzle and select three response options that, when combined, reconstructed the puzzle. Participants were asked to look at all the pieces for each puzzle and then choose only three correct pieces from 6 response options that could be put together and rearranged to complete the puzzle. Pieces were not allowed to be placed on top of each other or overlap, and three pieces had to be chosen to fit together to complete the puzzle. For each puzzle, participants were given 20 seconds to respond. The first four puzzles were practice items, and there were 26 total puzzle questions. The total number of correctly identified puzzle options for items 5 to 26 was recorded. Administrators discontinued the task if the participant scored 0 on three consecutive trials. This task was designed to measure nonverbal reasoning and an individuals' ability to analyze and synthesize visual stimuli as well as anticipate relationships among parts.

Explicit Memory Test. A laptop and PowerPoint presentation was used for administration. Instructions were read verbally to the participants, and they were instructed to read along as the instructions were presented on the screen. The presentation then automatically displayed a list of 12 common words one at a time, followed by a quick arithmetic question. Next, the administrator asked the participant to recall as many of the words presented on the screen, the order was not important, and responses were recorded on the scoring sheet. This process was repeated two more times with two different word lists, each containing 12 words. The total number of correctly recalled words was recorded as well as any additional words that were recalled but not presented in each list. The outcome measure for this task was the total number of correctly recalled words across all three trials. This task measured working memory and visual attention as it included a distractor (arithmetic question) in-between the visual presentation of words and prompted verbal recall.

Statistical Analyses. Statistics were performed using SEM. All data preparation and statistical analysis was performed using SPSS Statistics version 26. Data was checked for missing values, and for data entry errors. Skewness and kurtosis were examined for all variables to ensure each was normally distributed. Prior to analyses, all data was reviewed using missing data analysis. Little's (1988) Missing Completely At Random Test was nonsignificant for both activity and meaningfulness questionnaires: for the EMAS, χ^2 (8) = 11.76, p = .16, and for the VLS-AQ, χ^2(200) = 224.19, p = .12 meaning that the data was missing at random. Less than 5% of the data was missing from the VLS-AQ and EMAS, and expectation maximization (EM) procedures were used to input missing data for these constructs. EM is an iterative method to find the maximum likelihood estimates for model parameters when data is incomplete or missing. For the cognitive tasks, EM estimates were not computed because there was no missing data.

Prior to testing the mediation models using SEM, a series of factor analyses were performed for each of the main variables: activity, meaningfulness, cognition. This was necessary to confirm prior factor solutions proposed by Jopp & Hertzog (2010) for the VLS-AQ, and by Eakman et al. (2010a) for the EMAS. For the VLS-AQ and EMAS, confirmation of prior factor solutions was first conducted, prior to any exploratory analysis. Then, to determine the factor structure that best fit the present data, exploratory factor analysis (EFA) was performed, followed by confirmatory factor analysis (CFA), which evaluated model fit for the factor structure identified through EFA. The same process of EFA and CFA was performed for all main variables including cognition. The goal of the factor analysis for cognition was to classify tasks with similar functional properties and to determine the cognitive factor structure that best fit the data. Once the ideal factor structure underlying each latent variable was confirmed, descriptive statistics were reported, and mediation analysis proceeded. These factor analyses are described in the results section.

Mediation Models. Two mediation models were tested to address each of the research questions for Study 1. In each model, there were three latent variables: Activity, Meaningfulness, and Cognition. For each model, standardized regression coefficients (β) were reported as well as SEM indicators of model fit (e.g., χ^2 goodness of fit statistic, root-mean-square error approximation). Figure 3.1 shows the steps involved in Model 1 which tested the direct and indirect effects of activity on cognition (Hypotheses 1*a* and 1*b*).

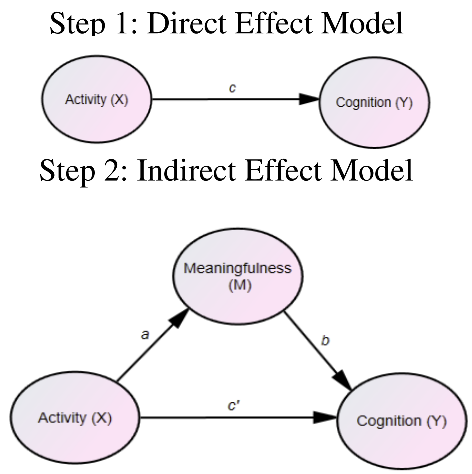

Figure 3.1. *Testing Mediation Model 1*

To address research question 1, Activity was the independent predictor variable (*X)*, Meaningfulness was the mediator variable (*M),* and Cognition was the outcome or dependent variable (*Y)*. In step one, the *direct effect* of the independent variable, Activity (*X)* on the dependent variable, Cognition (*Y*) was tested, denoted by pathway (*c).* In step two, the mediator variable, Meaningfulness (*M)* was added to the model. The direct effect of the independent, variable, Activity (*X),* on the mediator variable, Meaningfulness (*M),* was denoted by path (*a).* Path (*b)* referred to the direct effect of the mediator variable, Meaningfulness (*M),* on the dependent variable, Cognition (*Y).* Path (*c'*) denoted the *indirect effect* of Activity (*X),* on Cognition (*Y),* as mediated by Meaningfulness (*M).*

To address research question 2, Meaningfulness served as the latent predictor or independent variable (*X)* and Activity was the mediator variable (*M)*. Figure 3.2 shows the steps for Model 2 which was used to address the second research question (Hypotheses 2*a* and 2*b*).

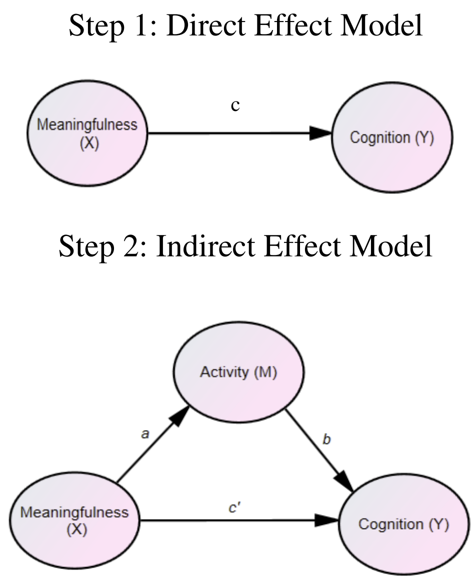

Figure 3.2. *Testing Mediation Model 2*

In step one, the direct effect of the independent variable (*X)* on the dependent variable (*Y*) was tested, denoted by pathway (*c).* Here Meaningfulness served as an independent predictor (*X)* of Cognition (*Y).* In step two, the mediator variable (*M)* was added to the model, here Activity served as the mediator variable. The *direct effect* of the independent variable, Meaningfulness (*X)* on the mediator variable, Activity (*M)* was denoted by path (*a),* path (*b)* referred to the direct effect between the mediator, Activity (*M)*, and the dependent variable, Cognition (*Y),* and path (*c'*) referred to the *indirect effect*, which denoted the association between predictor, Meaningfulness (*X)*, and outcome, Cognition (*Y).*

The purpose of testing these models in separate steps was to allow for comparison of model fit statistics between the direct effect model and the indirect effect models. In the indirect effect models, the presence of mediation will have occurred if the regression path from the independent variable (*X)* to the dependent variable (*Y*), denoted by path (*c')* is non-significant although the direct effect of the independent variable (*X*) on the mediator variable (*M*) denoted by path *(a)* is significant; the regression path (*b)* linking the mediator variable (*M*) to the outcome variable (*Y*) is also required to be significant.

Baron and Kenny's (1986) paper on mediation reported three conditions that must be met to claim that mediation has occurred: (1) the predictor variable is significantly related to the mediator; (2) the mediator variable must be significantly related to the outcome variable; and (3) the relationship of the independent variable on the outcome variable diminishes when the mediator is added to the model (Little et al., 2007). According to this notion, each construct in the model must show evidence of a significant association with each other, and the effect of the independent variable on the outcome must decrease substantially upon adding the mediator as a predictor in the model (MacKinnon et al., 2002). Although Baron and Kenny (1986) provided a conceptually appealing description of the steps to follow to determine the presence of a mediation effect, there has been some disagreement in the literature on the appropriateness and necessity of these requirements, suggesting that these assumptions lead to increased risk for Type I and Type II error (MacKinnon et al., 2002; Zhao et al., 2010). Therefore, in addition to the traditional approach proposed by Baron and Kenny (1986) for estimating direct and indirect effects, bootstrapping methods in AMOS will obtain confidence intervals based on the sampling distribution of paths *(a)* and (*b)* (Arbuckle, 2019). Bootstrapping is a nonparametric approach to effect size estimation that makes no assumptions regarding the shape of each variable's distribution (Hayes, 2009; Preacher & Hayes, 2004). In this study, I chose to test the direct and indirect effects separately and then to compare model fit indices as well as determine the statistical significance of each pathway (direct and indirect effects) in these models. Bootstrapping methods will be used to test the statistical significance of the indirect effects and will provide estimated standard error and both upper and lower bounds of confidence intervals.

Age and education were treated as covariates in each of the models, meaning that each of these covariates will be regressed onto each of the latent variables in each model. The purpose of controlling these covariate effects is based on prior research and theory suggesting that both age and education influence cognitive performance (Hultsch et al., 1993; Schaie, 2001; Schooler, 1990). Age and education are also thought to influence activity engagement (Rousseau et al., 2005), however the effects on meaningfulness are less understood, which justified the need to control for these effects in the SEM models.

Power Analysis. G*Power was used to calculate sample size estimations (Faul et al., 2007; Mayr et al., 2007). However, power analysis programs such as G*Power are limited to simple statistical tests (e.g., t-tests, F-test) and thus are not advanced enough to provide information about required sample sizes for SEM models (Faul et al., 2009). Using simple linear multiple regression, with the power level (1- β) set to .80, a two-tailed linear model with 20 predictor variables would require a sample size of $N = 78$ to detect large effects. This was deemed sufficient given the sample size in the present study was slightly larger than these recommendations ($N = 81$).

Because these mediation models were tested using SEM, factor analysis guidelines must also be considered. Some recommendations for exploratory and confirmatory factor analysis suggest having 5-10 participants for each item in a scale (MacCallum et al., 1999), although others suggest minimums for sample size ranging from 3 to 20 times the number of variables in a model (Kyriazos, 2018). However, there is little empirical evidence to support these recommendations (Bujang et al., 2012). Based on past published CFAs of the VLS-AQ and the EMAS, there were 20 observed variables, 3 latent variables, and 2 covariates. According to sample size calculations for SEM, with observed power (1- β = .80) and probability (α = .05), the minimum sample size for detecting model structure with these parametrizations is N = 156 (Soper, 2020). Model parameters were expected to fluctuate from prior research, especially for cognition, as CFA of the cognitive tasks that were used in the present study have not been published, therefore it was unclear what factors would emerge. Minimum sample sizes appear to be smaller for higher ratios of the number of observed variables to the number of latent variables and when observed-to-latent variable ratios exceeds six (Westland, 2020). Given these sample size recommendations, it is likely that these a-priori mediation models will need to be adjusted and simplified following factor analyses. The latent variable Activity is of concern because it has an observed-to-latent variable ratio of 11:1 (Jopp & Hertzog, 2010), suggesting a larger minimum sample size will be required to detect effects.

Results

Results were obtained through several different analyses and findings are presented here in the order in which they occurred. First, the factor analysis of the activity questionnaire is reported (VLS-AQ). Second, the factor analysis of the meaningfulness survey (EMAS) is presented. Third, the factor structure of the cognitive ability variables is reported. In the final portion of the results for Study 1, mediation models were tested using SEM. In Model 1, a set of two SEMs are presented, comparing the direct effect of activity on cognition and the indirect effect of activity on cognition mediated by meaningfulness. In Model 2, another set of two SEMs are presented, in which the direct effect of meaningfulness on cognition and the indirect effect of meaningfulness on cognition as mediated by activity, were tested. Model fit was evaluated using several indicators: chi-square (χ^2) statistic, where lower values typically indicate better fit; root-mean-square error approximation (RMSEA), where values less than .05 indicate good model fit and generally lower values indicate better model fit; incremental fit index (IFI) and Tucker-

Lewis index (TLI), where for both IFI and TLI higher values indicate better fit; and comparative fit index (CFI), where values of .9 or higher indicates good model fit (Byrne, 2016).

Factor Analysis VLS-AQ-Activity Questionnaire (VLS-AQ). Item analysis was conducted for the VLS-AQ in two parts. In the first part two initial measurement models were tested, based on previous factor analysis using the VLS-AQ. The first was an eleven-factor model developed by Jopp and Hertzog (2010) which specified the following factors: Physical (items 1-6), Craft (items 7-10), Games (items 11-16), TV (items 17-20), Social Private (items 21-26), Social Public (items 27-29, 31), Religious (items 30, 32, 33) Travel (items 34-36), Experiential (items 37-43), Development (items 44-51) and Technology (items 52-57) (see Table 2). Using this eleven-factor structure, CFA revealed poor model fit, χ^2 (1484) = 2775.267, $p <$ .001, RMSEA = .104, confidence interval (CI) = .098-.110, IFI = .39, TLI = .30, CFI = .35.

Next, an alternative seven-factor model proposed by Hess et al. (2018) was tested. For this solution, Hess et al. (2018) justified using a modified 28-item version of the VLS-AQ, which included only the four highest factor loadings on each of the seven subscales (Physical, Games, Social, TV, Experiential, Developmental, Technical), as reported by Jopp and Hertzog (2010). Using the same seven-factor framework proposed by Hess et al. (2018), CFA revealed poor model fit, $\chi^2(329) = 447.024$, $p < .001$, RMSEA = .075, CI = .060-.089, IFI = .74, TLI = .67, CFI = .71.

There were several indications of misfit in both initial models tested, and therefore I doubted the usefulness of these structures and chose to explore other factor solutions that better fit my data. An important distinction between two previous studies that used the VLS-AQ (e.g., Jopp & Hertzog, 2010; Hess et al., 2018) and the present study, was the sample size. Jopp and Hertzog (2010) reported using two samples (N= 267; N = 218) for their 11-factor solution. Hess et al. (2018) reported a slightly smaller sample (N=153) and used a 7-factor structure; in both instances the samples were significantly larger than what was collected in the present study (N = 81).

Therefore, to evaluate the structure of the VLS-AQ within the presently unique and smaller sample, I chose to explore several alternative factor solutions. First, EFA was performed using principal axis factoring extraction and promax rotation with an eigenvalue of 1.0 set for item extraction. The Kaiser-Meyer-Olkin measure of sampling adequacy was .337, and Bartlett's test of sphericity was significant χ^2 (1596) = 2699.65, $p < .05$, indicating that the items were related, and the correlation matrix was suitable for structure detection. Nineteen factors were initially extracted using the eigenvalue criteria of 1.0, with communalities ranging from .46 to .95. Based on a scree plot I narrowed extraction down to seven factors that accounted for 45.99% of the variance in the VLS-AQ. There was little difference between the unrestricted promax and oblimin factor solutions, thus both solutions were examined in subsequent analyses before deciding to use a promax rotation for the final solution. According to the literature, these rotation methods (promax and oblimin) are similar and commonly interchangeable (Tabachnick & Fidel, 2013).

Next, each activity item was evaluated and items with poor statistical properties were removed. This data reduction process occurred sequentially, with the goal being to identify the simplest factor structure solution that provided the strongest fit for the data. Individual item frequencies revealed two items (collect stamps, coins, dolls, etc.; play an instrument) with more than 50% of the sample having reported never participating in these activities over the past two years. These items were removed due to a floor effect which positively skewed the data. Nine more items (travel out of town; travel out of state; travel abroad; read for leisure; read newspapers; garden indoors or outdoors; engage in sewing, knitting, or needlework; attend movies; prepare my own income taxes) were removed because they did not have factor loadings of .3 or above on any of the seven factors. The .3 factor loading cut-off was based on recommendation by Mulaik (2009). Table 2 reports the factor loadings for all activity items and * denotes activity items that were removed during the reduction process. The extracted communalities from this EFA are also listed. Using this reduced structure with the 21 items removed, another series of promax rotations were performed. During this next set of iterations, an additional ten items were eliminated because they failed to meet the minimum criteria of having a primary factor loading of .3 or above (outdoor activities; recreational sport; watch game shows on television; give a dinner for friends; eat out at a restaurant; attend club meetings; engage in prayer or meditation; write letters; read books as part of my job; attend a public lecture; go to the library). The remaining 34 items fit nearly exclusively across one of the seven factors (see bolded numerical values in Table 3.1 for factor loading determinations).

Table 3.1. *7-Factor EFA factor loadings and communalities for the VLS-AQ*

		Promax Rotated Structure Matrix							
		1	2	3	4	5	6	7	Communalities
1	Weight lifting, strength or calisthenics exercises				**.66**				.48
2	Aerobic activities: cardio, fitness, or working out				**.79**				.77
3	Flexibility activities: stretching, yoga, or tai chi				**.44**				.27
*4**	*Outdoor activities: sailing, fishing, or backpacking*								
5	Exercise activities: jogging, bicycling, or swimming		-.32		**.57**				.39
*6**	*Recreational sports: tennis, bowling, or golf*								
7	Repair a mechanical device			**.77**					.63
8	Do household repairs			**.74**					.61

9	Do woodworking or carpentry			**.70**				.55
10	Buy a new item requiring set-up			**.58**	.36			.49
11	Play word games		**.87**					.83
12	Play knowledge games		**.78**					.67
13	Play board games	.40	**.55**					.45
14	Play jigsaw puzzles							.25
15	Do cross-word puzzles		**.53**					.39
16	Play card games		**.39**					.30
17	Watch comedy or adventure programs on television				**.57**			.45
18*	*Watch game shows on television*							
19	Watch documentaries on television				**.73**			.59
20	Watch news programs on television				**.53**			.45
21	Go out with friends	**.64**						.44
22	Visit friends or relatives	**.68**				.32		.63
23	Attend parties (e.g. birthday)	**.59**						.41
24	Talk to (a) friend(s) on the phone	**.68**						.48
25*	*Give a dinner for friends*							
26*	*Eat out at a restaurant*							
27	Engage in political activities	.32					**.34**	.34
28	Give a public talk						**.51**	.41
29*	*Attend club meetings*							
30	Attend organized social events	**.65**					.42	.66
31	Volunteer	**.50**						.37
32	Attend church services or synagogue	**.42**						.25
33*	*Engage in prayer or meditation*							
34*	*Travel out of town*							
35*	*Travel out of state*							
36*	*Travel abroad*							
37	Engage in business activities not related to my job					**.56**		.46
38*	*Collect stamps, coins, dolls, etc.*							
39*	*Read for leisure*							
40*	*Read newspapers*							
41*	Garden indoors or outdoors							
42*	*Write letters*							
43*	*Engage in sewing, knitting, or needlework*							
44*	*Read books as part of my job*							
45*	*Attend a public lecture*							

46	Enroll in a course at a university		**.43**		.25
47	Engage in creative writing		**.43**		.26
*48**	*Go to the library*				
49	Study a foreign language		**.62**		.47
50	Engage in an on-the-job training program			**.61**	.42
*51**	*Attend movies*				
52	Use computer software	**.39**			.26
53	Use an electronic calculator			**.34**	.24
54	Do arithmetic calculations	**.42**			.25
55	Engage in photography			**.36**	.28
*56**	*Play an instrument*				
*57**	*Prepare my own income taxes*				

Notes: (*) indicates item was removed during data reduction process, 22 total items removed, items 38 and 56 were removed based on frequency distributions; items 4, 6, 18, 25, 26, 29, 33, 34, 42, 44, 45 were reduced because of indeterminate factor loadings across multiple factors; items 34, 35, 36, 39, 40, 41, 43, 51, 57 were eliminated because they dropped out of the structure and did not have any factor loadings >.3 across at least one of the seven factors.

Next, this seven-factor (Physical, Games, Home, TV, Social, Developmental, Technical) solution was tested using CFA. The CFA revealed poor model fit, $\chi^2(507) = 748.92$, $p > .001$, RMSEA = .077, CI = .065-.089, IFI = .68, TLI = .62, CFI = .66. Because the seven-factor structure revealed poor model fit, reduced solutions for six and five factor structures were subsequently explored. Exploratory analysis using principal axis factoring extraction and promax rotation was again performed, this time restricting the solution to extract only six factors from these 34 items to see how these remaining items loaded when the structure was further restricted. Table 3.2 lists the factor loadings and communalities for these 34 items, * denotes activity items that were removed during the reduction phase and bolding indicates primary factor preference. In this six-factor solution, Factor 1 was labeled Games, Factor 2 was labelled Social, Factor 3 signified Home activities which included items related to general household chores, maintenance and repairs, Factor 4 was labeled Physical, Factor 5 was labeled TV and Factor 6 was labeled Developmental activities and included items like engage in business activities not related to my job, engage in creative writing and studying a foreign language. These labeling classifications were kept in line with the original factors proposed by Jopp & Hertzog (2010).

Table 3.2. *6-Factor EFA factor loadings and communalities for the VLS-AQ*

		Promax Rotated Structure Matrix						
		1	2	3	4	5	6	Communalities
1	Weight lifting, strength or calisthenics exercises				**.69**			.47
2	Aerobic activities: cardio, fitness, or working out				**.82**			.72
3	Flexibility activities: stretching, yoga, or tai chi				**.40**			.21
5	Exercise activities: jogging, bicycling, or swimming				**.57**			.39
7	Repair a mechanical device			**.76**				.60
8	Do household repairs			**.76**				.63
9	Do woodworking or carpentry			**.66**				.48
10	Buy a new item requiring set-up			**.58**				.44
11	Play word games	**.91**						.86
12	Play knowledge games	**.74**						.61
13	Play board games	**.57**	.41					.42
14	Play jigsaw puzzles	**.32**						.17
15	Do cross-word puzzles	**.55**						.41
16	Play card games	**.42**						.29
17	Watch comedy or adventure programs on television					**.67**		.50
19	Watch documentaries on television					**.71**		.58
20	Watch news programs on television					**.55**		.40
21	Go out with friends		**.61**					.42
22	Visit friends or relatives		**.69**					.53
23	Attend parties (e.g. birthday)		**.60**					.38
24	Talk to (a) friend(s) on the phone		**.70**					.50
*27**	*Engage in political activities*							
*28**	*Give a public talk*							
*30**	*Attend organized social events*							
31	Volunteer		**.47**					.33
32	Attend church services or synagogue		**.41**					.23
37	Engage in business activities not related to my job						**.60**	.47
*46**	*Enroll in a course at a university*							
47	Engage in creative writing						**.52**	.28
49	Study a foreign language						**.62**	.44
*50**	*Engage in an on-the-job training program*							
52	Use computer software	**.38**						.23
53	Use an electronic calculator						**.32**	.18
54	Do arithmetic calculations	**.39**						.25
*55**	*Engage in photography*							

Notes: * indicates item was removed during data reduction process. **Bolding** indicates factor determinations based on highest loading values.

The remaining 28 items had primary loadings of .3 or above on at least one of the six factors, accounting for 55.64% of the total variance. Next, using these 28 items, a six-factor

(Physical, Games, Home, TV, Social, Developmental) solution was tested using CFA. The CFA revealed poor model fit χ^2 (309) = 423.82, p > .001, RMSEA = .068, CI = .051-.084, IFI = .79, TLI = .75, CFI = .77. Returning to exploratory analysis the same extraction and rotation procedures were performed again, this time restricting the solution to extract only five factors. In doing so, three TV items were excluded (watch comedy or adventure programs on television; watch documentaries on television; watch news programs on television) because they did not have a primary factor loading of .3 or above on any of the five factors. Two additional items were removed because they also did not have a primary factor loading of .3 or above (use an electronic calculator, play board games), and one item (exercise activities: jogging, bicycling, or swimming) was eliminated because it had cross-loadings of >.3 on multiple factors. This five-factor solution accounted for 53.21% of the variance and included 23 items. Table 3.3 displays the factor loadings for these items, * indicated items that were removed, and bolding signifies the primary factor determinations used in the CFA. The factor labels for this solution were: Factor 1: Games, Factor 2: Social, Factor 3: Home, Factor 4: Physical, Factor 5: Developmental.

Table 3.3. *5-Factor EFA factor loadings and communalities for the VLS-AQ*

		Promax Rotated Structure Matrix					
		1	2	3	4	5	Communalities
1	Weight lifting, strength or calisthenics exercises				**.68**		.48
2	Aerobic activities: cardio, fitness, or working out				**.87**		.77
3	Flexibility activities: stretching, yoga, or tai chi				**.40**		.19
*5**	Exercise activities: jogging, bicycling, or swimming	-.31			**.53**		
7	Repair a mechanical device			**.74**			.56
8	Do household repairs			**.79**			.66
9	Do woodworking or carpentry			**.69**			.51
10	Buy a new item requiring set-up			**.55**			.35
11	Play word games	**.92**					.86
12	Play knowledge games	**.73**					.61

*13**	*Play board games*						
14	Play jigsaw puzzles	**.33**					.18
15	Do cross-word puzzles	**.59**					.43
16	Play card games	**.43**					.27
*17**	*Watch comedy or adventure programs on television*						
*19**	*Watch documentaries on television*						
*20**	*Watch news programs on television*						
21	Go out with friends		**.64**				.43
22	Visit friends or relatives		**.70**				.54
23	Attend parties (e.g. birthday)		**.57**				.33
24	Talk to (a) friend(s) on the phone		**.68**				.48
31	Go out with friends		**.50**				.33
32	Visit friends or relatives		**.38**				.20
37	Engage in business activities not related to my job					**.61**	.42
47	Engage in creative writing					**.46**	.26
49	Study a foreign language					**.65**	.48
52	Use computer software	**.32**					.18
*53**	*Use an electronic calculator*						
54	Do arithmetic calculations	**.39**					.25

Notes: (*) indicates item was removed during data reduction process, bolding indicates primary factor loading preference.

Next CFA was performed using this five-factor solution. The results indicated adequate model fit, χ^2 (220) = 284.80 p = .002, RMSEA = .061, CI = .038-.080, IFI = .86, TLI = .82, CFI = .85. The standardized loading coefficients from this CFA are reported in Table 3.4. The standardized factor loadings from this CFA were all significant ($p < .05$). However, the correlations between the latent factors were low and showed substantial variation, according to the CFA latent variable correlations which ranged from -.01 between Home and Developmental to .23 between Home and Social.

Table 3.4. *Five Factor EFA factor loadings and communalities for the VLS-AQ*

	Item	VLS-AQ Activity Factors				
		Physical	Games	Home	Social	Developmental
1	Weight lifting, strength or calisthenics exercises	.75				
2	Aerobic activities: cardio, fitness	.85				
3	Flexibility activities: stretching, yoga	.43				
7	Repair a mechanical device			.71		
8	Do household repairs			.83		
9	Do woodworking or carpentry			.66		
10	Buy a new item requiring set-up			.54		
11	Play word games		.92			
12	Play knowledge games		.71			
14	Play jigsaw puzzles		.34			
15	Do cross-word puzzles		.62			
16	Play card games		.43			
21	Go out with friends				.68	
22	Visit friends or relatives				.73	
23	Attend parties (e.g. birthday)				.57	
24	Talk to (a) friend(s) on the phone				.68	
31	Go out with friends				.44	
32	Visit friends or relatives				.32	
37	Engage in business activities not related to my job					.45
47	Engage in creative writing					.46
49	Study a foreign language					.88
52	Use computer software		.29			
54	Do arithmetic calculations		.33			

Internal consistency was examined using Cronbach's alpha. The alphas were moderate: Factor 1: Physical α = .70; Factor 2: Games α =.73; Factor 3: Home α =.77; Factor 4: Social α =.70; Factor 5: Developmental α =.59. No substantial increases in Cronbach's alpha for any of the factors could have been achieved by removing any of the items. Next, composite scores were created for each of the five factors, based on the mean of the items which had their primary loadings on each factor, with higher scores representing greater frequency of activity engagement. Descriptive statistics are presented in Table 3.5. Although a promax rotation was used, only small correlations between each of the composite scores existed. Table 3.6 displays the correlation matrix for the factor composite scores. Overall, these analyses indicate that five distinct factors underlie the VLS-AQ in our sample and that these factors scales were moderately internally consistent. Only 23 of the 57 items comprised the final solution, thus a significantly reduced and modified version of the original factor structure proposed by Jopp and Hertzog (2010) was used for remaining present analyses.

Table 3.5. *Descriptive statistics of the five factor composite scores of the VLS-AQ (N = 81)*

	M (SD)	Skewness	Kurtosis	Cronbach's alpha
Factor 1: Physical	4.92 (2.12)	-0.72	-0.24	.70
Factor 2: Games	4.66 (1.46)	-0.52	-0.35	.73
Factor 3: Home	2.88 (1.16)	0.99	1.39	.77
Factor 4: Social	4.06 (1.20)	0.44	-0.28	.70
Factor 5: Developmental	1.30 (1.39)	1.29	1.08	.59

Table 3.6. *Correlation matrix of Activity factor composite scores*

	Physical	Games	Home	Social	Developmental
Physical	1	.02	-.12	.13	.12
Games	.02	1	.05	.08	-.01
Home	-.12	.05	1	.10	.01
Social	.13	.08	.10	1	.14
Developmental	.12	-.01	.01	.14	1

Note: The correlation matrix shown above reports the factor composite score correlations which were created by combining the means of all items with primary loadings together for each of the five factors.

Factor Analysis of EMAS. Item analysis was conducted for the EMAS in two parts. My initial measurement model followed the proposal of Eakman et al., 2010b, which specified two components of the EMAS: Social-Experiential Component (SEC) and Personal Competence Component (PCC). This two-structure model of the EMAS has also been validated by others (Prat, 2018). According to this structure, items 1-5 represented the PCC and items 6-12 represented the SEC component. Using this factor structure, CFA revealed adequate model fit, $\chi^2(54) = 95.17$, $p < .001$, RMSEA = .098, CI = .064-.129, IFI = .86, TLI = .83, CFI = .86. However, the chi-square statistic was significant ($p < .001$), the RMSEA was greater than .05 and the CFI was below the .90 recommendation (Byrne, 2016), meaning that this model was an adequate but not good fit for the data.

Next, to evaluate the structure of the EMAS within our sample, exploratory factor analysis was conducted using principal components with an eigenvalue of 1.0 set for item extraction. The Kaiser-Meyer-Olkin measure of sampling adequacy was .84, above the recommended value of .6, and Bartlett's test of sphericity was significant $\chi^2(66) = 335.13$, $p < .05$. In search for simple structure, varimax and promax rotations were utilized as with the VLS-AQ. Structure coefficients (> 0.30 to identify substantial loadings) were used to guide interpretation.

Both EFAs resulted in a three-structure factor solution that explained 60.7% of the variance in the EMAS; communality values ranged from .29 to .77. The varimax (uncorrelated components) rotation first used to identify the simple structure resulted in half of the EMAS items having structure coefficients (ranging from .31 to .75) loading across all three factors. The promax (correlated components) rotation was then employed resulting in half of the items having structure coefficients (ranging from .32 to .87) loading across all three factors. Upon examination, there was little difference between the three-factor varimax and promax solutions (see Table 3.7). Factor 1 accounted for 39.04% of the variance and contained items 1, 2, 3, 7. Factor 2 accounted for 12.32% of the EMAS variance and contained items 4, 8, 11, 12. Factor 3 accounted for 9.34% of the EMAS Variance and contained items 5, 6, 9, 10.

Table 3.7. *EFA and item analysis coefficients for the EMAS*

	Item Statement	Varimax Factor 1	Varimax Factor 2	Varimax Factor 3	Communalities	Promax Factor 1	Promax Factor 2	Promax Factor 3	Communalities
1	Take care of self	**.69**			.55	**.73**	.42		.55
2	Reflect the person I am	**.76**			.58	**.75**			.58
3	Express my creativity	**.71**			.56	**.73**		.37	.56
4	Sense of accomplishment	.45	**.51**	.37	.60	.61	**.66**	.56	.60
5	Feel competent	.46		**.58**	.60	.59	.43	**.69**	.60
6	Valued by others	.32		**.71**	.62	.46	.32	**.77**	.62
7	Help others	**.50**			**.29**	**.53**			.29
8	Give me pleasure	.42	**.73**		.74	.57	**.81**	.34	.74
9	Feeling of control	-.33		**.77**	.74			**.72**	.74
10	Express personal values	.51		**.60**	.65	.64	.41	**.71**	.65
11	Sense of satisfaction		**.80**	.32	.77	.38	**.87**	.52	.77
12	Right amount of challenge		**.76**		.58		**.74**		.58

The decision to use the correlated (promax) rotation as the final solution was based on model fit indices between the two CFAs reported below; the first used uncorrelated (varimax) components and the second allowed components to be correlated (promax). Using a three-factor, varimax rotation, CFA revealed poor model fit, χ^2 (54) = 132.145, p = .000, RMSEA = .134, CI = .106-.164, IFI = .74, TLI = .67, CFI = .73. However, when a promax rotation was applied to the three latent structures, the CFA revealed significantly better model fit, χ^2 (51) = 66.33, p = .073, RMSEA = .061, CI = .000-.100, IFI = .95, TLI = .93, CFI = .95. Standardized regression weights (factor loadings) for each item based on the results of the CFA are reported in Table 3.8. All factor loadings were significant (p < .05). There were moderate significant correlations between each of the latent factors: Factors 1 & 2 (r = .64, p < .05); Factors 2 & 3 (r = .75, p < .05); and Factors 1 & 3 (r =. 73, p < .05). There is prior research (Eakman et al., 2010b; Eakman, 2012), showing that meanings, such as those evaluated by the EMAS, seem to be correlated which offers further validity for this analytic decision.

Table 3.8. *CFA Standardized Regression Weights for the EMAS Factors*

	Factor 1: Self-Expression & Caring	Factor 2: Personal Experiential	Factor 3: Social Value & Competence
Take care of self	.66		
Reflect the person I am	.63		
Express my creativity	.67		
Help others	.44		
Sense of accomplishment		.73	
Give me pleasure		.78	
Sense of satisfaction		.82	
Right amount of challenge		.48	
Feel competent			.73
Valued by others			.65
Feeling of control			.32
Express personal values			.78

Factor labels proposed by Eakman et al. (2010) were referenced and an additional label was created to account for all three factors. Factor 1 was labeled Self-Expression & Caring, and included items with activity meanings related to self-care, expressing creativity, and helping behaviors. Factor 2 was labeled Personal Experiential and included three items with activity meanings related to personal experiences and sensations (e.g., pleasure, accomplishment, and satisfaction). Factor 3 was labelled Social Value & Competence, and included items related to social value and personal self-control.

Internal consistency for each of the scales was examined using Cronbach's alpha. The alphas were moderate: for Self-Expression & Caring $\alpha = .68$; for Personal Experiential $\alpha =.78$; for Social Value & Competence $\alpha =.72$. All components consisted of 4 items. No substantial increases in alpha for any of the scales could have been achieved by removing any items. Overall, these analyses indicated that three distinct factors underlie the EMAS in our sample and that these factors scales were moderately internally consistent. Composite scores were created for each of the three factors, based on the mean of the items which had their primary loadings on each factor, with higher scores representing more frequent engagement in meaningful activity. Descriptive statistics are presented in Table 3.9. All three factor composite scores were significantly (p < .001) and positively correlated: r = .51 between Factor 1 and Factor 2; r = .56 between Factor 2 and 3; r = .47 between Factor 1 and Factor 3. An approximately normal distribution was evident for the composite score data; thus, the data was well suited for parametric statistical analyses.

Table 3.9. *Descriptive Statistics for the Three-Factors of the EMAS*

	M (SD)	Skewness	Kurtosis	Cronbach's alpha
Factor 1: Self-Expression & Caring	2.89 (.45)	-0.12	0.21	.68
Factor 2: Personal Experiential	3.02 (.45)	0.07	0.26	.78
Factor 3: Social Value & Competence	2.88 (.45)	-0.68	1.47	.72

Factor Analysis of Cognitive Ability. Given the wide range of cognitive tasks used in this study, EFA was performed to reduce and categorize the number of cognitive ability variables. EFA was conducted using principal axis factoring with an eigenvalue of 1.0 set for item extraction of seven cognitive variables. The Kaiser-Meyer Olkin measure of sampling adequacy was .76, greater than the recommended value of .6, and Bartlett's test of sphericity was significant, $\chi^2(21) = 96.48$, p < .05. In search for simple structure, varimax (orthogonal-uncorrelated components) and promax (oblique-correlated components) rotations were utilized in the EFA. Structure coefficients (> 0.30 to identify substantial loadings) were used to guide interpretation. Then, CFA was used to compare model fit between the uncorrelated and correlated structures.

Both EFAs resulted in two factors that explained 54.85% of the variance in the cognitive ability variables; communality values ranged from .19 to .69. The varimax (uncorrelated components) rotation first used to identify the simple structure resulted in four of the cognitive variables items having structure coefficients (ranging from .39 to .55) loading across both factors. The promax rotation was then employed resulting in three of the items having structure coefficients (ranging from .43 to .66) loading across both factors. Factor 1 accounted for 37.09%

of the variance and contained coding-symbol digit, opposites, and explicit memory. The second factor accounted for 17.77% of the variance and contained letter sets, letter number sequencing, TMT difference score, and visual puzzles. There were moderate correlations between the factors, $r = .48$. The rotated coefficient factor scores are listed in Table 3.10 for both varimax and promax rotations, along with the corrected item-total correlation for each cognitive variable. Upon examination, there was little difference between the two-factor varimax and promax rotations (see Table 3.10), thus an additional CFA were performed using both the uncorrelated and correlated structures to compare model fit.

Table 3.10. *EFA and Item Analysis for Cognitive Ability Factors*

	Varimax Factor		Communalities	Promax Factor		Communalities
	1	2		1	2	
Coding Symbol Digit	**.83**		.69	**.81**		.69
Letter Sets	.48	**.55**	.53	.58	**.66**	.53
Opposites	**.40**		.19	**.43**		.19
Letter Number Sequence	.38	**.55**	.44	.48	**.64**	.44
TMT Difference Score		**.45**	.22		**.40**	.22
Visual Puzzles		**.39**	.19		**.43**	.19
Explicit Memory	**.64**		.43	**.65**	.34	.43

Using a two-factor uncorrelated structure, CFA revealed poor model fit, $\chi^2(14) = 26.85$, $p = .020$, RMSEA = .107, CI = .041-.168, IFI = .85, TLI = .76, CFI = .84. However, when the two-factors were correlated the CFA revealed excellent model fit, $\chi^2(13) = 7.495$, $p = .875$, RMSEA = .00, CI = .000-.056, IFI = 1.063, TLI = 1.11, CFI = 1.00. The standardized factor loadings from this CFA listed in Table 3.11 were all significant ($p < .05$), except for TMT Difference ($p = .127$).

Table 3.11. *CFA Standardized Regression Weights (Factor Loading) Cognitive Ability*

	Factor 1: Fluid-Memory	Factor 2: Reasoning-Executive Functioning
Coding Symbol Digit	.72	
Opposites	.46	
Explicit Memory	.72	
Letter Sets		.79
Letter Number Sequencing		.65
TMT Difference		.22
Visual Puzzles		.40

Factor 1 (Fluid-Memory) was represented by three items: coding symbol digit, a measure of processing speed; opposites, a measure of verbal fluency; explicit memory, which required both working memory and visual attention. Factor 2 (Reasoning-Executive Functioning) included four items: Letter Sets, which measured reasoning ability; Letter Number Sequencing, a task that involves attention and executive functioning; TMT Difference Score, which measured executive functioning (task-switching and attention) and was distinct from spatial processing because it was calculated using both parts A and B of the TMT; Visual Puzzles, a task involving nonverbal reasoning and an ability to analyze and synthesize visual stimuli (i.e., executive functioning). Scores on these tasks were first converted into t-scores and then combined to create a mean composite score for each cognitive factor. Internal consistency for each of the factors was examined using Cronbach's alpha. The alphas were moderate: for Fluid-Memory (Factor 1) α =.65; for Reasoning-Executive Functioning (Factor 2) α =.59.

Interestingly, Letter Number Sequencing (LNS) and Explicit Memory (EM), both involving working memory requiring participants to recall verbal information, were factored separately. I argue that LNS can be distinguished from other types of working memory tasks such as EM because of the nature in which information is recalled. LNS not only requires recall working memory but also the organization of verbally presented information, as participants not only had to recall letters and numbers sequentially but to do so following sequential rules (i.e., repeating sequence back starting with the numbers first, followed by the letters in alphabetical order), whereas EM only required verbal recall of visually presented information. In the EM task a computer PowerPoint presented words one at a time on the screen and then the participants were asked to recall the words in any order. The LNS seems to involve more complex executive functions (e.g., attention, task-switching), above and beyond just recalling visually presented information.

Other research has distinguished between similar executive functioning and working memory tasks (Engeroff et al., 2018), suggesting that LNS and EM activate different cognitive skills. This differentiation has been described in the physical activity literature, which has identified attention, processing speed, executive function, memory, and working memory all as separate areas of interest (Engeroff et al., 2018). However, a test that is described as a memory test in some papers can be classified as executive function in others; for example, working memory tests are often grouped within the executive function domain (Sanders et al., 2019) rather than within memory domains. I argue that working memory as measured by the EM task is separate from the more complex executive functioning skills that were required for LNS (e.g., attention, task-switching). Therefore, even though both tasks can serve as indicators of working memory, LNS was grouped along with the other more complex executive functioning tasks.

Mediation Model 1. To address research question 1, the latent independent variable Activity (*X)* was regressed on to the latent outcome variable Cognition (*Y*). Age and education were included as covariates in the model and were regressed onto each of the latent variables. Figure 3.3 shows the SEM diagram and Table 3.12 reports the standardized regression coefficients and *p*-value for path (*c*).

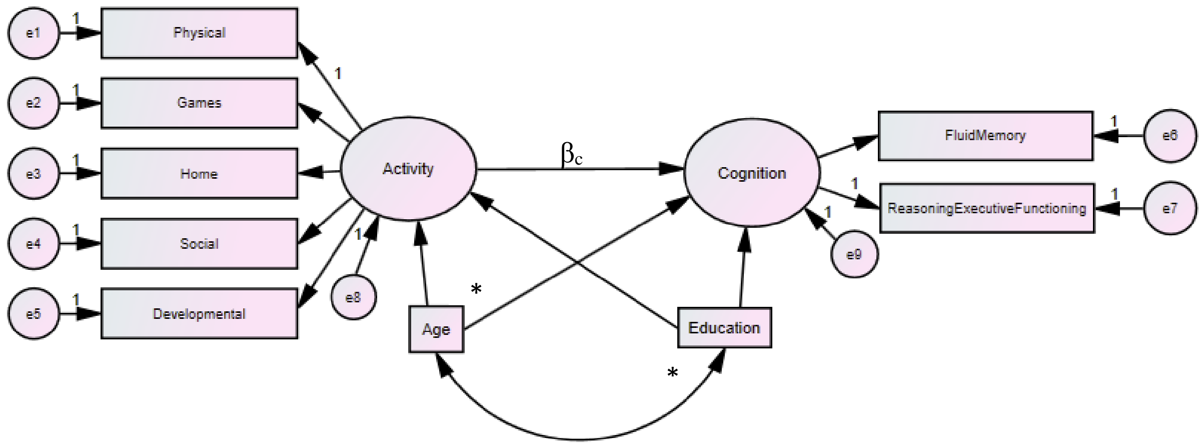

Figure 3.3. *SEM Diagram Model 1 Testing the Direct Effect of Activity on Cognition*

According to fit indices for SEM, direct effect Model 1 provided poor fit, χ^2 (23) = 33.19, p = .08; additional model fit statistics are presented in Table 3.13. Model parameters for the direct effect model are reported in Table 3.12, including the standardized regression weights (β) for each association. The direct effect hypothesis was not supported as the standardized regression coefficient (β) for path (c) = .29, p = .77 (see Table 3.12) linking Activity (*X)* and Cognition (*Y)* was not statistically significant. There was a significant positive effect of age on activity (β = .61, p = .01), meaning that as years of age increased by 1, the frequency of activity engagement increased by .61. There was also a significant positive effect of education on activity, (β = .68, p = .01); as years of education increased by 1, the frequency of activity engagement increased by .68. Neither age nor education directly predicted cognition (*p's* > .05); see Table 3.12 for the nonsignificant standardized regression coefficients.

Table 3.12. *Standardized Regression Coefficients (β) for Direct Effect Model for Q1*

	Pathway Coefficients	
Direct Effect Model	β	*p*
Activity → Cognition (*c*)	.29	.77
Age → Activity	.61	.01**
Age →Cognition	-.91	.15
Education → Activity	.68	.01**
Education → Cognition	-.06	.93

Notes: * denotes significance at the p < .05 level, ** denotes significance at the p < .01.

Next, the indirect effect model was tested, and Meaningfulness (*M)* was added to Model 1 as the mediating variable. Bootstrapping methods were used to test the statistical significance of the indirect effect. Figure 3.4 shows the SEM path diagram for the indirect effect Model 1 and Table 3.13 reports the standardized regression coefficients (β) for each pathway in this model, including covariates.

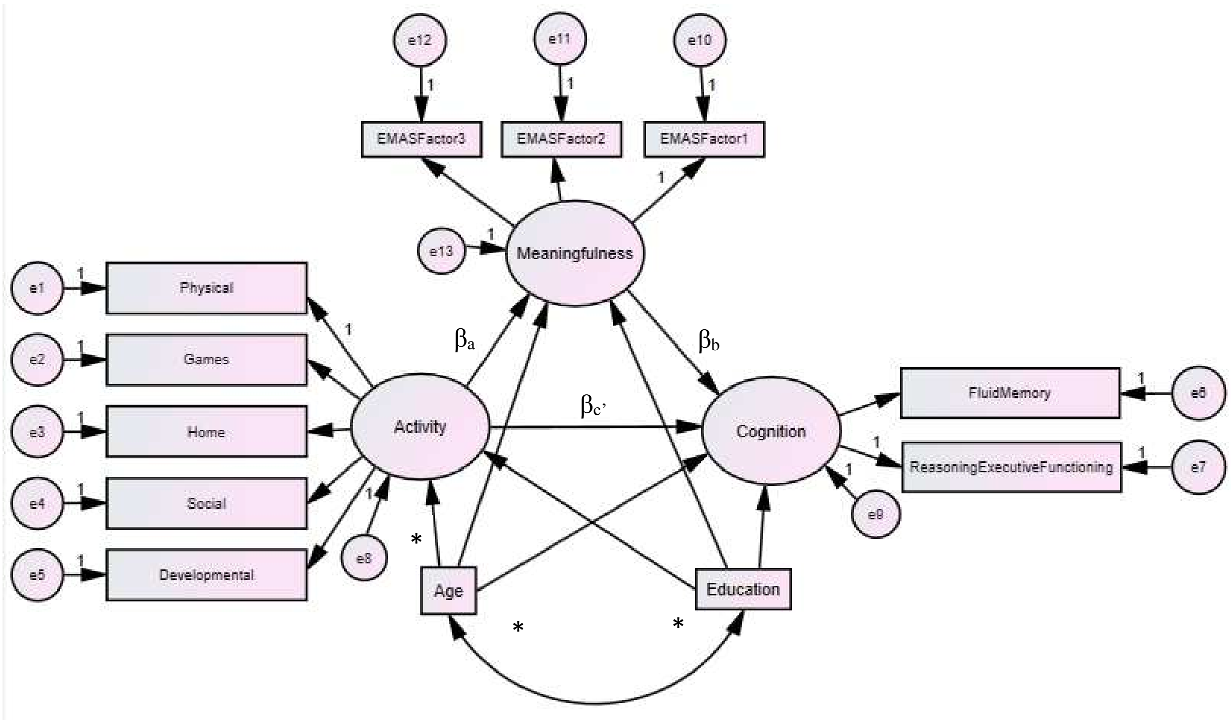

Figure 3.4. *SEM Diagram for Model 1 Testing the Indirect Effect of Activity on Cognition via Meaningfulness*

According to model fit indices for SEM, indirect effect Model 1 provided good fit, χ^2 (46) = 56.40, p = .14; see Table 3.13 for additional model fit indices. In comparison to the direct effect model, the fit indices for the indirect effect were significantly better (i.e., e.g., higher IFI, TLI, CFI), and acceptable in terms of the classifications for a "good-fitting" model. Table 3.13 presents the model fit statistics relating to research question 1. The second hypothesis for Model 1 (indirect effect) was not supported as the regression coefficients for path (*a)* and path (*b)* were not statistically significant ($p < .05$). These results indicate that activity did not predict meaningfulness, and neither activity nor meaningfulness predicted cognition. Further, the association between activity and cognition was not mediated by meaningfulness. The significance of the indirect effect was tested using bootstrapping procedures. Unstandardized indirect effects were computed for each of the 1,000 bootstrapped samples, and the confidence interval was computed by determining the indirect effects at the 5^{th} and 95^{th} percentiles. The bootstrapped unstandardized indirect effect of Activity on Cognition as mediated by Meaningfulness was -.10, S.E. = .64, and the 95% CI ranged from -2.39, .53. At the two-tailed significance level, this bias-corrected indirect effect was not statistically significant ($p = .51$).

Table 3.13. *SEM Fit Statistics for Mediation Model 1*

	Model Fit Statistics					
	χ^2 (*df*)	*p-value*	RMSEA	IFI	TLI	CFI
Direct Effect Model	33.19 (23)	.08	.09	.89	.80	.87
Indirect Effect Model	56.40 (46)	.14	.05	.94	.90	.93

Notes: In SEM, a model can be defined as having "good" fit if the following criteria are met: the χ^2 goodness of fit statistic is non-significant ($p > .05$); RMSEA < .05; IFI > .90; TLI > .80; CFI > .90.

The model parameters for the indirect effect model are reported in Table 3.14. None of the primary pathways in the indirect effect model were significant (see Figure 3.4). However, there were significant effects of the covariates on the latent variables. Age had a significant effect on activity ($\beta = .54$, $p = .01$), and cognition ($\beta = -.68$ $p < .01$), but the regression coefficient between age and meaningfulness was not significant. Education had a significant effect on activity ($\beta = .72$, $p < .01$), but not on meaningfulness or cognition.

Table 3.14. *Standardized Regression Coefficients (β) for Indirect Effect Model 1*

	Pathway Coefficients	
Indirect Effect Model	β	*p*
Activity → Meaningfulness (*a*)	2.67	.58
Meaningfulness → Cognition (*b*)	.17	.75
Activity → Cognition (*c'*)	-.21	.75
Age → Meaningfulness	-1.03	.69
Age → Activity	.54	.01**
Age → Cognition	-.68	.00**
Education → Meaningfulness	-1.84	.59
Education →Activity	.72	.00**
Education → Cognition	.28	.54

Notes: * denotes significance at the $p < .05$ level, ** denotes significance at the $p < .01$.

The standardized regression coefficient (β) for the direct effect of activity on meaningfulness was quite large (β = 2.67) as was the effect of age and education on meaningfulness (β = -1.84). Standardized values outside the range of (-1, 1) can sometimes be valid (Jöreskog, 1999), indicating a high correlation between predictor variables. It can also indicate that unreasonable model constraints have been imposed, however no error messages were incurred for this model nor was the maximum iteration reached, therefore these values were deemed acceptable. Rather, the range for standardized coefficients (-1,1) was likely exceeded due to the small correlations between the EMAS Factors that make up the latent variable of meaningfulness and the social activity factor. The multicollinearity between observed factors of the EMAS likely contributed to the magnitude of the standardized regression coefficient linking meaningfulness to activity (Bentler & Chou, 1988; Deegan, 1978; Grewal et al., 2004). Table 3.15 reports the correlation matrix for all observed variables.

Table 3.15. *Correlation Matrix of Observed Variables in SEM Models*

	AF1	AF2	AF3	AF4	AF5	EMAS1	EMAS2	EMAS3	Cog1	Cog2
AF1	1	.02	-.12	.13	.12	.15	.13	.23*	.14	.03
AF2	.02	1	.05	.08	-.01	-.12	.11	.08	-.08	.19
AF3	-.12	.05	1	.10	.01	.17	.08	.17	-.23*	.03
AF4	.13	.08	.10	1	.14	.28*	.35**	.27*	-.21	-.24*
AF5	.12	-.01	.01	.14	1	.13	.17	.24*	.17	-.01
EMAS1	.15	-.12	.17	.28*	.13	1	.51**	.47**	-.17	-.22*
EMAS2	.13	.11	.08	.35**	.17	.51**	1	.56**	-.15	-.27*
EMAS3	.23*	.08	.17	.27*	.24*	.47**	.56**	1	.04	-.13
Cog 1	.14	-.08	-.23*	-.21	.17	-.17	-.15	.04	1	.45**
Cog2	.03	.19	.03	-.24*	-.01	-.22*	-.27*	-.13	.45**	1

Notes: AF1 = Activity Factor 1: Physical; AF2 = Activity Factor 2: Games; AF3 = Activity Factor 3: Home; AF4 = Activity Factor 4: Social; AF5 = Activity Factor 5: Developmental. EMAS1 = EMAS Factor 1: Self-Expression & Caring; EMAS2 = EMAS Factor 2: Personal Experiential; EMAS3 = EMAS Factor 3: Social Value & Competence. Cog1 = Fluid Memory; Cog2 = Reasoning Executive Functioning. * Denotes significance at the $p < .05$ level, ** denotes significance at the $p < .01$.

As shown in Table 3.15 there were several significant correlations between the EMAS and VLS-AQ Factors (referred to as Activity Factors (AF) 1-5 in the table). For example, there was a significant positive correlation between the social activity factor and the three factors of the EMAs (.28, .35, .27). Because the multicollinearity is considered quite small (less than 0.4) by research standards (Grewal et al., 2004), it did not pose a significant threat to this analysis but rather helps to explains the existence of larger standardized regression coefficients in this model.

Mediation Model 2. To address research question 2, the roles of the latent variables were reversed. In the second mediation model tested, meaningfulness served as the independent variable predicting cognition. For Model 2, the first step was to evaluate the direct effect of meaningfulness on cognition (Hypothesis 2*a*). Figure 3.5 shows the simplified path diagram.

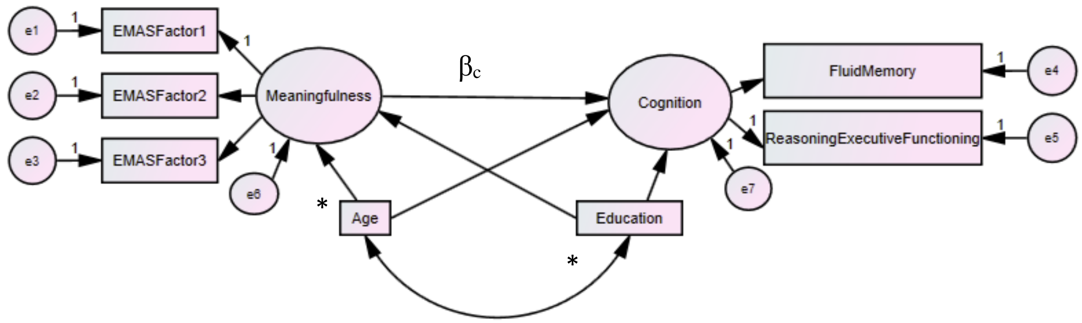

Figure 3.5. *SEM Diagram for Model 2 Testing the Direct Effect of Meaningfulness on Cognition*

According to model fit indices for SEM, direct effect Model 2 provided good model fit, χ^2 (10) = 10.09, p = .43. In this model, the path coefficients between age and meaningfulness (β = .41, p < .001) and age and cognition (β = -.72, p < .001) were significant. However, the direct effect of meaningfulness on cognition was not statistically significant (p > .05). Hypothesis 2*a* was also not supported, path (*c*) was not significant demonstrating that greater meaningfulness was not associated with higher cognition. In comparison to the direct effect model of activity on cognition (Model 1), the model fit statistics for this direct effect were much stronger. Model parameters for this direct effect model are reported in Table 3.16.

Table 3.16. *Standardized Regression Coefficients (β) for Direct Effect Model for Q2*

	Pathway Coefficients	
Direct Effect Model	β	*p*
Meaningfulness → Cognition (*c*)	-.02	.89
Age → Meaningfulness	.41	.01**
Age →Cognition	-.72	.01**
Education → Meaningfulness	.07	.58
Education → Cognition	.14	.23

Notes: * denotes significance at the p < .05 level, ** denotes significance at the p < .01.

The covariate age had a significant effect on both meaningfulness (β = .41 p < .01) and cognition (β = -.72, p < .01) but education was not statistically associated with either latent variable. Next, activity was added to the model as the mediator variable to test hypothesis 2*b*. Figure 3.6 displays the simplified path diagram for this indirect effect model which tested whether mediation occurred in Model 2. Table 3.17 presents the model fit statistics relating to research question 2. According to fit indices for SEM, the indirect effect Model 2 provided adequate model fit, χ^2 (46) = 56.35, *p* = .14.

Table 3.17. *SEM Fit Statistics for Mediation Model 2*

	Model Fit Statistics					
	χ^2 (*df*)	*p*	RMSEA	IFI	TLI	CFI
Direct Effect Model	10.09 (10)	.43	.01	.99	.99	.99
Indirect Effect Model	56.35 (46)	.14	.05	.94	.90	.93

Notes: In SEM, a model can be defined as having "good" fit if the following criteria are met: the χ^2 goodness of fit statistic is non-significant ($p > .05$); RMSEA < .05; IFI > .90; TLI > .80; CFI > .90.

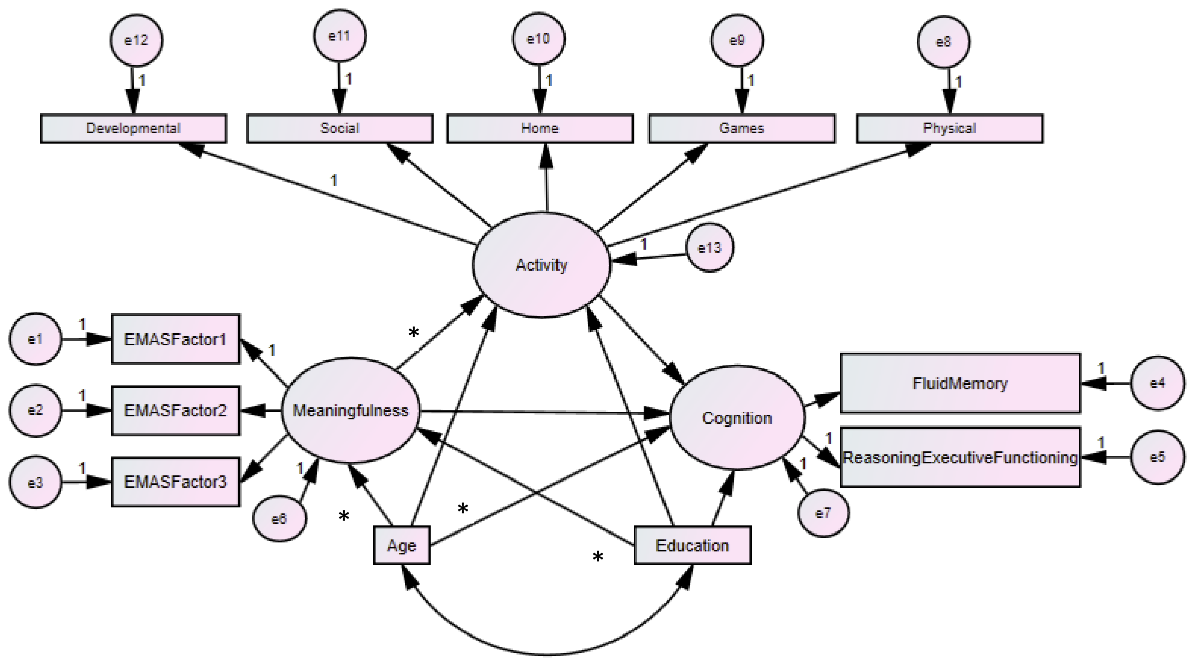

Figure 3.6. *SEM Diagram of Mediation Model 2 Testing the Indirect Effect of Meaningfulness on Cognition via Activity*

Path (*a*), represented by the arrow from Meaningfulness (*X*) to Activity (*M*) was statistically significant, (β = .82, *p* = .04), however path (*b*) linking Activity (*M*) to Cognition (*Y*) was not significant. The significant effects of meaningfulness on activity show that the meaning of activity explained the frequency of activity participation. As meaningfulness scores increased by a unit of 1, the frequency of activity engagement increased by .82. The indirect effect path

(c') represented by the arrow connected Meaningfulness (*X)* to Cognition (*Y)* was also not significant (see Table 3.17). The significance of the indirect effect was tested following the same bootstrapping procedures as Model 1. The bootstrapped unstandardized indirect effect of meaningfulness on cognition as mediated by activity was .20, standard error = .84 and the 95% confidence interval ranged from -.47, 4.57. At the two-tailed significance level, the bias-corrected indirect effect was not statistically significant ($p = .40$). Table 3.18 reports the standardized regression coefficients for each pathway including covariates for the indirect effect tested in Model 2.

Table 3.18. *Standardized Regression Coefficients (β) for Indirect Effect Model 2*

	Pathway Coefficients	
Indirect Effect Model	β	*p*
Meaningfulness → Activity (*a*)	.82	.04*
Activity → Cognition (*b*)	-.21	.75
Meaningfulness → Cognition (*c'*)	.17	.75
Age → Meaningfulness	.40	.00**
Age → Cognition	-.68	.00**
Age → Activity	.21	.31
Education → Meaningfulness	.06	.61
Education → Cognition	.28	.54
Education → Activity	.67	.03*

Notes: * denotes significance at the $p < .05$ level, ** denotes significance at the $p < .001$.

Hypothesis 2*b* was only partially supported in that higher meaningfulness did predict higher levels of activity engagement, however higher levels of activity did not predict cognition nor was the relationship between meaningfulness and cognition mediated by the frequency of activity engagement. Age had a significant effect on both meaningfulness ($\beta = .40$, $p < .01$) and cognition ($\beta = -.68$, $p < .01$) but not on activity. Education had a significant effect on activity ($\beta = .67$, $p < .05$) but not on either of the other latent variables (see Table 3.18).

Discussion

This cross-sectional study investigated the structural associations between activity engagement, meaningfulness, and cognitive ability using baseline measurements from the

REACT study. Using a sample of middle-aged and older adults aged 41 to 94, the purpose was to examine the predictive ordering patterns and relational connections between these variables. A series of factor analyses were first performed to identify the underlying factor structure for each latent variable. Multiple SEM models were then tested to identify the best fitting model and determine whether mediation had occurred. Within this section, the results of the SEM mediational analyses are discussed with reflection on how these findings relate to prior research. A broader discussion of the combined issues for both Study 1 and Study 2 (e.g., the sample characteristics, sample size limitations, and implications for future research) was withheld from this section and instead are presented in the final concluding chapter of this dissertation.

Mediation Analyses. Two models were tested using SEM; the models differed in their structural arrangement and the directionality of the predictor and mediator variable associations. For research question 1, neither hypothesis was supported, indicating no associations between the frequency of activity engagement, meaningfulness, and cognitive ability. In Model 1, the frequency of activity engagement did not predict cognitive ability (Hypothesis 1*a*), and the meaningfulness of activity engagement did not serve as a mediating pathway through which engagement in activities was related to higher cognitive performance (Hypothesis 1*b*). In Model 2, the roles of the predictor and mediating variables were switched, and meaningfulness served as the predictor of cognition. At the same time, the frequency of activity engagement was tested for mediating effects. For research question 2, neither hypothesis was supported. The result of meaningfulness on cognition was not significant (Hypothesis 2*a*); further, the indirect effect of meaningfulness on cognition as mediated by the level of activity engagement was also not significant (Hypothesis 2*b*). Although meaningfulness did not predict cognition, either directly or indirectly, meaningfulness did significantly predict activity. The path (*a)* regression coefficient

(b) was positive and significant, demonstrating that higher levels of meaningfulness predicted higher levels of activity participation.

Directional Associations. Regarding the direction of effects, the model fit statistics were much stronger for the second model, when meaningfulness predicted cognition, rather than when activity predicted cognition in the first model. The direct effect for Model 2 provided the most robust overall fit compared to any other model variation. This demonstrated that meaningfulness served the model best when it was the sole independent predictor variable rather than existing as a mediator. The model fit weakened when activity was tested as the mediator and was strongest when the meaningfulness factor independently predicted cognition. These findings imply that involvement in more meaningful activities may help stimulate and promote higher activity participation levels in middle-aged and older adults. Although this effect did not extend to higher cognitive ability, it seems that engaging in more meaningful activities has a motivational influence associated with an increase in the frequency of activity participation. Based on evidence reported in the correlational analysis (see Table 3.15), all three EMAS factors were positively correlated with factors of the VLS-AQ; these findings support the argument that greater meaningfulness is associated with more frequent engagement in social activity. Other evidence supporting favorable associations were found between physical and developmental activity factors, both of which were positively correlated with factor 2 of the EMAS (i.e., personal experiential).

These findings can be explained by theories of leisure and recreation, which state that meaningfulness motivates self-creation and promotes participation in novel types of experiences (Kelly & Kelly, 1994). This effect may be heightened for social, physical, and developmental activities, given the significant, positive correlations reported between factors. According to

Atchley (1989), individuals select and develop ideas, relationships, environments, and activities based on personal dispositions about what defines meaning in their lives. These notions of personal meaning influence both individual and social expectations regarding activity engagement and suggests that when an activity is perceived to be more meaningful (i.e., conducive to feelings of self-determination and competence), it is more likely to be expressed through patterns of behavior and engaged in more frequently (Kelly & Kelly, 1994; Mattingly, 1998). Combining the correlation and mediation analysis shows that the directional associations between activity and meaningfulness were driven primarily by meaningfulness as an independent predictor of activity. The results showed that having more meaningful engagements predicted a greater frequency of social activity and higher participation in physical, social, and developmental activities. This is in line with the selective engagement hypothesis (Hess, 2014), which proposed that activities with greater meaning are selected more often and engaged in more frequently than less meaningful activities. This also algins with occupational therapy research, reporting that more meaningful and frequent activity engagement in older adults explains higher life satisfaction and other favorable outcomes related to psychological health & well-being (Eakman et al., 2010a). Physical, social, and developmental types of activities seem to hold greater meaning compared to games, or other home related activities, because these domains did not significantly correlate with factors of the EMAS (Atchley, 1989; Hocking, 2009; Scheier et al., 2006).

In terms of cognitive outcomes, however, meaningfulness did not directly or indirectly influence cognition. This was unexpected given theoretical predictions stemming from the environmental complexity hypothesis (Schooler et al., 1999), which suggests that due to the level of cognitive stimulation involved with meaningfulness, activities with greater meaning are selected more frequently. From this perspective, meaningfulness was thought to enhance cognitive ability by promoting activity selection and motivation (Atchley, 1989; Hocking, 2009; Scheier et al., 2006). Although the results showed that meaningfulness promoted changes in activity selection, these selections did not transfer to cognitive improvements. Explanations for this may lie in disentangling the correlational analysis. For example, the reasoning and executive functioning factor was negatively correlated with EMAS Factors 1 and 2 and the social activity factor. Although the magnitudes of these associations were small but significant, the directionality suggests that there may be more complex associations between different types of meaningful activities across other cognitive domains. These results are purely associational, and the cross-sectional design limited causal interpretations.

Further testing only baseline structural associations between these constructs may not have fully captured the dynamic and contextual influences of the subjective experiences associated with engagement. Furthermore, the smaller sample size complicated interpretations of the FAs, especially regarding the model fit for the VLS-AQ, and it is unclear how these complications may have impacted the mediational analysis. According to the environmental complexity hypothesis (Schooler et al., 1999), motivation to selectively engage in more meaningful activity occurs when cognitive skills are applied across various settings and situations. Thus, the inability to predict cognition may lie in the static nature of cross-sectional study design, highlighting the need to assess highly subjective constructs such as meaningfulness in the real-world context of everyday life and to conceptualize cognitive performance within the context of an individuals' naturalistic environment.

Activity Predicting Cognition. The present results did not support that prediction that a greater frequency of activity engagement would predict higher cognitive performance. These findings were unexpected, as an association between activity and cognition has been established by other researchers in the past (Christensen et al., 1996; Vance et al., 2005; Tang et al., 2018). Although some cross-sectional investigations have shown that increased participation in certain cognitively demanding leisure activities (e.g., reading the newspaper, Sudoku) is related to higher cognitive performance, others found that higher cognitive performance was associated only with a greater frequency of participation in activities that occurred within a social context or group setting (e.g., bowling, religious activity) (Tang et al., 2018; Vance et al., 2005). However, the lack of an association between activity and cognition found in the present study is consistent with some prior research (Hambrick et al., 1999; Parisi et al., 2010) that failed to show a significant association between greater activity engagement and higher cognition. Although these findings vary from most of the cross-sectional research, they highlight the issue of inconsistent support for the "use it or lose it" hypothesis.

These differences can be explained partially by the types of assessments used to collect activity-related information and methodological divergences between studies. Several key issues have been identified, including differences in the number of activities assessed, how activity information is acquired, and the time frame over which activity is reported (Bielak, 2010). Some researchers suggest that different time frames over which activity is assessed provide different engagement depictions by tapping into different underlying meaning and memory processes (Hatt et al., 2021). Considering activity over the past two years may not fully capture the subtle fluctuations in daily leisure participation, which might explain why the present results found a non-significant activity-cognition relationship. When activity is assessed over a shorter time frame (e.g., weekly, or daily), reported information may be less subject to cognitive biases and memory distortions. The nature of asking individuals to report information over more extended periods involves a heavy reliance on personal schematics and may predispose individuals to inaccurately report activity information (Jopp & Hertzog, 2007; Parisi et al., 2009). This explanation is in line with cognitive heuristics and biases (Kahneman et al., 1982), which states that people judge the likelihood of an event by the ease with which instances can be recalled. Activity estimated over two years, like in the VLS-AQ, may be more representative of the remembered self than the experienced self, and reported information may be influenced by the availability of activity-based memories and construed based on internal representations of what an individual considers "typical." This theory explains why different activity assessments, varying in the time frame assessed, may provide different information about activity engagement. It is unknown whether assessment at the daily level provides a stronger link to cognition, but research points to the benefit of using multiple types of assessments to measure activity in relation to cognition (Bielak, 2017). It seems that the specific kind of activity scale used, the length of assessment time, and how the questionnaire is administered may all contribute to differences in reported findings.

Overall, the present findings were not in line with prior cross-sectional research that has supported the "use it or lose it" hypothesis by providing empirical support that greater activity levels were associated with higher cognitive performance (Christensen et al., 1996; Hultsch et al., 1993; Ferreira et al., 2016; Vance et al., 2005). In both model variations, the pathways linking activity to cognition were not significant. Thus, the conceptual view that leading an active and engaged lifestyle in adulthood supports better cognitive health (Hultsch et al., 1999) was not supported in the current investigation. In addition to the conceptual explanations offered above, several other limiting factors may have contributed to the null effects. These include the small size of the sample and the subsequent reduction in VLS-AQ factors that were fitted to the data.

There has been substantial work devoted to clarifying the nature of improper solutions in SEM. These situations tend to occur with smaller samples and when models have fewer structural constraints (Bentler & Chou, 1988; Gagne & Hancock, 2006). Low factor loadings (poor scale reliability) can also contribute to the likelihood of negative error variances occurring (Kolenikov et al., 2007). The lack of inclusion of various activities due to factor constraints in the structural model may also explain the lack of an association between activity and cognition. Other research reporting significant effects on cognition has generally used much larger sample sizes, which allowed for more activity items to fit within factor parameters (Hess et al., 2018; Jopp & Hertzog, 2010).

Factor Solutions. The final factor solution of the VLS-AQ included only 23 of the 57 items initially proposed by Jopp and Hertzog (2010). In this sample, a five-factor structure emerged as the best fitting model, based on several iterative EFAs with promax-rotated solutions. As items were reduced, the amount of variance with respect to the diversity and frequency of activity participation also diminished. Put differently, to achieve the "optimal" fit that aligned with structural criteria for these categories, there was a loss in the amount of variability and diversity of self-reported activity engagement at the individual level.

Interestingly, a paper by Lingard & Rowlinson (2006) reported that sample size might have less of an impact on the outcomes of a factor analysis when there were fewer variables (i.e., e.g., items) used. According to these authors, model fit likely suffers when the ratio between the sample size (N) and the number of parameters (P) decreases. The models reported in the present study had the following ratio (N = 81: P = 23), whereas Jopp & Hertzog (2010) reported a ratio of (N = 218: P = 57). As sample size increases, the number of items allowed to fit into observed factor solutions in SEM also increases, as indicated by a reduction in the $N{:}P$ ratio.

Another issue was the magnitude of the commonalities between items. For the VLS-AQ communalities ranged from .18 to .86, indicating an exaggerated range compared to the norms of most social science research, which ranges from .30 to .50; when commonalities become lower, the size of the sample has a more significant impact upon the factor analysis outcomes (Lingard & Rowlinson, 2006). Overall, these issues demonstrate that the reduced factor solution for the VLS-AQ used in the present analysis may not represent the more stable structure evident in larger samples. Furthermore, item reduction was necessary for the VLS-AQ as the item to factor ratio fitted in prior studies (Jopp & Hertzog, 2010; Hess et al., 2018) was not feasible for the present sample. The goal of the EFA process was to identify the best fitting model. In doing so, significant item reduction occurred. A considerable amount of explained variance was lost to fit these structural expectations. The reality of participant engagement was likely deflated, as the depth or variety of leisure activity experiences expressed in this analysis was greatly diminished. For example, during the item reduction processes, all questions related to the frequency of TV watching were removed and thus were not represented in the final factor solution. Research examining the effects of sedentary behaviors, such as TV watching, has shown that higher engagement is associated with lower physical activity levels and a higher risk for cognitive decline in older adulthood (Fancourt et al., 2018). Unfortunately, due to factor restrictions on this analysis (i.e., small sample size), several essential activity items were reduced and unrepresented in this study.

The issues of fitting the factors structure for the VLS-AQ indicate the possibility of improper solutions stemming from inadequate sample size when performing EFA (Chen et al., 2001; MacCullum et al., 1999; Osbourne & Costello, 2004). For factor analysis to be robust, factor patterns must be stable across multiple studies using different samples. This was not the case in the present investigation, as a five-factor solution for the VLS-AQ was the best fitting model for our data, compared to prior factor solutions provided by Jopp and Hertzog (2010), which suggested an eleven-factor solution. Hess et al. (2018) performed a similar EFA on the VLS-AQ, reporting a seven-factor solution. Although this structure from Hess et al. was theoretically modeled in line with what was proposed by Jopp and Hertzog (2010), results were conflicting. The inability to re-produce a stable factor pattern for the VLS-AQ across two different studies highlights that factor solutions may be sample specific and difficult to replicate. Small samples present problems due to various forms of sampling error, which can manifest in factors specific to one data set, limiting the extent to which data can be deemed representative of a larger population. Costello and Ostoborne (2005) provided empirical support for the effect of sample size on factor analysis results, reporting that larger samples tend to produce more accurate solutions. Although several iterations of EFA eventually produced a stable factor solution in the present study, many items were lost or reduced during the process. Therefore, the five-factor solution fitted to this data seems to be sample-specific, resulting from sampling error, and should be interpreted with caution as this solution may not be representative of the larger population. Another problem associated with conducting factor analysis in small samples is splintering factors and/ or misclassified items. Unfortunately, this problem was not evident during the initial factor analysis. It manifested post-hoc, as seen in multicollinearity issues and unusually high standard errors values for the latent variable activity (Osborne & Costello, 2004).

Regarding the factor structure for meaningfulness, a three-factor EMAS solution emerged in this sample, and CFA revealed a strong model fit. Eakman et al. (2010b) used a similar analytical approach to the one described here but reported only a two-factor solution. There are functional relations between the two-factors proposed by Eakman et al. (2010b), which were labeled Personal Competency Component and Social Experiential Component, and the present three-factor model, which was labeled Self-Expression & Caring (Factor 1), Personal Experiential (Factor 2), and Social Value & Competence (Factor 3). According to a recent qualitative research review, there are three underlying themes of meaning: *social, selfhood,* and *pleasure* (Eakman et al., 2018). Drawing from this perspective, Factor 1 includes aspects of all three themes, social (e.g., helping), selfhood (e.g., identify), and pleasure (e.g., stimulating creativity). Two significant themes represented by Factor 2 included selfhood (e.g., mastery, self-esteem, purpose) and pleasure (e.g., satisfaction, enjoyment). For Factor 3, two themes are represented by Factor 3, social (e.g., belonging) and selfhood (e.g., control). According to these representations, some functional overlap has occurred, especially for Factors 1 and 3, both of which involved social themes of meaningful engagement that are likely entangled with one another. The social nature of meaningful engagement may be biased based on the individual's subjective social perceptions and environment (Hammal, 2004). Another possible explanation is that socially meaningful engagements may be split based on the activity being considered; meaningful engagements such as helping or caring for others might occur across multiple contexts and be perceived by the individual as a self-motivated process that is naturally intrinsic (Iso-Ahola, 1990). Other items may be more extrinsically rewarding, such as social belonging, a type of engagement usually influenced by groups of people or occurs within a social setting (Ross et al., 2010). The differences seem to involve social themes of meaning that might contain a single factor, as was the case in the two-factor model. These items might group onto multiple factors, as was the case in the present study. Some social items, such as helping or caring for others, were grouped into Factor 1 and seemingly tapped into issues related to the expression of personal identity (Christiansen, 1999; Kaufman, 1986); this explains the functional overlap evident between the present analysis and that reported by Eakman et al. (2010b). Both versions have been validated by other researchers using diverse samples. In favor of the two-factor fit, Prat et al. (2019) demonstrated the reliability of the EMAS in a Spanish sample of individuals with serious mental illness.

On the other hand, another cross-cultural analysis conducted by Maruta et al. (2020) reported a three-factor solution in a community-dwelling Japanese older adult sample. Because both two and three-factor models for the EMAS have been utilized and psychometrically validated cross-culturally by different researchers, it seems that there is no "one-size fits all" model when it comes to identifying the factor structure for this assessment. The nature of the factor solution is likely subject to the characteristics and size of the sample being studied.

Accurate interpretations of any factor solution often require examining additional statistical constructs such as the correlational associations among the observed factors. One notable statistical anomaly presented in the analysis was the high standardized regression weight (b) linking activity to meaningfulness in Model 1. As mentioned in the results, these high values can often be valid (Jöreskog, 1999) and are due to high correlations among the predictor variables in a model. Examining the correlations between the VLS-AQ and EMAS factors indicated significant positive correlations between all three factors of the EMAS and the VLS-AQ Social activity factor. When the significance of these effects was tested with bootstrapping methods, the standardized weight sizes diminished, suggesting that the multicollinearity present among the EMAS factors might explain this anomaly. According to some statistical resources, Monte Carlo simulations offer a non-biased correction for the standardized estimates, which considers and accounts for violations of normality assumptions for predictor variables in SEM models (McCormick & Salcedo, 2017). Upon further examination of this simulation, it seemed that there was an unusually high standard error value for the estimate linking activity to meaningfulness, indicating that there may be problems of model convergence and inadmissible solutions (Gagne & Hancock, 2006). According to SEM criteria, correlations of .85 or larger in absolute value indicate poor discriminant validity. The significant positive correlations between the EMAS and VLS-AQ activity factors were relatively small (less than .40), indicating that the magnitude of the meaningfulness and activity relationship was likely driven by these significant associations.

Covariate Effects. Although the results were not in line with either hypothesis, several other important trends emerged worthy of discussion. The covariates of age and education both had significant effects on activity in both models. These effects of increasing age and higher education predicting higher levels of activity have been reported by other researchers (Rousseau et al., 2005). Parisi et al. (2010) reported that higher levels of educational attainment were associated with more frequent participation in intellectually stimulating activities. These authors suggested that education may build the skills and competencies for individuals to pursue more intellectual activities, and more highly educated individuals may be more likely to create environments that are of high cognitive demand (Parisi et al., 2010).

Gerontological models such as activity theory (Havighurst, 1951) and continuity theory (Atchley, 1989) state that aging successfully depends on continued engagement in the same activities as in midlife. When maintenance is no longer possible, individuals find new alternative activities. The theories suggest that aging adults would be expected to show a stable pattern of activity level across middle-aged and older adulthood; however, some studies report declines in the frequency of activity participation with increasing age. The latter was evident in a study by Nilsson et al. (2015), which showed a progressive decline in levels of leisure participation between youngest old (50- 64 years old) and oldest-old age groups (65-80 years old). However, the results from this present sample showed that increasing age predicted higher levels of activity engagement. Although continuity theory suggests consistent patterns across most of the lifespan, some patterns of change in the frequency of activity engagements do occur. These changes seem to vary based on age and activity type (Agahi et al., 2006; Iso-Ahola, 1994). According to other research, older adults reported spending more time watching television, reading newspapers or magazines, and participating in various hobbies and spent fewer hours participating in clubs, using computers, supervising activities, socializing with friends, teaching, writing, and engaging in musical or artistic activities (Iso-Ahola et al., 1994; Paillard-borg et al., 2009; Verbrugge et al., 1996). Taken together, it seems that although patterns of activity may stay consistent across most of the lifespan, the frequency of participation seems to shift with increasing age and be contingent on the type of activity under consideration.

The significant effect of age on cognition was expected and is in line with prior research (Hultsch et al., 1993; Schaie, 2001; Schooler, 1990), which showed poorer cognition was associated with increasing age. However, the effect of age on meaningfulness is more novel and intriguing. From a lifespan perspective, the SOC model (Baltes & Baltes, 1990; Freund & Baltes, 1998) provides some theoretical justification for this effect, explaining that as individuals age, they select more appropriate leisure and social activities based on their level of competence of functioning. It is more adaptive for aging individuals to engage in more meaningful types of activities. Across the lifespan, changes in the level of meaningful engagement have been associated with increased motivation to derive emotional meaning from daily activity engagements (Carstensen et al., 2003). Researchers have argued that as the frequency of emotional investments increases with age, so does motivation to seek out more meaningful pursuits (Coleman & Iso-Ahola, 1993). Another perspective, called the socioemotional selectivity theory, proposed by Carstensen (2003), suggests that as individuals age, they experience more significant declines in physical health-related to shifting values and the importance of more socially meaningful types of engagements (Carstensen, 1992). Taken together, these theories explain how age influences engagement in meaningful activities and why older individuals may be more likely to engage in more meaningful leisure pursuits.

Statistically speaking, when a covariate variable (e.g., age, education) exhibits a significant influence on the predictor variable in a mediation model, it often suggests that possible moderation may be occurring and that post-hoc multiple group analyses may be warranted (Baron & Kenny, 1986; Little et al., 2007). However, due to the limited size of this sample and the finding of a non-significant indirect effect, this analytical approach (i.e., moderated mediation) was deemed not suitable for this study, as performing such multiple comparisons would have resulted in model oversaturation (Hayes, 2009; Preacher & Hayes, 2004). Although no mediation effects were detected in the present analysis, it seems that the significant impacts of age and education on the level of activity engagement may suggest a moderating presence exists (Park et al., 2018). Although there were no indications of mediating effects of meaningfulness, whether other psychological or cognitive factors mediate the activity-cognition relationship is unknown. Some research suggests that certain types of activity mediate the association between different kinds of activity and cognition (Brown et al., 2016). This remains an interesting topic that should be further explored using larger, more diverse samples.

There may be structural associations between activity, meaningfulness, and cognition that vary based on the nature of the leisure activity, the individual's age, and educational attainment.

Another potential influencing factor that was not represented in the current analysis was gender. Some studies have suggested that gender differences exist at the cross-sectional level; Queen and Hess (2018) reported that the linkage between motivation, frequency of activity engagement, and cognition was more robust and more consistent for women than men. Future studies should consider and address the role that gender differences and other factors (e.g., health, retirement status) play in understanding the relationship between activity, meaningfulness, and cognition.

Conclusion. The results of this cross-sectional study did not support the predictions of mediating influences of activity engagement and meaningfulness on cognition. However, findings showed that meaningfulness served the model best as an independent predictor of activity engagement, rather than as a mediator through which activity influenced cognition. The significant pathway linking meaningfulness to activity suggested that individuals who had higher ratings of meaningfulness at baseline, also engaged more frequently in activity. However, neither baseline meaningfulness nor activity predicted higher cognitive performance. Because the present data were cross-sectional, causal inference about the directionality of any observed associations could not be established, and future studies using longitudinal data are encouraged.

Moreover, although the present findings identified and adjusted for a few potentially confounding variables (e.g., age and education), other covariates were not controlled because of the added complexity that tended to over-saturate the tested models. Due to model restrictions, factors such as gender, subjective health status, marital and retirement status were not included as covariates in the present analysis, reducing the generalizability of the current findings.

Another notable limitation of this study was the small sample size which limited the stability of the factor analysis. It reduced the range of analytical opportunities that could be explored post-hoc (e.g., moderated mediation). Short-term, micro-longitudinal studies are recommended for future research; studies investigating how the activity-cognition relationship functions at the daily level will provide insight into the contextual factors that influence engagement and will help clarify how certain patterns of daily activity and meaningfulness are related to momentary shifts in daily cognitive performance.

CHAPTER 4: STUDY 2

Overview

Identifying lifestyle activities associated with cognitive aging has been challenged by methodological constraints surrounding activity engagement and cognition measurement. Longitudinal studies exploring the relationship between activity and cognition often rely heavily on long-term retrospective reporting for activity (e.g., several months, years, or even decades), which has limited translation to understanding how activity-cognition functions over shorter periods of time such as at the daily level. Relatively little information has emerged on the association between activity engagement and cognition at the daily level (Allard et al., 2014; Bielak et al., 2019b; Phillips et al., 2016). Different processes emerge when describing short vs. long-term activity associations, and cognitive outcomes are sensitive to fluctuations in the environmental context in which assessment occurs.

The results of Study 1 provided some indication of the directional association between activity and meaningfulness at baseline, showing that greater meaningfulness predicted more frequent engagement in domain-specific activity (e.g., social). Although neither meaningfulness factors nor the frequency of engagement in domain-specific activity factors predicted higher cognitive ability at baseline, I argued that these non-significant associations were explained by cross-sectional design limitations used to measure an inherently dynamic process. Study 2 addressed these cross-sectional limitations by examining how activity, meaningfulness, and cognition interacted daily, using a short-term longitudinal design that involved multiple daily assessments designed to capture fluctuations in daily activity patterns and meaningfulness, modeled to predict daily cognitive performance.

Daily Associations. Shortening the time frame in which assessment occurs to the daily level can provide researchers with more information about how cognition operates in everyday life. Engaging in specific types of routine daily leisure activities may lead to short-term gains in cognitive ability, and with the passage of time could translate into long-term changes in both behavior and cognitive functioning (Bielak et al., 2019b; Howard et al., 2019; Menec, 2003). For example, in the physical activity literature, research has shown that just one single session of moderate physical exercise resulted in immediate benefits for cognitive performance (i.e., working memory) (Hogan et al., 2013). However, whether other forms of daily leisure (i.e., social or cognitive activity) produce similar favorable associations is unknown given the longer time frames over which activity and cognition are typically assessed.

It may be essential for future research to consider how daily cognitive performance changes in response to fluctuating daily activity levels. To prevent age-related cognitive decline, researchers must better understand the everyday associations between activity engagement and cognition. The key to understanding what lifestyle activities best promote cognitive functioning may lie in monitoring the more subtle, daily fluctuations in performance, which over time may result in better methods for early detection of cognitive impairment and help facilitate more effective prevention programming for aging adults. It is essential to consider how different forms of leisure have been classified into domains in the past and to question whether these operational definitions of separating activity based on a-priori domains are necessary for predicting cognitive outcomes at the daily level.

In one short-term study, Howard and colleagues (2016) demonstrated that over one year, engaging in physical activity, formal exercise, and specific recreational leisure activities (e.g., computers, crossword puzzles, handicrafts) showed negative associations with short-term cognitive decline. Bielak and colleagues (2019a) used an older adult sample to show that fluctuations in an individual's daily activities across seven days were associated with corresponding fluctuations in daily cognitive performance. Results demonstrated that changes in activity engagement across the week were related to corresponding fluctuations in processing speed, memory, and reasoning ability. These daily associations were strongest for social activities. This sort of coupling demonstrates the dynamic association between patterns of day-to-day activity and cognitive ability. Similarly, Allard and colleagues (2014) found a lagged effect between engagement in daily intellectual activities (e.g., crossword puzzles, reading) and later semantic memory performance over a subsequent three-hour period on the same day. However, this short-term longitudinal study reported no significant within-person effects for other types of daily life activities (e.g., socializing, physical activities, watching TV) on short-term cognitive performance (Allard et al., 2014).

Interestingly, Bielak et al. (2019a) showed that television watching was negatively associated with cognition. On days when individuals watched more TV or movies than usual, they had lower reasoning scores. This study also reported significant between-person effects of television watching on the rate of performance change (i.e., slope); individuals who watched more television on average experienced more minor improvement in backward digit span performance than individuals who reported lower than average weekly television watching time. Other significant within-person effects were reported for social-private activities; on days when individuals engaged more frequently in these activities, they also tended to have faster response times, higher episodic memory, and higher working memory performance. Another study reported similar daily associations between social activity and cognition; when individuals engaged more frequently in socially pleasant interactions, they had higher cognitive performance on that same day and the subsequent two days (Zhaoyang et al., 2021). Although these findings support the argument that daily social activity influences daily cognitive performance, less consistent support has been documented for other types of leisure activity, emphasizing the need for more research that explores the day-to-day interactions between various types of daily leisure activity and the immediate effects on different domains of cognition.

Specific to daily physical activity, Whitbourne and colleagues (2008) showed that when older adults reported engaging in more physical activity, they reported fewer memory failures on that same day. The lagged association between increased physical activity participation and reductions in memory failures was strongest for older adults, compared to younger and middle-aged individuals (Whitbourne et al., 2008). In contrast, other daily physical activity research by Phillips and colleagues (2016) failed to show any associations between cognitive task performance and participant's daily or moderate physical activity, as reported by an accelerometer, over the five-day testing period. Likewise, Bielak et al. (2019a) reported no significant within-person effects of daily physical activity on cognition. Other experimental exercise research contradicts these findings, showing that after individuals engaged in just one session of exercise, benefits in processing speed were evident (Tomporowski, 2003; Tomporowski & Pesce, 2019).

Overall, these findings imply that the relationship between different forms of leisure activity and cognition fluctuate based on the type of measurement and timescale used to index participation. Further, domain-specific activities (e.g., physical, social, cognitive) are differentially associated with cognition, displaying no relation, lagged associations, or dynamic coupling (Bielak et al., 2019a; Phillips et al., 2016; Whitbourne et al., 2008). More research is needed to disentangle the relative influences of these domain-specific effects. One explanation for these various outcomes may be the type of assessment used to assess and categorize activities into respective domains and differences in the assessment timeframe.

Most of the available research exploring the link between activity and cognition has used the frequency of engagement as a primary tool for measurement (Bielak, 2010). Typically, the total time spent engaged in various activities over a certain period (e.g., week, month, year) is self-reported using retrospective questionnaires. In terms of measurement timing, some argue that activity information collected over more extended periods is subject to heightened cognitive biases that interfere with the accuracy of self-reported activity information (Aartsen et al., 2002; Salthouse, 1996; Hatt et al., 2021). Under this assumption, activities reported over a shorter time frame (i.e., at the daily level) may be less susceptible to error and offer a more representative account of actual patterns of daily engagement.

Collecting daily information may augment longitudinal studies by providing more information about how the activity-cognition relationship operates over more extended periods and how this relationship works under different measurement occasions, such as at the daily level (Bielak & Gow, 2022). When activities are reported at the moment or shortly after they are engaged in (e.g., within the last three to four hours), participation must be evaluated more quickly. In doing so, the present self is reporting on the activity experience in nearly real-time. When more time passes between the actual activity event and the assessment or reporting of that event, personality dispositions and transitory shifts in emotional processing may interfere with the quality of information reported (Iso-Ahola, 1980; Coleman & Iso-Ahola, 1993).

Contextual Factors. The literature has often ignored contextual information embedded in leisure activities, such as the subjective psychological experiences that are often attached to certain activities and experiences (Bielak, 2010; Stine-Morrow et al., 2020). For example, information about the intensity and level of stimulation associated with different types of engagement is often overlooked. Other psychological characteristics of activity, such as personal meaning, which help to classify engagement based on the context in which it occurs, have typically been omitted from activity-cognition research. Nothing is known about how the psychological context (i.e., meaningfulness) functions in relation to cognition at the daily level (Allard et al., 2014; Bielak et al., 2019a; Hyun et al., 2019; Phillips et al., 2016; Whitbourne et al., 2008). Theorists suggest that the meaningfulness or personal significance of any given activity is part of the cognitive process and, therefore, should be considered in addition to the frequency of participation (McCabe, 1986). It is necessary to yoke these concepts in some way so that the characteristics of our environment (i.e., meaningfulness) are considered along with our cognitive processes.

Because people naturally change over time, it is expected that meaningfulness of participation also fluctuates in response to different environmental or even physical demands of daily life. Drawing from time-use studies, theorists have suggested that both time and space influence activity participation at the most basic level. A person's day is thought to consist of both the nature and diversity of activity pursuits. Further, activity engagement also involves belief perspectives and individual social preferences regarding how time is best spent (Hanson & Hanson, 1993). These psychological characteristics are influenced by the environmental context in which activity is embedded. Researchers in occupational therapy had demonstrated that time spent engaged in certain activities fluctuated in response to when the activity or task was performed, where the activity took place, and with whom the activity occurred (Atler, 2014; Atler et al., 2015). One study examining the short-term effects of stress on cognition reported that individuals who had higher stress in the morning had significantly worse working memory performance later that same day (Hyun et al., 2019). These findings suggest that both external environmental characteristics and internal emotional states (e.g., stress level) can interact with cognitive ability at the daily level. More research is needed to consider these contextual factors and whether they facilitate or hinder cognitive performance.

Analytical Considerations. Although it is conceivable that individual patterns of meaningful leisure engagement stay consistent across the adult lifespan (Kelly & Kelly, 1994), whether fluctuations in activity and meaningfulness at the individual-daily level predict changes in cognitive performance similarly across all individuals is unknown. Analytically, Bielak & Gow (2022) noted that the failure to separate time-varying variables, such as activity, into within-person and between-person components had misled longitudinal study interpretation. Within-person components refer to the variability observed from occasion to occasion within an individual, whereas between-person components refer to the variability between individuals on an outcome. It is necessary to disentangle the relative contribution of within-person and between-person effects of activity on cognition as individuals engage in differing degrees of activity each day. Within-person processes do not occur in a vacuum, and fluctuations at the individual level are often unrecognized when only between-person effects are examined. These two sources of variation have the potential to differentially associate with longitudinal outcomes. Thus, future research should consider differentiating between time-varying components in longitudinal analysis and may benefit from using various time scale measures.

In one recent study, Campbell, and colleagues (2020) examined the relationship between daily activity and neurocognitive performance in middle-aged and older adults with and without HIV. In this study, at the between-person level, a greater percentage of time spent engaging in daily cognitively stimulating activities was associated with better verbal learning performance, whereas at the within-person level, spending more time each day engaged in cognitively stimulating activities was associated with higher executive functioning performance (Campbell et al., 2020). Although these results are not generalizable to healthy adult populations, this study provided a clinical example of the feasibility of using short-term cognitive assessment in aging research and the added analytical value of appropriately separating time-varying effects into group and individual levels. In doing so, researchers can better disentangle the relative between (e.g., group) and within (e.g., individual) level effects that drive significant patterns of covariation. These components describe different patterns of covariation; the between-person effects are considered at the group level and are measured by comparing average differences between individuals on a particular outcome. The within-person component describes patterns of covariation between predictor and outcome at the individual level, thus comparing intra-individual fluctuations over time.

Given that these components differ in how they relate to and describe the amount of variation accounted for in cognitive performance, due to either group-level (between-person) or individual-level (within-person) processes (Bielak, 2017), assessment of both components is encouraged (Bielak et al., 2012; Bielak et al., 2014). More time-sensitive metrics are needed to fully understand the dynamic associations and temporal patterns between meaningfulness, activity, and cognition (Bielak et al., 2010; Bielak et al., 2014). Recent advances in mobile technology offer new and exciting opportunities for researchers to overcome some of the methodological challenges and temporal constraints of contemporary measurement techniques by incorporating repeated momentary assessment into longitudinal research designs (Weizenbaum et al., 2020). Research that monitors the subtle fluctuations in daily activity although concurrently collecting information about the momentary psychological context (e.g., meaningfulness) in which the activity occurred is recommended. Findings will provide context-specific details about what types of leisure activities relate most strongly to daily cognitive performance and whether daily performance fluctuates in response to changes in meaningfulness and daily activity (Aartsen et al., 2002; Bielak, 2017; Mitchell et al., 2012; Salthouse, 1996; Staff et al., 2018).

Ecological Momentary Assessment (EMA) seems to be a promising new approach for studying healthy cognitive aging. EMA involves the repeated sampling of an individual's behaviors in real-time and in their natural environment. One of the primary incentives of ambulatory assessment is that it enhances ecological validity, which is especially important for cognitive research that is focused on understanding the relationship between assessment results and real-world cognitive outcomes in healthy adult populations (Spooner & Pachana, 2006). Another incentive for using EMA is based on repeated assessments, allowing researchers to assess short-term variation. EMA studies estimate events or experiences in individuals' lives using random timing sampling and technologies ranging from written diaries and telephone calls to electronic diaries and tablet testing (Shiffman et al., 2008). This method is believed to minimize recall bias and maximize ecological validity, allowing for the study of micro-processes that occur in real-world settings. EMA is more accurate than end-of-day testing (Timmers et al., 2014) and certainly more precise than weekly testing. It provides insight into individual daily fluctuations in activity and cognition that cannot be recorded using any other method. In terms of cognition, even psychometrically sound performance measures may not reflect elements sensitive to context-specific enrichment, further emphasizing the need for more utilization of ecologically valid assessments in cognitive aging research (Stine-Morrow et al., 2020).

Recent advances in mobile technology have enabled researchers to insert objective cognitive assessments into studies that use EMA protocols (Riediger & Rauers, 2014; Sliwinski et al., 2016; Weizenbaum et al., 2020). For example, devices such as the Electronically Activated Recorder (EAR) record naturalistic ambient audio from the environment and relate everyday social and cognitive activities to ecologically sampled audio information (Demiray et al., 2020). Specific to cognition, ecologically designed tools for a measurement called Ambulatory Cognitive Assessment (ACA) have been psychometrically validated in older adult populations and offer great potential for assessing cognitive ability in vivo (Sliwinski et al., 2018). Typical cognitive assessment often relies on a single testing session, influenced by random and systematic within-person variability. Repeated sampling throughout the day allows performance to be aggregated across several repeated time measurement occasions, thereby reducing the effects of within-person variability (Sliwinski et al., 2018; Weizenbaum et al., 2020). Measurement at the daily level and separation of between and within-person levels of effect will help to clarify the relative impact of different forms of daily leisure activity and meaningful engagement on cognitive performance (Bielak & Gow, 2022).

Utilizing innovative technology-based approaches (e.g., EMA, ACA, EAR) offers enormous potential for cognitive aging researchers to expand understanding and inform theory regarding how to operationalize the activity and cognition relationship. In doing so, researchers can describe how these processes function at the daily level in the real-world everyday environment. By shortening the assessment period to the daily level, more subtle fluctuations in the activity-meaningfulness-cognition relationship can be explored, and patterns of performance can be detected (Cain et al., 2009). Another benefit of applying daily assessment approaches to longitudinal research is that it encourages exploring other time-varying social, psychological, and biological processes and how these dynamic and temporal processes are associated with daily shifts in cognitive ability throughout adulthood (Weizenbaum et al., 2020). Increased clarity regarding the activity-cognition relationship has broad implications for understanding daily patterns of cognitive performance, as they interact with and respond to different forms of meaningful activity. This study explored the unique contribution of meaningfulness of engagement in addition to daily activity levels to predict daily cognitive ability and changes in performance over time using MLM.

Research Questions and Hypotheses. The primary purpose of Study 2 was to examine the short-term (i.e., daily) associations between activity participation, meaningfulness, and cognition using an EMA approach. This short-term longitudinal study used beeped surveys to collect daily data for 14-days using a tablet device. The study was observational and used intensive measurement intervals (e.g., burst design) that were administered on technological devices, allowing for assessments to capture momentary "snap-shots" of engagement, meaningfulness, and cognitive performance several times throughout the day (Cain et al., 2009). The investigation aimed to model day-to-day variation in activity levels and meaningful engagements to determine whether variations were associated with daily cognitive performance and cognitive change over the two-week testing period.

Two-level MLMs were applied to 14-days of EMA testing because the data was nested in nature (i.e., days within persons). Multilevel models of change were appropriate for this analysis because they simultaneously measured individual changes over time (level-1) and how they differed across or between individuals (level-2). MLM also facilitated the separation of between- and within-person processes and allowed for the investigation of individual differences in within-person processes for daily activity level and the frequency of engagement in meaningful daily activities (Bielak & Gow, 2022). The between-person components were modeled as time-invariant predictors of cognitive level (i.e., daily cognitive ability) and slope (i.e., change in performance). This allowed for investigating whether between-person differences in activity level and daily meaningfulness predicted initial cognitive ability (i.e., intercept) and change in ability (i.e., slope) over 14 days. The within person components were modeled as time-varying predictors of same-day cognition.

Research Question. How does daily activity and meaningfulness predict daily cognitive performance and change in performance over the two-week testing period?

Hypothesis 1. At the between-person level, I predicted that individuals who had higher daily activity levels and engaged more frequently in meaningful types of activity when TIME = 0 would have higher initial cognitive ability (i.e., activity and meaningfulness-between predicting the intercept). The results of the cross-sectional mediation analysis conducted in Study 1, displayed small, positive, but not statistically significant regression coefficients linking both meaningfulness and activity to cognition. Based on these findings, at the group-intercept level, I expected significant fixed between-person effects to emerge for both predictor variables.

Analyses of between-person differences were also used to determine whether there were substantive differences in the overall level of cognitive performance change (i.e., slope) based on between-person differences in the level of daily activity and the frequency of daily meaningful engagements. Daily studies have reported significant intercept-only effects for covariates such as age, gender, and education on daily working memory performance (Hyun et al., 2019). Using a similar MLM approach, researchers demonstrated that the interaction between covariates (e.g., age) and predictor (e.g., morning stress anticipation) was time-invariant and did not predict the rate of change in cognitive performance at the daily level. However, no study has examined the time-varying associations between meaningfulness and cognition, justifying the need to examine components both at the between and within-person level, for each predictor independently, and in congruence.

Hypothesis 2. At the within-person level, I predicted that on days when individuals engaged in higher-than-average levels of activity and reported greater-than-average meaningfulness, they would have higher daily cognitive performance. These predictions were based on research claiming that engagement in various daily leisure activities had a favorable impact on daily cognitive performance (Allard et al., 2014; Bielak et al., 2019a; Whitbourne et al., 2008). Here, I expected significant time-varying covariation to emerge between activity, meaningfulness, and cognition. Based on prior research showing fluctuations in daily activity were associated with corresponding changes in daily cognitive performance (Bielak et al., 2019a), I expected similar patterns of covariation to emerge for activity and meaningfulness on cognition. The strong positive association between meaningfulness and activity reported in Study 1 justified these expectations; meaningfulness should produce similar associations to cognition as activity at the daily level. Results supporting this hypothesis would show significant within-person fixed effects for both activity and meaningfulness on daily cognitive performance, such that on days when activity and meaningfulness were higher than average for that individual, cognitive performance on that day would be significantly improved. Further, the results of Study 1 showed that the strongest SEM model fit occurred when meaningfulness predicted cognition at baseline. Thus, at the daily level, I expected meaningfulness to be a stronger predictor of daily cognitive performance than activity.

Methods

Participants. Data from this study also came from the Recording Everyday Activity and Cognition using Tablets (REACT) study, as described in Study 1. As noted earlier, of the 100 adults who participated in the REACT study, only 81 individuals completed all study parts, 59 were female and 22 were male (71.5% female), the mean age of the sample was 61.26 years old (*SD* = 12.12), and participants ranged in age from 41 to 94 years old. The average education was 17.35 years (*SD* = 3.72). There were 13 who did not complete the two-week tablet testing portion or declined to participate in the study following either the 1st or 2nd testing session. An additional 6 participants were excluded from the analysis for having invalid or incomplete data. Valid data meant that the individual must have completed all baseline questionnaires and cognitive testing. Compliance was rewarded. All participants who completed the entire study received one entry into the drawing to win one of several prizes. These prizes included 20 Amazon gift cards, and five Samsung Galaxy tablets. Individuals with a daily survey response rate of 90% across all 14-days of testing received an extra entry into the drawing. Demographic characteristics for all participants (N = 81) were reported in Chapter 3 and were described in the methods section for Study 1. Figure 4.1 displays a histogram reporting the daily frequency of beeped survey responses completed each day. There was a total of 4148 beeped survey responses across all 14 days of testing. 87% of participants completed all four beeped surveys each day (i.e., 100% daily compliance).

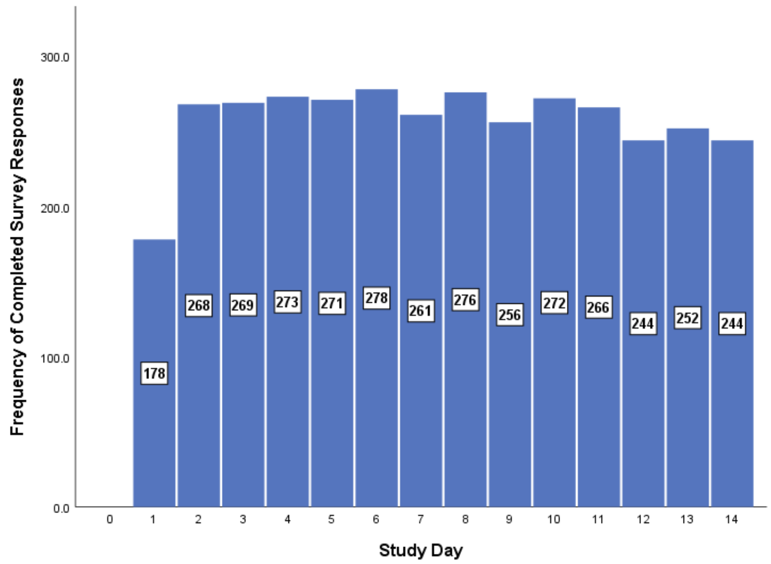

Figure 4.1. *Histogram of Completed Survey Responses by Study Day*

Procedure. The same testing schedule and general procedures for Study 1 were used, and the procedure here will only elaborate on the details relevant to Study 2. During the initial screening, participants were asked what time they typically wake up on weekdays. This information was used to assign one of six alarm schedules, as the tablet was developed to accommodate different sleep/wake cycles and these schedule determinations were designed to not disturb the individual's natural sleep times (see Appendix C for the six alarm schedules). For example, if a participant reported typically waking up at 6:45 am, he or she would receive the 7:00 am schedule (for waking times between 6:01 am and 7:00 am), which generally had the first beep occurring around 8:00 am, and the last beep around 6:00 pm. If an individual reported waking at the half hour, times were rounded up to the nearest hour to find the appropriate beeping schedule. Each of the six schedules included four daily alarms occurring approximately every three to four hours throughout the day, but the exact alarm times varied each day.

Following the completion of questionnaires at the baseline testing session, participants were trained in using the tablet. Participants were given their tablet and asked to follow along with a PowerPoint presentation given by the tester. The loaned tablets prompted participants to answer brief surveys and cognitive tests, using EMA, each day, for a two-week period. Participants were provided handouts with tips and reminders about how to use the tablet (see Appendix D for Participant Handout). First, they were instructed on how to use the tablet (i.e., how to turn on the tablet, get to the home screen, what icon to press to launch the survey, and how to turn the volume up) and told that four times throughout the day they would be "beeped" via a melody on the tablet and asked to complete the "beeped survey", followed by three cognitive tasks or "Exercises".

Participants were notified that all apps on the home screen other than the "Launch Survey" icon would be locked and not accessible for use. The beep sound (i.e., melody) was demoed, and this sound indicated that it was time for the participants to find their tablet and respond to the survey. Participants were told that it was especially important to try and do the survey as close to when the alarm sounded but never to complete the survey if doing so could be dangerous (i.e., although driving, crossing the street, cooking). The survey remained available on the screen for 30 minutes after the alarm sounded (see Figure 4.2).

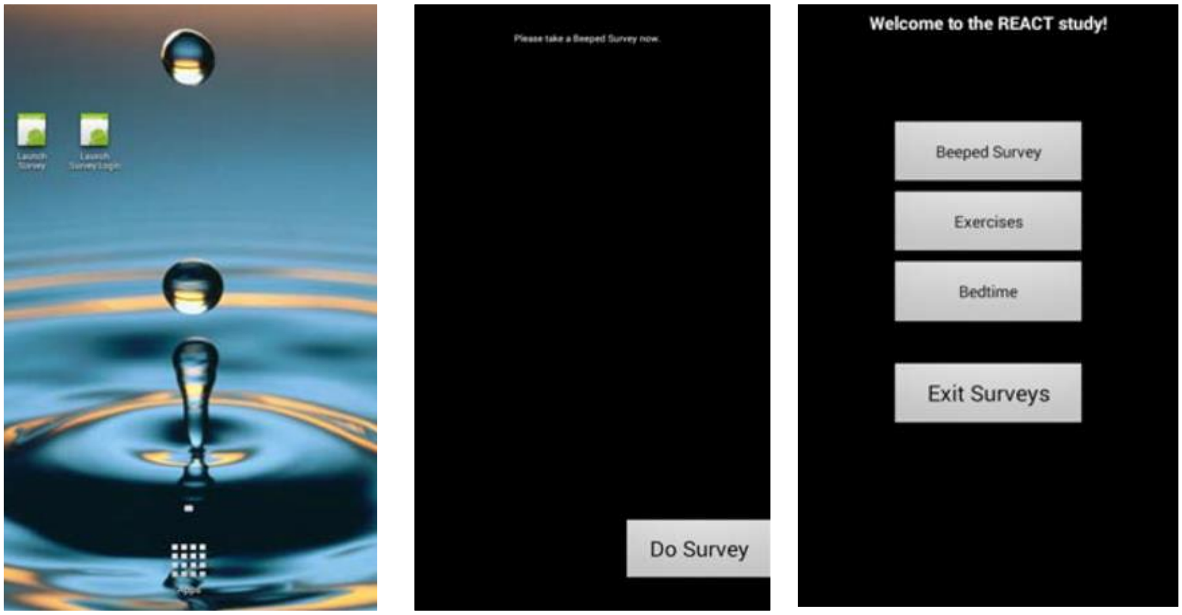

Figure 4.2. *Screenshots of Launch Survey*

Participants were told if they missed a “beeped survey” to try and complete it within 30 minutes after the alarm went off, but if it had been more than 30 minutes after the tablet alarm sounded then participants were asked to skip it and wait until the next alarm to complete the survey. For each of the cognitive exercise demonstrations, instructions were provided on the screen of the tablet and read aloud to the participants. An example of the screen and images of the task and instructions were shown during the tablet training session on a PowerPoint and participants were encouraged to follow along on their own using their tablet. At the end of all surveys and games, a screen popped up that said, “Your data is being finalized,” and this indicated the completion of the beeped survey. Participants were to then choose the “Exercises” survey to complete the cognitive tasks. Participants were informed that each beep should take less than 15 minutes to complete as not to seriously interrupt their day.

After the baseline session, participants took the tablet home for two to three days of practice and then returned to the lab for the 2nd testing session which included a series of paper-and-pencil as well as computerized cognitive tasks (see Study 1 Methods, Cognitive Tests). At the beginning of the 2nd testing session the tester downloaded the data from the tablet to make sure data was being recorded correctly and to ensure the participant was answering the surveys and completing the cognitive exercises. All practice data was downloaded, checked and saved on a secure computer desktop in the lab. Any problems with the tablet or questions that the participant had about completing the surveys were answered and addressed, and the same tablet was then returned to the participant to complete the two-week tablet testing period. If any problems were encountered during the data check, participants were assigned a new tablet for the two-week testing period. The official start date for the two-weeks of tablet testing was the day following the completion of the 2nd testing session and this date was recorded as well as the anticipated stop date (14-days later).

After this two-week testing period participants were scheduled to return to the lab for their final session. This 3rd and final testing session required participants to return their tablet and charging accessory to the lab and meet with a research assistant to complete a brief feedback questionnaire. The entire visit took approximately 15 minutes. The data from the two-week testing period was downloaded from the tablet and saved to a secure computer in the lab.

Measures. Each measure described below was obtained using a form of EMA, which involves repeated sampling of participants' current activities and cognitive ability in real-time, and in the participant's natural environment using handheld tablet devices. During each beep, several questions were displayed on the tablet followed by a series of cognitive tasks. The ambulatory surveys and cognitive tasks task were administered on Samsung Galaxy Tablets, on an Android version 4.4.2 system (Model Number SM-T21OR). Each tablet had an 8" display and a 60 Hz refresh rate, and response times were recorded in milliseconds.

Momentary Activity Assessment. Participants were asked about the activities they had participated in because the last time they filled out the survey. Participants were instructed to focus on what they had been doing in the last three to four hours, or because they were last beeped; with the caveat that the first beep of the morning should report information because they woke up for the day, not including time spent sleeping. The first alarm was scheduled approximately three to four hours after the reported waking time (see Appendix C). A list of 20 activities was presented and participants were instructed to check off as many of the activities that applied to them, but only to include activities that they participated in for 15 minutes or longer (see Figure 4.3). During the training, participants were reminded to check all activities that were engaged in for at least 15 minutes of time, continuous activity was not required. For example, one could have five minutes of walking one hour and then another ten minutes of stretching an hour later, in this case total physical activity participation time (walking + stretching) met the 15-minute requirement, thus the activity box for physical activity should be checked. The questions chosen for this daily activity survey were adapted from the Activity Characteristics Questionnaire (Bielak, 2017) and expanded to include everyday specific activities. The activity survey was split onto three successive screens because it contained so many questions, and responses were reported using a “check all the boxes that apply” format.

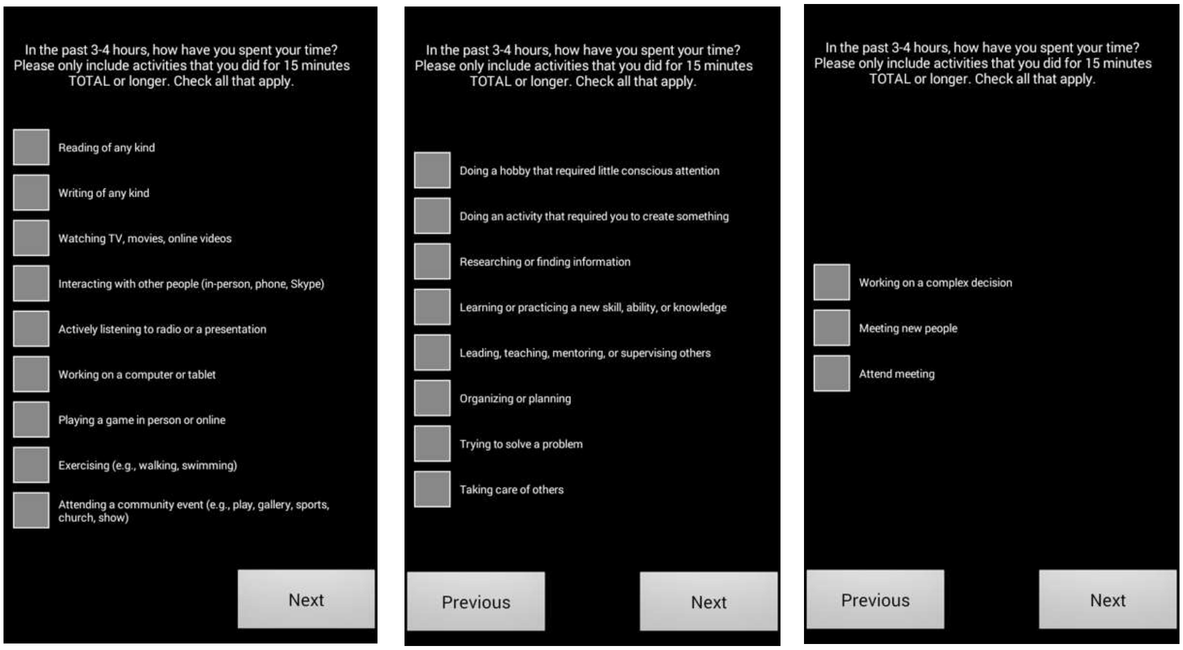

Figure 4.3. *Tablet Screenshots of Ambulatory Activity Assessment*

The total number of activities checked as well as the corresponding activity types were recorded, however for the present study only the total number of activities checked was used to indicate activity level. Each activity item was recoded as a dichotomous count and then counts were combined across all four occasions of the beeped survey to create a combined daily activity count. Given there were 20 response options presented four times daily, the range of total daily activity counts was 0-80.

Momentary Meaningfulness Assessment. The meaningfulness momentary survey asked several questions about how frequently participants engaged in meaningful activities. This daily survey was adapted from the Engagement in Meaningful Activities Survey (EMAS). Modifications were made to the original survey to specify a relevant daily time frame, which was over the past three to four hours. The original survey did not specify a timeframe and asked more generally about meaningful engagement in day-to-day activities (Eakman, 2012; Eakman et al., 2010a; Eakman et al., 2010b). The original response scale: 1 = rarely, 2 = sometimes, 3 =

usually, 4 = always, was revised to the following four response options: 1= none of the time; 2 = some of the time; 3 = most of the time; 4 = all the time, where this new scale referred to the past few hours. On the 1st screen the instructions were presented stating, "You will now see a list of activities that you have been doing in the past three to four hours. Please read each one carefully and choose the response option that describes the extent to which each statement is true for you. Then on the next 12 screens successive screens the following prompt was presented, "In the past three to four hours the activities I was doing…" each screen then displayed the 12 different meaningful statements (see Table 4.1). Possible scores ranged from 12-48 for each beeped survey. An average daily meaningfulness score was calculated by taking the average response for each item across all four daily beeped survey occasions; this served as an indicator of the frequency of daily meaningful activity engagement.

Table 4.1. *List of Meaningful Statements*

Helped me take care of myself	Contribute to my feeling competent	Give me a feeling of control
Reflect the kind of person I am	Are valued by other people	Help me express my personal values
Express my creativity	Help other people	Give me a sense of satisfaction
Give me a sense of accomplishment	Give me pleasure	Have just the right amount of challenge

Ambulatory Cognitive Assessments. Three ambulatory measured visual processing speed (symbol search task), and working memory performance (location dot memory, flip-back). Screenshots of each task are displayed below in Figure 4.4.

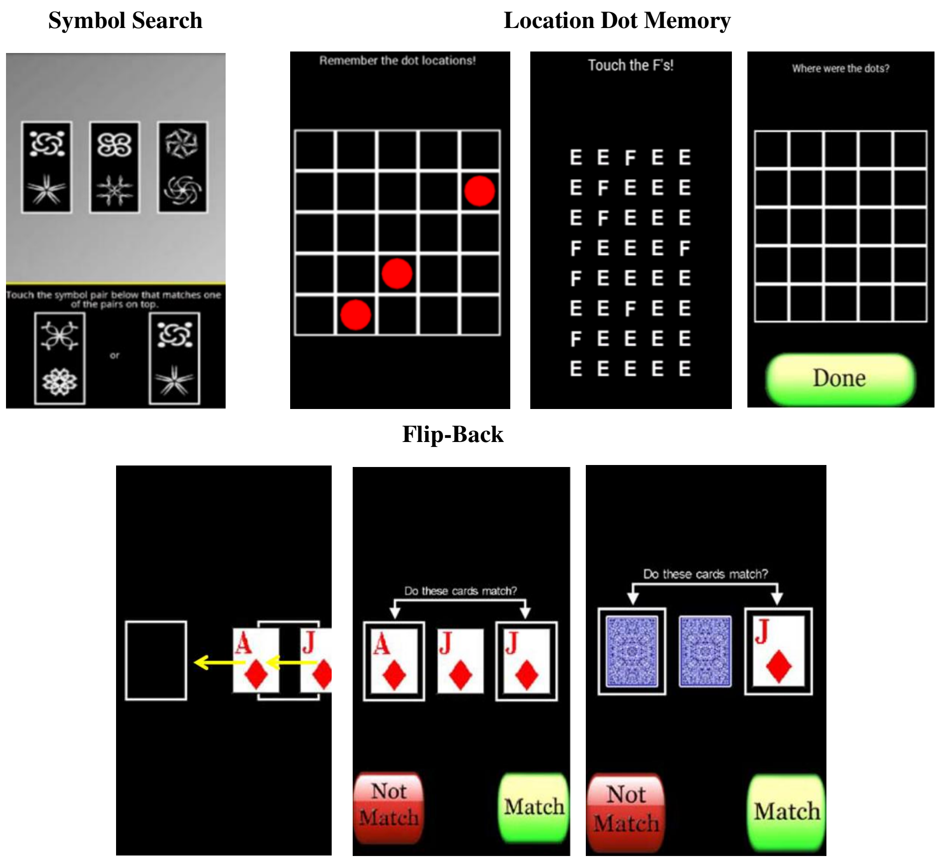

Figure 4.4. *Screenshots of Ambulatory Cognitive Tasks*

Symbol Search Task. Symbol Search served as a measure of processing speed. For each trial participants saw a row of three symbol pairs at the top of the screen and were presented with two symbol pairs at the bottom of the screen (see Figure 4.4). Participants decided, as quickly as possible, which of the pairs located at the bottom matched one of the pairs shown at top and completed a total of 12 trials. The stimuli stayed on the screen until a response was provided and there was a 200-millisecond (ms) interval between each response and the presentation of the next trial. Because this task required timed comparisons and symbol matching it served as an indicator of perceptual speed. According to research comparing this ambulatory assessment to traditional laboratory based tests of perceptual speed (Sliwinski et al., 2018), findings demonstrated strong construct validity. This ambulatory cognitive test produced highly reliable average scores in adults aged 25-65 years old (>.97) (Sliwinski et al., 2018), which is higher compared than reported values for response time tasks conducted by other researchers (Brose et al., 2014; Dirk & Schmiedek, 2015). Response time (RT) for each of the 12 trials was recorded. Mean RT on correct responses for each beeped survey was calculated and then averaged across the four daily occasions to create a mean daily performance score for this task.

Location Memory Dot Task. The Location Memory Dot task was used to measure working memory. Each trial of this task consisted of three phases: encoding, distracting, and retrieval (see Figure 4.4). For the encoding phase of this task, a grid appeared on the tablet screen with three red dots and the participant was asked to remember the locations of each dot. Following a three-second period, the 5 x 5 grid disappeared, and the distraction phase began, during which participants were asked to locate and touch as many F's amongst the E's as possible before the screen changed. After eight seconds of performing the distraction task, an empty 5 x 5 grid reappeared on the tablet screen asking participants to tap where the location of the three red dots were. Two trials (encoding, distractor, retrieval) were competed with a one-second delay in between each of the trials.

Scoring for this task was determined by calculating the Euclidean error score with partial credit being given based on the amount of deviation from the original dot locations (Hyun et al., 2019). A score of zero indicated that all dots were correctly recalled in the right location. If there was one or more retrieval errors, Euclidean distances were calculated between the location of the incorrect dot to the correct grid location, where higher scores indicated less accuracy in dot placement and poorer performance (Siedlecki, 2007; Sliwinski et al., 2018). Rationale for using this task as a viable indicator of working memory was based on the idea of controlled-attention, a trademark of most traditional working memory tasks (Unsworth & Engle, 2007; Unsworth & Spillers, 2010). By including an interference or distractor phase of the task, the test required active maintenance and then controlled recall as participants must correctly identify previous dot locations during the final retrieval phase. To further support this, prior research (Miyake et al., 2001) using factor analysis tested a similar dot memory task and found that it loaded highly to a working memory factor. Sliwinski et al. (2018) showed that this test is a valid indicator of working memory performance and revealed similar correlations with age and fluid intelligence as did laboratory-based assessments of working memory. The results also demonstrated good within- and between-person reliabilities for this ambulatory assessment across a 14-day period and averaging across assessments from a single day produced a reliability coefficient (Cronbach's alpha) of >.90 (Sliwinski et al., 2018). The average daily Euclidean distance was calculated by averaging scores across all four survey occasions to create a mean daily performance score for this task.

Flip-Back Task. The Flip-Back task was a modified version of the *n-back*, a commonly used measure of working memory (Schmiedek & Lindenberger, 2009). In this task, participants saw a series of three playing cards slide across the screen, moving from right to left. There were two phases of this task. In the practice phase, all cards were presented facing up, and participants were asked to decide if a *target* card in the right box matched the *test* card in the left box. There were ten practice trials and after each response was made there was a 500-millisecond delay during which the cards shifted positions across the screen with a new card appearing in the box on the right (see Figure 4.4). After the practice phase, participants began the next condition in which each new *target* card would turn face down prior to shifting positions across the screen. As the cards moved positions across the screen, participants were asked to determine if the current *target* card was the same as the card presented two-cards back that was currently facedown. If a card was chosen correctly, the boxes turned green, and the cards slid over for another round. If chosen incorrectly, the boxes turned red, and the card was flipped over to show the correct concealed target card. There were 12 trials of this condition, and both reaction time (speed in milliseconds) and the proportion of correct responses (accuracy) were recorded; for the present study only the reaction time (RT) was used for the outcome of task performance. Average RT across all 12 trials was calculated and then averaged across all four beeped survey occasions to create a daily mean performance score for the Flip-back task. Prior research has demonstrated that this ambulatory assessment is highly correlated with in-lab working memory tasks as well as in-lab perceptual speed tasks, demonstrating high between-person reliability (Sliwinski et al., 2018).

Data preparation. Prior to creating the daily composite scores for activity and meaningfulness, an EFA was performed to identify the underlying factor structure, at the daily level, for the EMAS. In Study 1, the results of the EFA resulted in a three-factor solution however it is probable that the underlying structure may look different at the daily level given the different response options used for the momentary survey. The justification for performing EFA on the EMAS was to characterize the construct of meaningfulness both in terms of analytical associations between items but also in terms of conceptualizing what questions shared similar features. A promax rotated principal component analysis was performed, setting an eigenvalue of 1.0 for item extraction. The Kaiser-Meyer-Olkin measure of sampling adequacy was .89, above the recommended value of .6, and Bartlett's test of sphericity was significant, $\chi^2(66) = 26636.97$ ($p < .001$). The EFA resulted in a two-factor solution that explained 60.5% of the variance in the momentary EMAS; communalities ranged from .31 to .84. Factor 1 accounted for 48.07% of the

EMAS variance and contained items 1, 2, 3, 4, 5, 8, 9, 10, 11, 12 and Factor 2 accounted for 12.42% of the variance in the EMAS and contained items 6 and 7.

Table 4.2. *EFA and Item Analysis for Meaningfulness*

		Promax Rotated Pattern Matrix		Corrected Item-Total Correlation
		Factor 1	Factor 2	
1	Take care of self	**.75**		.47
2	Reflect the person I am	**.69**		.68
3	Express my creativity	**.46**		.56
4	Sense of accomplishment	**.75**		.75
5	Feel competent	**.76**		.74
6	Valued by others		**.91**	.49
7	Help others		**.95**	.41
8	Give me pleasure	**.83**		.66
9	Feeling of control	**.78**		.65
10	Express personal values	**.75**		.73
11	Sense of satisfaction	**.86**		.74
12	Right amount of challenge	**.46**		.48

Internal consistency for each factor was examined using Cronbach's alpha, the alphas were high: .91 for Factor 1 and .86 for Factor 2. Composite scores were created for each of the two factors, based on calculating the mean for all items which had their primary loadings on each factor (see bolding indications in Table 4.2). Higher scores represented more frequent engagement in meaningful types of activity. Factor 1 included 10 items which described meaningful engagements that represented self-expression, provided a sense of pleasure, accomplishment, and challenge, and expressed personal values of control and competence; Factor 1 was labelled Self-Expression, Experience & Personal Competence (SEEPC). The remaining two items (e.g., helping others, valued by others) loaded onto Factor 2 which was labelled Social Care (SC).

Valid survey entries. Momentary beeped surveys were considered valid if the participants responded within 60 minutes of the original alarm, either before or after. In the case that participants answered the survey before the alarm went off, these before-beeped survey responses were included to not exclude participation solely based on anticipatory response. Based on this inclusion, duplicate entries were possible, for example if the participant answered the survey in anticipation right before the alarm went off, and then restarted the survey when the alarm went off. Alternatively, they may have started a survey but then stopped responding for a brief period, and the application may have closed requiring participants to re-enter the survey through the "Launch Survey" icon. Duplicate cases were examined on an individual basis. If both duplicates were within 60 minutes of the original alarm, then the chosen case was based on which entry had more data. In some cases, this decision was quite clear, with one entry being barely done, and the other done completely. In other instances, duplicate entries were quite similar with no clear indication of which timestamp was more valid. In these rare cases, the entry that was closer to the original alarm schedule was chosen as valid.

Trimming and Recoding. Because both the Symbol Search and Flip-Back tasks used reaction time (RT) as an outcome, data was first cleaned and trimmed separately for each task. First, incorrect responses were removed to ensure that the outcome was not the result of slower incorrect responses. All remaining RT latencies were then trimmed for outliers. Lower limit trims included removing any trials where the response was below 200 ms, and higher limit trims involved removing any trials that exceeded 7000 ms. Next, means and standard deviations were calculated for each participant across all trials, and any latencies that exceeded +3 *SDs* for that individual were removed. Any remaining missing values were then imputed using a regression substitution process described in the literature as a conservative method for estimating inconsistency and reducing within-person variation (Bielak et al., 2012; Hultsch et al., 2000).

The following parameters were re-centered to establish a meaningful starting point or "0". Study day was recoded to range from 0 to 13, with 0 representing the first day of tablet testing and 13 representing the final day of the two-week testing period. Gender was dichotomized (0 = Females, 1= Males), age was centered around the minimum age of the sample (41 years old), although education was centered at the minimum year of total education for the sample (12 years).

Statistical Analyses. IBM SPSS Statistics version 26 was used to conduct all analyses. MLM used to evaluate the associations between daily activity, daily meaningfulness, and daily cognitive performance. MLM was appropriate for this longitudinal analysis because this procedure simultaneously measures both individual changes over time (level-1) and how these changes differ across or between-individuals (level-2). Activity level was determined based on the total number of daily checked activity responses, which were coded as dichotomous (i.e., yes/no) responses for each activity item. Total activity item responses were counted for each survey and summed across all four beeped survey occasions to create a total daily activity count, with higher counts representing greater levels of participation in a variety of different daily activities[4].

For meaningfulness, based on the EFA structure, daily composite variables were created for each factor based on the mean of all item responses measured across all four beeped survey occasions. For cognition, scores were combined across the day for each of the 3 cognitive tasks, and separate models were analyzed for each of the three cognitive outcomes (i.e., symbol search, location dot memory, flip-back). The reason for averaging scores across all daily beeped occasions was to produce an aggregate total daily performance score for each cognitive task.

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[4] Since a different activity assessment was used for the momentary surveys than was used in Study 1 (VLS-AQ), factor reduction techniques were not deemed necessary since the modified momentary activity assessment included only 20 items compared to the 57 items of the VLS-AQ (Jopp & Hertzog, 2010). Further, the count (yes/no) response scale was different from the frequency-based scale used in Study 1.

Between- and within-person component scores were created for activity, and for each of the meaningfulness factors. For activity, the between-person component was obtained by calculating an average activity level for each person across all 14 days of testing; the within-person activity level component was obtained by subtracting each person's total daily activity level from their individual mean activity level across all study days (i.e., activity-between). The same formula was followed to calculate the between- and within-person component scores for each meaningfulness factor. Between-person components for activity level and the meaningfulness factors served as level-2 predictors although the within-person components were level-1 predictors.

Multilevel Models. MLM, also referred to as hierarchical linear modeling, is an extension of the general linear model that does not require observations to be independent. This is suitable for daily data because of its autoregressive nature and hierarchical structure which allows for daily observations to be nested within each participant (Singer & Willett, 2003). Both fixed and random effects can be estimated with MLM; fixed effects refer to the "average effects" or effects that hold over all individuals and represent the amount of variance accounted for, although random effects reflect subject-specific variance and represent the amount of variance remaining to be accounted for.

The models discussed below specified two-levels of analysis. The within-person components (level-1) indicated significant time-varying covariation between change in daily activity, change in the frequency of daily meaningful engagement, and change in cognitive performance at the daily level. The between-person components (level-2) for daily activity and meaningfulness factor scores were modeled as time-invariant (e.g., fixed effects) predictors of the intercept of daily cognitive performance and change in performance over the two-week testing period (i.e., slope). In these models, time-invariant (e.g., fixed effects) were examined only for level-2 predictor variables (i.e., the *between-person* components). Random effects tested whether there was significant residual variation in the time-invariant level-2 fixed effects.

All level-2 (between-person) model variations tested the following variables for covariate effects to examine whether there were between-person differences in the outcome based on age, gender, and education. Past research using a similar 14-day EMA design (Hyun et al., 2019) reported age, gender, and education as significant covariates, which is in line with other longitudinal research that has explored the activity-cognition connection (Bielak et al., 2014; Bielak, 2017). Meaningfulness may also vary with age, as researchers have argued that the frequency of emotional investments increases with age, leading older individuals to seek out more meaningful pursuits (Coleman & Iso-Ahola, 1993; Carstensen, 2003). If covariate effects were nonsignificant in the level-2 intercept equations, they were subsequently removed from future model variations to improve model fit.

All models were estimated using the Maximum Likelihood (ML) method. The ability of conditional models (e.g., models with predictor variables) to predict performance was evaluated in a stepwise fashion comparing model fit to previous model variations; this process was used to determine Goodness of Fit for each step throughout model construction (Kim et al., 2018). Model fit was evaluated based on the -2 Log Likelihood (-2LL) which represented a deviation value used to compare fit between conditional models. Figure 4.4 displays the predicted sequence in which MLMs were tested.

Multilevel Model Identification	
0	$Model_0$ = Unconditional Model (Null)
1	$Model_1 = Model_0$ + Study Day
2	$Model_2 = Model_1$ + Study Day^2
3	$Model_3 = Model_2$ + Age + Gender + Education
4	$Model_{4a} = Model_3^*$ + Meaningfulness Factors 1 & 2
	$Model_{4b} = Model_3^*$ + Activity
5	$Model_5 = Model_{4a} + Model_{4b}$

Note: * In Model 3, nonsignificant predictor variables in the level-1 equation (Study Day) & (Study Day^2), and level-2 equation (age, gender, education) were subject to removal from the MLM analysis based upon significance of the fixed effects in prior model iterations.

Figure 4.4. *Sequence of Multilevel Model*

Models were built in a series of steps. First, the unconditional model which included no predictor variables was ran to determine intraclass correlations ($ICC = \mu_{0i} / (\mu_{0i} + e_{ij})$). *ICC* is the proportion of variance in the outcome that is between (vs. within) person. Next, a series of conditional models were evaluated, where fixed and random effects were examined sequentially with time as the initial predictor. Then the between- and within- person effects for both meaningfulness factors and activity were added to separate conditional models (see Figure 4.4; Models 4_a and 4_b) to test for significant effects on cognition. In the final conditional model (Model 5) both meaningfulness factors and activity were examined collectively. As the model progressed, if any of the fixed effects in either the intercept or slope equations were non-significant, they were removed from the model to enhance goodness of fit.

Table 4.3[*] displays the hypothesized level-1 and level-2 model equations for each step in this analysis. The entire sequence was performed separately for each of the three cognitive tasks

[*] *Table 4.3 Note:* In addition to the linear effect of Study Day, the quadratic effects (Study Day^2) were also included in the level-1 equation in Model 2. The random residual effect for the quadratic effect (μ_{2i}) is often challenging for model convergence, and it was unclear if it would be included in the analysis after this step (in fact, as noted below, this random effect was not significant in any of the models and excluded from the later models). In Model 3 * indicates covariate fixed effects that were subject to removal based on significance in prior model iterations. These removals were specific to each cognitive task being evaluated.

(i.e., Symbol Search, Location Dot Memory, Flip-Back). First, in the unconditional model (Model 0), each person's daily performance (Cognitive $Task_{ij}$) was modeled as a function of their average score (β_{0i}) and variability around their own scores (e_{ij}). In the level-2 equation for Model 0, β_{0i} was modeled as a function of the sample average for cognitive task performance (γ_{00} -fixed effect or mean) and variability around the sample average (μ_{0i} – random effect or variance). Next, a series of conditional models (Models 1-2) were tested adding in fixed and random effects of time (e.g., Study Day) as a level-1 predictor. Both linear (Model 1- γ_{10}) and quadratic (Model 2- γ_{20}) fixed effects were examined. In Model 2, individual quadratic slopes (β_{2i}) were modeled as a function of the fixed quadratic effect (γ_{20}); only significant fixed effects were retained in the model going forward.

Table 4.3. *Planned MLM Analysis: Level-1 and Level-2 Equations*

Step	Model	Level-1 Equation	Level-2 Equation
0	Unconditional Model	Cognitive $\text{Task}_{ij} = \beta_{0i} + e_{ij}$	$\beta_{0i} = \gamma_{00} + \mu_{0i}$
1	Conditional Model	*Linear:* Cognitive $\text{Task}_{ij} = \beta_{0j} + \beta_{1i}$ (Study Day) + e_{ij}	$\beta_{0i} = \gamma_{00} + \mu_{0i}$ $\beta_{1i} = \gamma_{10} + \mu_{1i}$
2	Conditional Model	*Quadratic:* Cognitive $\text{Task}_{ij} = \beta_{0i} + \beta_{1i}$ (Study Day) + β_{2i} (Study Day^2) + e_{ij}	$\beta_{0i} = \gamma_{00} + \mu_{0i}$ $\beta_{1i} = \gamma_{10} + \mu_{1i}$ $\beta_{2i} = \gamma_{20} + \mu_{2i}^{*}$
3	Conditional Model	Cognitive $\text{Task}_{ij} = \beta_{0i} + \beta_{1i}$ (Study Day) + β_{2i} (Study Day^2) + e_{ij}	$\beta_{0i} = \gamma_{00} + \gamma_{01}$ (Age) + γ_{02} (Gender) + γ_{03} (Education) + μ_{0i} $\beta_{1i} = \gamma_{10} + \mu_{1i}$ $\beta_{2i} = \gamma_{20}$
4_a	Conditional Model*	Cognitive $\text{Task}_{ij} = \beta_{0i} + \beta_{1i}$ (Study Day) + β_{2i} (Study Day^2) + β_{3i} (Meaningfulness Factor 1-Within) + β_{4i} (Meaningfulness Factor 2-Within) + e_{ij}	$\beta_{0i} = \gamma_{00} + \gamma_{01}$ (Age)* + γ_{02} (Gender)* + γ_{03} (Education)* + γ_{04} (Meaningfulness Factor 1-Between) + γ_{05} (Meaningfulness Factor 2-Between) + μ_{0i} $\beta_{1i} = \gamma_{10} + \gamma_{14}$ (Meaningfulness Factor 1-Between) + γ_{15} (Meaningfulness Factor 2-Between) + μ_{1i} $\beta_{2i} = \gamma_{20}$ $\beta_{3i} = \gamma_{30}$ $\beta_{4i} = \gamma_{40}$
4_b	Conditional Model*	Cognitive $\text{Task}_{ij} = \beta_{0i} + \beta_{1i}$ (Study Day) + β_{2i} (Study Day^2) + β_{3i} (Activity-Within) + e_{ij}	$\beta_{0i} = \gamma_{00} + \gamma_{01}$ (Age)* + γ_{02} (Gender)* + γ_{03} (Education)* + γ_{04} (Activity-Between) + μ_{0i} $\beta_{1i} = \gamma_{10} + \gamma_{14}$ (Activity-Between) + μ_{1i} $\beta_{2i} = \gamma_{20}$ $\beta_{3i} = \gamma_{30}$
5	Conditional Model	Cognitive $\text{Task}_{ij} = \beta_{0i} + \beta_{1i}$ (Study Day) + β_{2i} (Study Day^2) + β_{3i} (Meaningfulness Factor 1-Within) + β_{4i} (Meaningfulness Factor 2-Within) + β_{5i} (Activity-Within) + e_{ij}	$\beta_{0i} = \gamma_{00} + \gamma_{01}$ (Age)* + γ_{02} (Gender)* + γ_{03} (Education)* + γ_{04}(Meaningfulness Factor 1-Between) + γ_{05} (Meaningfulness Factor 2-Between) + γ_{06}(Activity-Between) + μ_{0i} $\beta_{1i} = \gamma_{10} + \gamma_{14}$ (Meaningfulness Factor 1-Between) + γ_{15} (Meaningfulness Factor 2-Between) + γ_{16} (Activity-Between) + μ_{1i} $\beta_{2i} = \gamma_{20}$ $\beta_{3i} = \gamma_{30}$ $\beta_{4i} = \gamma_{40}$ $\beta_{5i} = \gamma_{50}$

Next, age, gender, and education were entered as level-2 predictors in the intercept equation for Model 3. All three covariates have been linked to cognitive function in previous studies (Livingston et al., 2017; Karlamangla et al., 2009; Laws et al., 2018). Covariate effects were exclusive to the intercept model as prior research has reported significant between-person fixed effects of age and education on differences in baseline cognitive scores, but not on the rate of change in performance (i.e., slope) at the daily level (Bielak et al., 2019a). In Model 4_a and Model 4_b, the fixed effects for both meaningfulness factors and activity were independently added to each model predicting cognitive performance. All within-person effects were modeled in the level-1 equation and the between-person effects were modeled in the level-2 equation.

Finally, in Model 5, meaningfulness and activity were examined collectively for between- and within-person effects on cognition. In the level-1 equation each person's daily performance (Cognitive Task_{ij}) was modeled as a function of their average score for Study Day = 0 (β_{0i} – the intercept), plus a slope parameter (β_{1i}), reflecting their average linear rate of change per additional day, plus the average quadratic slope (β_{2i}), reflecting their average quadratic rate of change across days, plus (β_{3i}) reflecting the average within-person change in meaningfulness factor 1 scores, plus (β_{4i}), reflecting the average within-person change in meaningfulness factor 2 scores, plus (β_{5i}), the average within-person change in activity, plus the within-subject residual variance remaining to be explained (e_{ij}). In the level-2 equation, individual intercepts (β_{0i}) were modeled as a function of the average performance at Study Day = 0 (γ_{00}), plus any significant between-person fixed effects for age (γ_{01}), gender (γ_{02}), education (γ_{03}) discovered in Model 3, plus the between-person fixed effects for meaningfulness factor 1 (γ_{04}), meaningfulness factor 2 (γ_{05}), and activity (γ_{06}), plus between-person residual variance in the intercept (μ_{0i}). Individual linear slopes (β_{1i}) were modeled as a function of average daily performance change (γ_{10}) per one unit increase in Study Day (e.g., 0 to 1, 1 to 2), plus between-person fixed effects in meaningfulness factor 1 (γ_{14}), meaningfulness factor 2 (γ_{15}), and activity (γ_{16}), plus the random effects of between-person variance in slope (μ_{1i}). β_{2i} was modeled as function of the fixed quadratic effect of (γ_{20}). Within-person changes in meaningfulness factor 1 (β_{3i}), meaningfulness factor 2 (β_{4i}), and activity (β_{5i}) were modeled as functions of the respective fixed within-person components ($\gamma_{30,}$ $\gamma_{40,}$ γ_{50}). Within-person random effects were exclusive to the linear slope parameter (β_{1i}), as the model failed to converge when random effects for μ_{2i} and μ_{3i} (i.e., within-person residual variances) were determined.

Results

Daily survey data for *N* = 81 participants included in the present analysis resulted in a total of 4,536 beeped survey occasions across the 14-day testing period, and 324 daily beeped survey response options. The total number of completed beeped surveys was 3,608, indicating that on average, participants completed 79.5% of all daily beeped surveys. Table 4.4 reports the descriptive statistics for all model parameters and cognitive outcomes.

To ensure that there was enough within- and between-person variance in each three cognitive outcomes to conduct MLM analysis (Raudenbush & Bryk, 2002), *ICCs* were calculated separately for each outcome. Figure 4.5 displays separate spaghetti plots for each cognitive task. The results of Model 0 indicated that 77% of the total variance in symbol search task performance was attributable to between-person effects, although 23% of the total variance was due to within-person effects. For location dot memory, *ICC* = .40, which means that 40% attributable to between-person effects, and (1 - .40 = .60) or 60% of the total variance was due to within-person effects. For flip-back performance, between-person effects accounted for 80% of the total variance in performance, although 20% was attributable to within-person effects.

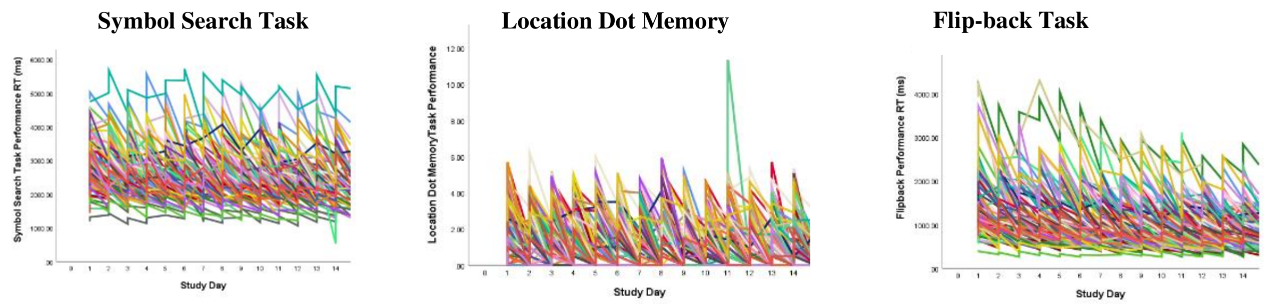

Figure 4.5. *Individual (Within-Person) Fluctuations in Cognitive Performance*

Table 4.4. *Descriptive Statistics for Model Parameters*

		Measures								
		Symbol Search	Location Memory Dot	Flip-Back	Meaning Factor 1 (Within)	Meaning Factor 1 (Between)	Meaning Factor 2 (Within)	Meaning Factor 2 (Between)	Activity (Within)	Activity (Between)
Study Day	# Beeped Surveys	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
1	178	2812.93 (716.94)	1.36 (1.28)	1446.93 (745.39)	.07 (.47)	1.51 (.47)	.05 (.50)	1.19 (.50)	.28 (1.61)	5.50 (1.61)
2	268	2800.09 (771.93)	1.47 (1.31)	1312.02 (587.69)	.08 (.49)	1.54 (.49)	.06 (.51)	1.20 (.51)	.03 (1.67)	5.56 (1.67)
3	269	2636.13 (738.50)	1.26 (1.24)	1215.40 (574.25)	.06 (.49)	1.51 (.49)	-.04 (.49)	1.18 (.49)	-.30 (1.69)	5.49 (1.69)
4	273	2610.74 (693.14)	1.15 (1.23)	1192.63 631.06)	.02 (.50)	1.53 (.50)	-.08 (.50)	1.19 (.50)	-.44 (1.69)	5.55 (1.69)
5	271	2613.58 (715.94)	1.21 (1.37)	1207.63 (633.70)	.02 (.46)	1.52 (.46)	-.06 (.49)	1.15 (.49)	-.38 (1.64)	5.48 (1.64)
6	278	2596.16 (741.04)	1.23 (1.21)	1183.30 (625.36)	-.03 (.49)	1.52 (.49)	.04 (.50)	1.17 (.50)	-.18 (1.67)	5.52 (1.67)
7	261	2601.59 (753.84)	1.20 (1.26)	1102.37 547.98)	-.05 (.49)	1.51 (.46)	.00 (.50)	1.15 (.50)	.52 (1.64)	5.53 (1.64)
8	276	2565.04 (711.22)	1.24 (1.39)	1063.83 (503.56)	-.07 (.49)	1.52 (.49)	.00 (.50)	1.17 (.50)	.44 (1.71)	5.53 (1.71)
9	256	2469.34 (654.01)	1.11 (1.27)	1048.21 (518.40)	.01 (.49)	1.53 (.49)	.04 (.48)	1.17 (.48)	.01 (1.67)	5.46 (1.67)
10	272	2480.33 (701.70)	1.04 (1.11)	1020.91 (514.92)	.00 (.48)	1.49 (.48)	-.02 (.49)	1.16 (.49)	-.16 (1.69)	5.51 (1.69)
11	266	2474.10 (686.48)	1.12 (1.38)	1029.10 (501.64)	.04 (.51)	1.53 (.51)	.00 (.50)	1.16 (.50)	-.17 (1.64)	5.38 (1.64)
12	244	2470.76 (659.61)	1.03 (1.20)	992.88 (468.20)	-.03 (.48)	1.51 (.48)	-.01 (.50)	1.17 (.50)	.18 (1.71)	5.50 (1.71)
13	252	2464.02 (739.19)	.97 (1.20)	960.13 (435.23)	.03 (.48)	1.51 (.48)	.09 (.49)	1.15 (.49)	.08 (1.69)	5.46 (1.69)
14	244	2507.44 (759.64)	.96 (1.24)	976.19 (460.61)	-.10 (.48)	1.51 (.48)	.02 (.48)	1.13 (.48)	.16 (1.65)	5.40 (1.65)
Total	3608	2559.62 (715.94)	1.15 (1.27)	1100.55 (557.37)	.00 (.48)	1.51 (.47)	.01 (.49)	1.16 (.49)	.04 (1.70)	5.49 (1.67)

Notes: Symbol search and Flip-Back performance were measured in RT (milliseconds), where larger values represented slower RT and smaller values represented faster RT. Location Dot Memory was measured as the mean Euclidean distance between original dot and response (across 2 trials), 0 indicated a perfect score. All numerical values reported for the cognitive outcomes represent values after data was cleaned and prepped for analysis.

Multilevel Modeling. All fixed and random effects for each cognitive outcome are reported in Table 4.5. For each of the three cognitive tasks, the intercept-only model provided a baseline proxy of between- and within-person variation (See Table 4.5, Model 0). Next, the linear rate of change (Study Day) was assessed to determine whether there was significant change in performance across the 14-day period (Model 1). Next, the quadratic effects (Study Day^2) were added to each model to test for significant quadratic change in performance.

Table 4.5. *Multilevel Model Parameter Estimates Predicting Cognition*

	Cognitive Task		
	Symbol Search	Location Dot Memory	Flip-Back
Model 0	Estimate *(SE)*	Estimate *(SE)*	Estimate *(SE)*
Fixed Effects			
Intercept	2570.40 (71.81) **	1.17 (.09) **	1120.08 (57.68) **
Random Effects			
Residual	126845.17 (2812.91) **	.98 (.02) **	71443.26 (1586.28) **
Intercept	414932.71 (65657.15) **	.62 (.10) **	267929.72 (42375.51) **
Model fit, *df* = 3	-2LL = 60925.16 AIC = 60931.16	-2LL = 11987.88 AIC = 11993.88	-2LL = 58414.61 AIC = 58420.61
Model 1			
Fixed Effects			
Intercept	2746.52 (73.74) **	1.38 (.09) **	1335.17 (68.61) **
Study Day	-24.51 (2.60) **	-.03 (.01) **	-30.79 (2.66) **
Random Effects			
Residual	108042.98 (2603.63) **	.95 (.02) **	47446.89 (1146.97) **
Intercept	430890.16 (68949.83) **	.64 (.11) **	376997.19 (59988.88) **
Study Day	376.45 (84.75) **	.00 (.00)	493.76 (92.85) **
Model fit, *df* = 5	-2LL = 52571.75 AIC = 52581.75	-2LL = 10357.03 AIC = 10367.03	-2LL = 49618.17 AIC = 49628.17
Model 2			
Fixed Effects			
Intercept	2809.29 (74.62) **	1.39 (.10) **	1398.96 (69.02) **
Study Day	-53.99 (5.18) **	-.03 (.02) *	-60.75 (4.36) **
Study Day^2	2.25 (.40) **	.00 (.00)	2.29 (.26) **
Random Effects			
Residual	107047.18 (2579.95) **	.95 (.02) **	46403.53 (1121.67) **
Intercept	431604.99 (69056.72) **	.64 (.11) **	377299.21 (60016.35) **
Study Day	376.79 (84.89) **	.00 (.00)	504.06 (94.25) **
Study Day^2	-	-	-
Model fit, *df* = 6	-2LL = 52539.78 AIC = 52551.78	-2LL = 10356.95 AIC = 10368.95	-2LL = 49542.98 AIC = 49554.98
$\chi 2$ (Δdf)	37.97 (1) **	.08 (1)	75.19 (1) **

Note: * $p < .05$; ** $p < .001$. $\chi^2 = \Delta$ -2LL. In all models displayed, the sequencing was performed in a stepwise fashion, first adding in fixed effects, followed by random effects for each time-varying predictor. The model failed to converge when the random quadratic effects (Study Day^2) were added in Model 2 and thus the random quadratic effect were removed.

Overall, there were significant fixed effects on the intercept for each cognitive task, there was also significant random variation in both within (residual) and between (intercept) person effects. Across all three cognitive tasks, there was significant linear changes in performance across the 14 days. For all three tasks, the linear effect was negative indicating that for the average participant there was significant change in performance across study days. There were significant reductions in RTs on the Symbol Search and Flip-Back tasks, indicating that participants responded faster over the 14 days. In addition, random effects for intercepts and for the rate of linear performance change was also significant for both RT tasks, indicating significant individual differences in both the level of initial performance and in the rate of change over time. Performance on the Location Dot Memory task also improved over time, as indicated by the significant negative fixed linear effect. The random effects of time were not significant for location dot memory (see Table 4.5, Model 1).

The same pattern of effects emerged when quadratic effects were added to each model (see Table 4.5, Model 2); significant fixed quadratic effects emerged for both RT tasks but were non-significant for Location Dot Memory. Random effects on the slopes of both RT tasks remained significant ($p < .001$) but the random quadratic effects did not converge. The non-significant fixed and random quadratic effects for Location Dot Memory were removed from subsequent analysis (see Table 4.5).

According to the model fit statistics (i.e., -2LL, AIC) presented in Table 4.5, fit improved when the fixed and random effects of Study Day were included in Model 1, as demonstrated by lower AIC values compared to Model 0. In comparing model fit between the linear and quadratic variations (Model 1 vs. Model 2), for both RT tasks, AIC values were lowest when both fixed and random effects of Study Day were involved. For Location Dot Memory, model fit was reduced when the quadratic effects were involved, thus justifying the removal of quadratic effects from the level-1 equation predicting task performance going forward. Model fit improved significantly for both Symbol Search and Flip-Back when fixed and random linear and fixed quadratic effects were added in Model 2, as indicated by positive χ^2 values, which represented change (Δ) in -2LL *(*Model 1 – Model 2).

The Role of Covariates. Next, between-person fixed effects of age, gender, and education were added (see Table 4.6, Model 3). Here the three covariates (age, gender, education) were entered independently as level-2 predictor variables on the intercept in each of the MLMs.

Table 4.6. *Fixed Effects of Age, Gender, & Education on the Intercept of Cognitive Performance*

	Cognitive Task		
	Symbol Search	Location Dot Memory	Flip-Back
Model 3	Estimate *(SE)*	Estimate *(SE)*	Estimate *(SE)*
Fixed Effects			
Intercept	2807.40 (78.45) **	1.32 (.11) **	1402.63 (70.86) **
Study Day	-54.69 (6.11) **	-.03 (.00) **	-60.43 (4.53) **
Study Day^2	2.27 (.41) **	-	2.27 (.27) **
Age	.68 (.52)	.00 (.00)	-.04 (.35)
Gender	-38.41 (14.22) **	-.06 (.04)	6.10 (9.41)
Education	.36 (2.26)	.01 (.01)	-1.02 (1.50)
Random Effects			
Residual	106767.87 (2573.19) **	.96 (.02) **	46386.77 (1121.26) **
Intercept	431466.57 (69035.48) **	.64 (.10) **	377273.60 (60013.02) **
Study Day	379.24 (85.15) **	-	503.85 (94.21) **
Model fit, df = 9, *df = 7, df = 9*	-2LL = 52531.04 AIC = 52549.04	-2LL = 10354.14 AIC = 10368.14	-2LL = 49541.70 AIC = 49559.70
Model 3 final *(sig. only)* $^{\wedge}$	-2LL = 52532.75 df = 7	-2LL = 10357.03 df = 5	-2LL = 49542.98 df = 6
χ^2 (Δdf)	8.74 (3) *	2.81 (1)	1.28 (3)

Note: * p < .05; ** p < .001; $^{\wedge}$Model 3 final (*sig. only)* referred to the fit statistics for the model including only significant fixed and random effects, this model was used for comparisons with future nested model variations (i.e., Model 4a & Model 4b). χ^2 values represented change (Δ) in -2LL *(*Model 2 – Model 3). For Location Dot Memory, the fixed quadratic and random linear effects were excluded (-), thus the final Model 3 df = 5, and Δdf = 1.

There were no significant fixed effects for age or education in any of the Model 3 variations (see Table 4.6). For the Symbol Search task, there was a significant fixed effect of gender ($p < .001$) on performance, suggesting that females began the study with significantly lower RTs on the Symbol Search task, than did males ($\gamma_{02} = -38.41$). χ^2 values represented change (Δ) in -2LL between Models 2 and 3. In comparing Models 2 and 3 for this task, $\chi^2 = 8.74$, $\Delta df = 3$, $p < .05$, demonstrating significantly improved model fit when covariates were added in addition to the parameters from the previous model.

In comparing Goodness of Fit between Models 2 and 3 for the Location Dot Memory task, $\chi^2 = 2.81$, $\Delta df = 3$, $p > .05$, which was not considered statistically significant (Kim et al., 2018). The same was true for Flip-Back performance, as there were no significant fixed effects for any of the covariates on the intercept, and the χ^2 indicated only a slight increase in the – 2LL, not substantial for significance. The fixed intercept effect of gender on Symbol Search performance was retained for subsequent model building, and all other non-significant fixed effects were removed. Table 4.7 reports the correlations between covariates and cognitive outcomes.

Table 4.7. *Correlations Between Covariates & Intercept-Level Cognitive Outcomes*

	Age	Gender	Education	SST	LDM	FBT
Age	1	-.29**	-.08**	.08**	.04**	.10**
Gender	-.29**	1	.25**	-.00	.00	-.03
Education	-.08**	.25**	1	.02	.04*	.00
SST	.08**	-.00	.02	1	.37**	.44**
LDM	.04*	.00	.04*	.37**	1	.15**
FBT	.10**	-.03	.00	.44**	.15**	1

Notes: * $p < .05$; ** $p < .001$. SST = Symbol Search Task; LDM = Location Dot Memory; FBT = Flip-Back Task.

Meaningfulness and Activity on Cognition. To address the research question and hypotheses for Study 2, day-to-day variation in both meaningfulness factor scores, and activity were explored first independently (Model 4_a and Model 4_b) as predictors of cognition. Model 4_a added the between- and within-person effects for both meaningfulness factors and Model 4_b included these effects for activity. All effects are presented in Table 4.8.

Table 4.8. *Meaningfulness (Model 4_a) & Activity (Model 4_b) Predicting Cognition*

	Cognitive Task		
	Symbol Search	Location Dot Memory	Flip-Back
Model 4_a (Meaningfulness)	Estimate *(SE)*	Estimate *(SE)*	Estimate *(SE)*
Fixed Effects			
Intercept	2677.39 (342.25) **	1.57 (.76) *	1470.22 (281.52) **
Study Day	-62.09 (10.49) **	-.02 (.01)	-72.12 (9.58) **
Study Day^2	2.22 (.45) **	-	2.37 (.30) **
Gender	-38.62 (12.21) **	-	-
MF1-Within	-230.58 (138.68)	-.33 (.39)	-99.34 (91.71)
MF2-Within	813.48 (216.28) **	.88 (.38) *	150.59 (188.52)
MF1-Between	350.28 (136.84) *	.78 (.46)	20.38 (89.96)
MF2-Between	-911.95 (216.06) **	-1.14 (.44) *	-251.50 (188.85)
Study Day x MF1-Between	-6.59 (6.31)	-.01 (.01)	12.09 (6.42)
Study Day x MF2-Between	11.95 (6.33)	.00 (.01)	-7.36 (6.46)
Random Effects			
Residual	106513.43 (2566.44) **	.96 (.02) **	46389.33 (1121.38) **
Intercept	365623.48 (58625.78) **	.62 (.10) **	365778.88 (58212.08) **
Study Day	360.79 (81.74) **	-	479.79 (90.05) **
Model 4_a fit *df* = 13, *df* = 10, *df* = 12	-2LL = 52506.80 AIC = 52535.80	-2LL = 10349.24 AIC = 10369.24	-2LL = 49535.97 AIC = 49559.97
Model 3 (sig. only)	-2LL = 52532.75 *df* = 7	-2LL = 10357.03 *df* = 5	-2LL = 49542.98 *df* = 6
χ^2 (Δdf)	25.95 (6) **	7.79 (5)	7.01 (6)
Model 4_b (Activity)			
Fixed Effects			
Intercept	3439.28 (278.70) **	2.56 (.48) **	1802.39 (245.27) **
Study Day	-58.48 (10.48) **	-.05 (.01) **	-69.70 (9.84) **
Study Day^2	2.22 (.40) **	-	2.30 (.26) **
Gender	-31.42 (13.19) **	-	-
Activity-Within	62.80 (20.66) **	.14 (.06) *	2.26 (13.61)
Activity-Between	-109.96 (48.74) *	-.21 (.08) *	-73.35 (42.80)
Study Day x Activity-Between	.40 (1.57)	.00 (.00)	1.62 (1.60)
Random Effects			
Residual	106535.82 (2567.59) **	.96 (.02) **	46406.26 (1121.81) **
Intercept	425472.33 (68095.27) **	.64 (.10) **	363494.51 (57853.20) **
Study Day	379.11 (85.12) **	-	495.80 (92.99) **
Model 4_b fit *df* = 10, *df* = 7, *df* = 9	-2LL = 52522.36 AIC = 52542.36	-2LL = 10350.91 AIC = 10364.91	-2LL = 49539.03 AIC = 49557.03
χ^2 (Δdf)	10.39 (3) *	6.12 (2) *	3.95 (3)

Notes: * $p < .05$; ** $p < .001$. MF1 = Meaningfulness factor 1; MF2 = Meaningfulness factor 2. χ^2 values represented change (Δ) in -2LL between final Model 3, including only significant effects and both Model 4 variations. In Model 4_a, χ^2= (-2LL Model 3) – (-2LL Model4_a). In Model 4_b, χ^2 = (-2LL Model 3) – (-2LL Model4_b).

For symbol search performance, there was significant model improvement when meaningfulness ($\chi^2 = 25.95$, $\Delta df = 6$, $p < .001$), and activity ($\chi^2 = 10.39$, $\Delta df = 3$, $p < .05$), were added as independent predictors (see Table 4.8). For location dot memory, activity, but not meaningfulness, significantly improved model fit ($\chi^2 = 6.12$, $\Delta df = 2$, $p < .05$). For flip-back performance, the inclusion of neither predictor variables (i.e., meaningfulness nor activity) improved model fit (*p's* > .05) when compared to final Model 3 (see Table 4.6). Table 4.9 reports the correlations between primary predictors and cognitive outcomes. The specific significant parameters identified in each of the Model 4 variations are summarized in the sections below.

Table 4.9. *Correlations Between Predictors & Cognitive Outcomes*

	MF1-Within	MF1-Between	MF2-Within	MF2-Between	Activity-Within	Activity-Between	SST	LDM	FBT
MF1-Within	1	.99**	.56**	.56**	.25**	.26**	.12**	.10**	-.02
MF1-Between	.99**	1	.56**	.56**	.25**	.26**	.12**	.10**	-.03
MF2-Within	.56**	.56**	1	.99**	.41**	.41**	-.13**	-.01	-.17**
MF2-Between	.56**	.56**	.99**	1	.40**	.41**	-.12**	-.01	-.16**
Activity-Within	.25**	.25**	.41**	.40**	1	.98**	-.11**	-.06**	-.21**
Activity-Between	.26**	.26**	.41**	.41**	.98**	1	-.11**	-.06**	-.20**
SST	.12**	.12**	-.13**	-.12**	-.11**	-.11**	1	.37**	.44**
LDM	.10**	.10**	-.01	-.01	-.06**	-.06**	.37**	1	.15**
FBT	-.02	-.03	-.17**	-.16**	-.21**	-.20**	.44**	.15**	1

Notes: MF1 = Meaningfulness Factor 1 (SEEPC); MF2 = Meaningfulness Factor 2 (SC); SST = Symbol Search Task; LDM = Location Dot Memory; FBT = Flip-Back Task. * Denotes $p < .05$; ** denotes $p < .001$.

Meaningfulness Predicting Cognition (Model 4$_a$). The conditional model predicting symbol search task performance showed significant between-person effects for both meaningfulness factors on the intercept. At the between-person level, for meaningfulness factor 1 labelled SEEPC (i.e., Self-Expression, Experience & Personal Competence) there was a significant positive effect ($\gamma_{04} = 350.28$, $SE = 136.84$, $p < .001$). This indicated that individuals who spent more time on average engaged in daily activities that represented self-expression, provided a sense of pleasure or accomplishment, and expressed personal values of control, displayed slower baseline RTs on the symbol search task. Whereas for meaningfulness factor 2 (e.g., Social Care), there was a negative association (γ_{05} = -911.95, *SE* = 216.06, *p* < .001), demonstrating that individuals who spent more time on average engaged in meaningful activities that provided help to others or were valued by others, had better initial performance (i.e., faster RTs) for the symbol search task. There were no significant between-person effects for either meaningfulness factor on the cognitive slope over days (*p's* > .05). Model 4_a also reported a significant positive within-person effect for meaningfulness factor 2 (γ_{40} = 813.48, *SE* = 216.28, *p* = .011): On days when individuals engaged in more socially meaningful activities than usual, they had significantly slower RTs for the symbol search task on that same day.

The conditional model predicting location dot memory performance showed significant between-person effects for meaningfulness factor 2 (i.e., Social Care). Individuals who engaged more frequently in socially meaningful activities on average displayed better initial performance (γ_{05} = -1.14, *SE* = .44, *p* = .01). There were also significant within-person effects for meaningfulness factor 2, indicating that on days when individuals engaged more frequently in socially meaningful activities than usual, they displayed poorer performance on the location dot memory task on that same day (γ_{40} = .88, *SE* = .38, *p* = .02). There were no significant between or within-person effects for either meaningfulness factors in the conditional model predicting flip-back performance (see Table 4.8).

Activity Predicting Cognition (Model 4_b). For symbol search performance, there were significant between-person effects for activity (γ_{04} = -109.96, *SE* = 48.74, *p* = .03), indicating that on average, individuals who engaged in higher levels of daily activity had faster initial RTs or better performance; there were no significant between-person effects on the slope. There were also significant within-person effects for activity (γ_{30} = 62.80, *SE* = 20.66, *p* = .002), however the positive within-person effect showed that on days when individuals engaged in higher-than-usual activity levels, they had slower RTs or poorer symbol search task performance that same day. For location dot memory performance, there were also significant between- and within-person effects for activity. At the between-person or group level, individuals who engaged in higher levels of daily activity on average, had significantly better initial performance ($\gamma_{04} = -.21$, SE = .08, $p = .01$). There were no significant between-person activity differences in the rate of performance change. At the individual level, the significant within-person activity effect revealed that on days when individuals had higher-than-usual activity levels, they performed significantly worse on the location dot memory task on that same day ($\gamma_{30} = .14$, $SE = .06$, p = .02). There were no significant between or within-person activity effects in the conditional model predicting flip-back performance (see Table 4.8).

Both Variables Predicting Cognition (Model 5). Model 5 examined the collective effect of both meaningfulness and activity on each of the three cognitive outcomes (see Table 4.10). Comparing Model 4_b and Model 5, the χ^2-value was significant ($\chi^2 = 18.03$, $\Delta df = 6$, $p < .01$), indicating that adding in meaningfulness as a predictor of SST performance improved model fit versus activity alone. When activity was added to the meaningfulness only model (i.e., Model 4_a vs. Model 5), fit improvements were not statistically significant. Further, the inclusion of both predictors in Model 5 did not significantly improve model fits for either models predicting location dot memory or flip-back task performance (see Table 4.10). The conditional model predicting symbol search performance showed significant between-person effects for both meaningfulness factor 1 ($\gamma_{04} = 713.28$, $SE = 228.51$, $p = .002$), and meaningfulness factor 2 (γ_{05} = -743.70, $SE = 244.27$, $p = .003$) on the intercept. The positive between-person effect for factor 1 indicated that individuals who engaged more frequently in SEEPC had slower response time initially on the symbol search task. On the other hand, for factor 2, the between-person effect was negative, meaning that individuals who engaged more frequently in SC had faster initial response times. As expected, between-person significant effects occurred only when predicting the intercept of cognitive ability; no influences on slope or rate of performance change between-persons emerged.

Table 4.10. *Meaningfulness + Activity Predicting Cognition (Model 5)*

	Cognitive Task		
	Symbol Search	Location Dot Memory	Flip-Back
Model 5 (Meaningfulness + Activity)	Estimate *(SE)*	Estimate *(SE)*	Estimate *(SE)*
Fixed Effects			
Intercept	2982.54 (409.60) **	2.37 (.90) *	1620.44 (339.48) **
Study Day	-58.38 (12.25) **	-.04 (.02) *	-79.56 (11.46) **
Study Day^2	2.18 (.45) **	-	2.38 (.30) **
Gender	-35.29 (13.43) *	-	-
MF1-Within	-126.87 (157.45)	-.10 (.45)	-124.47 (103.82)
MF1- Between	713.28 (228.51) *	.29 (.48)	50.87 (107.60)
MF2-Within	220.29 (165.70)	.57 (.50)	182.71 (193.43)
MF2-Between	-743.70 (244.27) *	-.72 (.53)	-201.37 (207.12)
Study Day x MF1-Between	-6.50 (6.32)	-.01 (.01)	11.81 (6.37)
Study Day x MF2-Between	12.90 (6.74)	-.00 (.01)	-10.14 (6.86)
Activity-Within	38.10 (27.40)	.09 (.08)	-9.18 (17.82)
Activity-Between	-64.40 (53.35)	-.18 (.10)	-46.73 (48.54)
Study Day x Activity-Between	-.71 (1.71)	.01 (.00)	1.98 (1.74)
Random Effects			
Residual	106474.65 (2565.90) **	.95 (.02) **	46388.06 (1121.43) **
Intercept	363856.14 (58362.26) **	.61 (.10) **	358821.47 (57126.06) **
Study Day	379.66 (85.20) **	-	470.68 (88.69) **
Model fit *df* = 16, *df* = 13, *df* = 15	-2LL = 52504.33 AIC = 52536.33	-2LL = 10343.59 AIC = 10369.59	-2LL = 49533.00 AIC = 49563.00
χ^2 (Δdf)			
Model 4_a vs. Model 5	2.47 (3)	5.65 (3)	2.97 (3)
Model 4_b vs. Model 5	18.03 (6) *1	-4.68 (6)	6.03 (6)

Notes: * $p < .05$; ** $p < .001$. MF1 = Meaningfulness factor 1; MF2 = Meaningfulness factor 2. [1] Critical values of chi-square with *df* (6) = 16.81, $p < .01$; at the $p < .001$ level, χ^2 cutoffs = 22.46, therefore model fit significantly improved when meaningfulness was added to the model, in addition to activity.

Discussion

The purpose of Study 2 was to model day-to-day associations between activity and meaningfulness to determine whether fluctuations between and within-person coupled with level and change in performance over the two-week testing period. This study used EMA data from the REACT study to examine the day-to-day interactions between meaningfulness, activity, and cognition. EMA offered an ecologically valid approach for measuring cognitive ability in an individuals' naturalistic environment, using a high-frequency, burst-design measurement that collects data across multiple occasions throughout the day using a handheld technological device (Sliwinski et al., 2018). To examine the unique contribution of daily meaningfulness and daily activity as independent predictors of cognition, a series of MLM were ran, with between- and within-person level effects independently tested. These two sources of variations differentially affect longitudinal outcomes (Bielak & Gow, 2022) and MLM allowed for the disentanglement of these relative effects. To address the primary research question for Study 2, hypotheses were separated into between-and within-person level effects for both meaningfulness and activity.

Between-Person (Level-2) Effects. At the between-person level (Hypothesis 1), there were significant effects of both meaningfulness factors and activity on cognition. As anticipated, between-person effects emerged only for the intercept equation but not for the slope, consistent with other daily research that reported intercept-only effects on cognition (Bielak et al., 2019a; Hyun et al., 2019). Most notably, positive meaningfulness factor 1 and negative meaningfulness factor 2 effects emerged when both activity and meaningfulness were entered simultaneously as predictors, however, for activity the between-person effects were non-significant.

Meaningfulness. In the first conditional model where meaningfulness predicted symbol search task performance (see Table 4.8), there were significant between-person level effects for meaningfulness factor 1 and meaningfulness factor 2, which were opposite in direction. This showed that factor score averages had opposing associations with initial task performance. Individuals who engaged more frequently in meaningfulness factor 1 (SEEPC: Self-Expression, Experience & Personal Competence) activities on average had higher initial processing speed (e.g., faster RTs). Interestingly, the reverse association applied for meaningfulness factor 2 (SC: Social Care) activities, where on average individuals who engaged more frequently in SC-related activities had significantly lower initial processing speed (e.g., slower RTs). The directional disconnect that emerged between these two factors of meaningfulness seems to represent two different functional domains of meaningful experiences, those that were self-directed (e.g., factor 1), versus those that were directed at or involved with others (e.g., factor 2). The social nature of engagement determined how participants interpreted meaningfulness at the daily level, depending on whether activity involved caring for or helping others or involved pursuits that were more personally-goal driven or internally rewarding (Coleman & Iso-Ahola, 1993).

Because no other study has conceptualized meaningfulness of engagement in association with daily cognitive performance, these findings are particularly novel. Although the findings presented in Study 1 showed no direct effect between baseline meaningfulness and cognition, in Study 2, significant between-person level effects emerged. To account for these differences, several explanations are discussed now and further explored in the Chapter 5 general discussion section. One explanation could be attributable to the factor solution differences that resulted in Study 1 versus Study 2, both of which used the same assessment to capture the frequency of meaningful activity (e.g., EMAS). In Study 1, the EMAS measured general meaningfulness, and no time constraint or period was prompted, whereas in Study 2, the ambulatory assessment for meaningfulness modified this scale to limit engagements over the past three to four hours. These temporal distinctions may have influenced how EMAS items factored differently at baseline, compared to when meaningfulness was assessed at the daily level.

Activity. The negative between-person effects of daily activity on cognition reported here were expected, predicting that individuals who engaged in higher-than-average levels of daily activity, had on average faster initial RTs for the symbol search task and higher performance on the location dot memory task. Although the present findings do not align entirely with prior research examining the daily associations between activity and cognition (Allard et al., 2014; Bielak et al., 2019a; Whitbourne et al., 2008), it is important to note that the daily activity level measurements differed across studies, as did the cognitive outcomes evaluated. Differences in the direction of between-person effects would be expected, based on the selection of different cognitive tasks and differing classifications for activity. For example, Allard and colleagues (2014) reported significant associations between intellectually stimulating activities (e.g., crossword puzzles, reading) and semantic memory performance. However, other forms of activities (e.g., socializing, general sustenance activities, physical activities, TV watching) were unrelated to daily cognitive performance (Allard et al., 2014). Another study by Whitbourne et al. (2008) showed significant associations only between daily leisure activity and self-reported memory, but job and home activity were unrelated to cognition. Further, one daily investigation by Bielak and colleagues (2019a), reported that average activity participation, reported daily over a week, was not associated with initial processing speed, but was associated with initial performance on other cognitive tasks (e.g., word recognition, backward digit span). These differences in findings for between-person activity effects may be justified due to differences in cognitive assessments used to measure performance the daily level. Here, the ambulatory cognitive assessment that indicated processing speed was the symbol search task, whereas Bielak et al. (2019a) used an object match task, and Allard et al. (2014) used a brief semantic memory task modeled after the Wechsler Similarities test (Johnson et al., 2009). Furthermore, in the present study activity level was calculated based on the total number of checked responses and then summed across all four beeped surveys; thus, the daily activity count was indicative of engagement in a variety of different leisure activities, unlike in other studies (Allard et al., 2014; Bielak et al., 2019a) which categorized activities into domain-specific groups (e.g., physical, intellectual, social). Moreover, in both the present study and the Bielak et al. (2019a) study, activity assessments were derived from the same original questionnaire (ACQ; Bielak, 2017). However, the prompted timeframe was adjusted based on the length of time over which activity was assessed, varying between one week (Bielak et al., 2019a) versus a two-week assessment collection period, as used in the present study. Further, in the Whitbourne et al. (2008) study an eight-day diary design was used to explore lagged associations between activity and cognition. These time-varying differences may explain why significant between-person effects emerged in the present study for total activity, and not in prior investigations (Bielak et al. 2019a; Whitbourne et al., 2008) which instead reported domain-specific activity effects.

Similar arguments apply when evaluating the direction of between-person activity outcomes reported in the Whitbourne et al. (2008) study, which also separated activity into domains, and found a positive association between leisure activity and memory failures. Importantly, in the Whitbourne et al. (2008) study, daily physical activity scores were created using the frequency of engagement, dichotomously categorized based on “yes” or “no” responses; as for cognition, self-reported daily memory failures (from 0 to 10) were summed across the study period. Another obvious difference between this example (Whitbourne et al., 2008) and others (Bielak et al., 2019a) lies in selection of cognitive assessments and how assessments were administered. In the present study, ambulatory cognitive assessments were used, whereas Bielak et al. (2019a) used computerized tasks, and Whitbourne et al. (2008) used subjective evaluations of cognitive performance (i.e., memory failures). Some researchers have argued that using self-reported measures may better capture information about the real-world environmental impact on cognitive capacity compared to objective, performance-based cognitive assessments (Schmitter-Edgecombe et al., 2020; Whitbourne et al., 2008). Yet, these authors and others (Bielak & Gow, 2022) still highlight how ambulatory forms of assessment offer enormous potential for modeling daily activity-cognition relations. Likely a combination of both subjective and objective assessments is optimal to better understand how variance is partitioned across various predictors variables and whether these predictors act independently or through interaction effects with covariates such as age. In relation to the present findings, interaction effects between covariates and predictors were not explored, but other research has reported interesting interactions between age and activity (Whitbourne et al., 2008).

To summarize, differences in the operationalization of activity, how cognition was assessed and varying temporal arrangement across studies, all explain why present findings differ in the direction and significance for activity effects at the between-person level (Bielak et al., 2019a; Whitbourne et al., 2008). Different temporal arrangements that characterize activity intentions and behavioral engagements may also explain discrepancies in these findings (Maher et al., 2017). Theories of social psychology suggest that when activities are reported shortly after they are engaged in (e.g., over the last three to four hours), participation tends to be subjectively evaluated more quickly and in doing so, the present self is reporting on the activity experience in real-time (Iso-Ahola, 1980; Coleman & Iso-Ahola, 1993). The original ACQ (Bielak, 2017) asked participants to report the amount of time they spent *yesterday* participating in various types of leisure activities that shared certain characteristics. In the 2019a report by Bielak and colleagues, daily ACQ reports were summed across seven days to create average activity scores for each participant, whereas in the present study the momentary activity survey was only loosely based on the original ACQ, and the response format was modified from the original (i.e., *yesterday)* format to promote participants to "check all activities that apply" to describe patterns of engagement over the past three to four hours.

The between-person effects of daily meaningfulness and daily activity on cognition were strongest for the symbol search and location dot memory tasks, but not for flip-back performance. Although both location dot memory and flip-back tasks represented working memory performance, the significance of predictors in the model was exclusive to models predicting location dot memory performance. Although both ambulatory cognitive assessments have been reported in prior EMA research (Riediger & Rauers, 2014; Sliwinski et al., 2016; Zhaoyang et al., 2021) as indicators of working memory, the tasks differed in how performance was calculated. For the location dot memory, the Euclidean distances were calculated, with higher scores indicating less accurate placement and poorer performance (Siedlecki, 2007). For the flip-back task, performance was measured by both RT and the proportion of correct responses (i.e., accuracy), however, only RT was used in the present outcome analysis. Some research has suggested using accuracy rather than RT for flip-back performance (Sliwinski et al., 2018), and other daily research has replaced the flip-back task with the color shape task, a measure of complex working memory (Zhaoyang et al., 2021). Thus, it seems certain ambulatory cognitive assessments are more sensitive to capturing subtle fluctuations in working memory performance at the daily level over others. As more research emerges, comparisons across different types of mobile assessments will become necessary, as different tools are already being utilized across various settings (Allard et al., 2014; Campbell et al., 2020).

The intercept-only effects were consistent with prior research which reported a non-significant effect for between-person activity differences on change in cognitive ability over the 7-day testing period (Bielak et al., 2019a). Further, the lack of slope effects was anticipated for the present study, which examined day to day change, whereas other studies exploring change over several days (i.e., over the course of a week) found effects on both intercept and slope or cognitive ability. Mella and colleagues (2017), used intraindividual variability (IIV) in cognitive performance, and reported significant effects on cognitive change from week to week over four weeks (i.e., slope). Specifically, the frequency of engagement in weekly physical activities was negatively related to change in IIV in verbal processing tasks, and greater social activities were related to less increase in IIV in verbal working memory tasks. It is important to note however that the Mella et al. (2017) report used a different temporal testing scheme: four waves of one-week long intervals of computerized cognitive testing; all cognitive tasks were individually administered on a computer in the laboratory using the E-Prime (Psychology Software Tools) platform. Thus, the lack of significant effects on the slope of cognitive change described here likely stems from procedural differences in how the data was prepped and analyzed, which produced different temporal arrangements between constructs.

The utilization of EMA in Study 2 and in the article by Bielak et al., (2019a), suggests that there is considerable variation across studies based on the use of traditional laboratory testing and others that administer cognitive testing in the naturalistic environment. In one article, Bielak, Hatt and Diehl (2017) discussed the issue of ecological validity, arguing that the standardized, controlled setting in which cognitive testing typically occurs may not fully capture the complexities and nuances of cognitive functioning as it functions in everyday life. These differential effects support the growing evidence in the literature that the activity and cognition relationship may vary considerably as a function of the cognitive domain being evaluated and how, when, and where testing was administered (Bielak et al., 2014). The utilization of multiple methods for assessment, both in controlled and naturalistic settings, seemed to tell different storylines, adding evidence in support of the apparent gap between lab-life cognitive assessments.

Activity & Meaningfulness Combined. Interestingly, when meaningfulness and activity were tested separately as independent predictors of cognition, the magnitude of between-person effects for both predictor variables were significant. When predictors were entered concurrently in the final conditional model, the fit of the model weakened, and the magnitude of level-2 (between-person) effects diminished. Thus, at the between-person level, daily meaningfulness and daily activity independently accounted for a larger amount of the variance in cognitive performance, than when in conjunction with one another. As expected from Study 1 findings, meaningfulness had stronger predictive value of cognitive performance than did activity. These findings are in support of the environmental complexity hypothesis (Schooler et al., 1999), which theorized that activity benefits cognition the most when selected engagements strongly align with personal meaning systems and involve a high level of stimulation (Atchley, 1989; Hocking, 2009; Scheier et al., 2006). One explanation for the weakened model fit when predictors were combined in Model 5 may lie in the functional overlap that exists between these constructs and the different directional patterns that emerged for each meaningfulness factors. This justification is strengthened by consulting the correlational matrix (shown in Table 4.9); positive correlations between both meaningfulness factors and activity (*r's* ranging from .25 to .41) emerged, suggesting that functional overlap between constructs may have weakened additional predictive value. Furthermore, different directional patterns emerged between predictors and outcomes when examining cross-sectional associations (i.e., correlations) than when observing short-term longitudinal patterns (i.e., multilevel modeling). Based on these arguments, it is likely that over even longer periods of assessment, still different patterns would emerge compared to what was reported here at the daily level. Future research designs should aim to incorporate both daily and functional assessment over longer periods of time to determine the optimal temporal period for detecting subtle cognitive fluctuations and predicting initial decline.

Covariates. Contrary to expectations, there were no significant between-person intercept level differences due to age or education. Only gender differences emerged on the intercept in the model predicting symbol search task performance, where females had significantly lower initial RTs on the symbol search task than did males. The expected intercept-level covariate effects for age, gender, and education were based on prior MLM research conducted at the daily level (Bielak et al., 2019a). Although the present findings reported non-significant between-person level effects of age and education on cognition, other research by Hyun and colleagues (2019) using a similar 14-day EMA design reported significant age differences at the between-person level. The study by Hyun et al., (2019) showed that older age was associated with higher error-scores in WM, (i.e., location dot memory performance). However, the age range of individuals differed in the present study compared to what was reported in prior research (Hyun et al., 2019; Schmitter-Edgecombe et al., 2020). For example, an article by Hyun et al. (2019) used a wider age range (e.g., ages 25 to 65). Therefore, between-person age effects may be more profound in the earlier stages of development (e.g., young adulthood to middle-aged adulthood) than in later stages of adulthood (i.e., middle-aged to older adulthood). Lastly, interactions between gender and age have been reported in the theoretical literature on leisure repertoires (Nilsson et al., 2006), but limited empirical research has been conducted to test for between-person differences in short-term cognitive outcomes controlling for these covariate interactions.

Within-Person (Level-1) Effects. As expected, at the within-person level (Hypothesis 2), there were significant positive effects for meaningfulness factor 2 and activity on cognition. As with between-person effects, at the within-person level, effects were strongest for models predicting daily performance on the symbol search and location dot memory tasks. However, these effects disappeared when both activity and meaningfulness were added to the model.

Meaningfulness. Positive within-person effects emerged for meaningfulness factor 2 but not for factor 1. On days when individuals engaged in higher-than-usual socially meaningful activities, they had a poorer same-day performance on processing speed and working memory tasks. These findings were inconsistent with prior research suggesting positive short-term associations between socially meaningful activity and daily cognition (Bielak et al., 2019a; Zhaoyang et al., 2021).

Researchers have explored the impact of multiple features of social interactions and how they relate to cognition at the daily level (Zhaoyang et al., 2021), suggesting that both the frequency and quality of pleasant interactions with close patterns (i.e., family members) had the strongest link to better performance. Zhaoyang and colleagues (2021) reported significant same-day effects (i.e., within-person), demonstrating that on days when individuals had more pleasant social interactions and interacted more than-usual with friends and family they had better performance on same-day processing speed and memory binding tasks (Zhaoyang et al., 2021). In contrast, the results reported here, particularly for meaningfulness factor 2, suggest that at the individual level, a higher frequency of engagement in socially meaningful activities was related to poorer performance on same day processing speed and working memory tasks.

One important distinction is the nature of the social interaction and the operational definitions provided in prior research. In the Zhaoyang et al. (2021) study, as with other domain-specific daily investigations (e.g., Bielak et al., 2019a), social activity was classified by quality and partner types (e.g., social-private, and close interpersonal interactions). Here, meaningfulness factor 2 represented activities that were either valued by other people or helped other people, where the social or external context is inherent; however, the quality of the interpersonal interaction cannot be assumed based upon the personal subjective meaning. In an occupational context or work setting, an individual may frequently engage in activities that are socially valued by their employer. For example, nurses and doctors spend much of their work-related time engaging in activities that are both valued by and help others. However, on days when they engaged more-than-usual in these externally directed activities (e.g., had more patients than usual, worked over-time), the present study suggests they might show poorer cognitive ability on that same day. According to research in occupational sciences, meaning systems have emerged classifying different positive meaningful experiences into three major themes of meaning: social, selfhood, and pleasure (Eakman et al., 2018). Applying these themes of meaning in occupation to the present discussion about cognitive performance, findings suggest that socially meaningful activities are particularly influential.

Outside of the occupational roles and employment settings, from a relational perspective, often leisure activity involves socially meaningful engagements, such as caregiving for a child, parent, or spouse. According to a recent national survey, in the U.S. more than one in five Americas (21.3%) are informal caregivers, providing care or daily help to an adult or child with special needs (National Alliance for Caregiving, 2020). Providing care to individuals with chronic illness and disability is commonly viewed as a major life stressor (Schulz & Tompkins, 2010), and studies have shown that engagement in these forms of family caregiving can significantly affect an individual's life, resulting in negative consequences including increased stress, depression and reduced psychological well-being (Palma et al., 2011). Research on the cognitive effects of caregiving has produced mixed opinions on whether effects are positive or negative. Garcia-Castro and colleagues (2021) investigated cognitive performance differences between caregivers and non-caregivers, reporting that although caregivers had faster RT, they were more likely to make mistakes leading to reduced accuracy on working memory and processing speed tasks. This line of discussion highlighted the importance of considering multiple features of care-related activities and how certain health behaviors, lifestyle engagements, and occupational contexts may modify or improve cognitive conditions for these individuals (Eakman et al., 2018; Garcia-Castro et al., 2021). Even outside of the context of formal or informal caregiving, the present study found that at the daily level, when individuals engaged more frequently in activities that were socially valued (e.g., occupational roles) or involved helping others (e.g., care-related activities), they had poorer daily cognitive performance. Understanding the perceived interpersonal benefits of engagement and the source of motivation, either internal or external, helps to further disentangle these individual-level effects on daily cognition.

In contrast to meaningfulness factor 1, which represented activities that were more personal, intrinsic, experiential, and self-fulfilling, factor 2 represented socially motivated pursuits that were either valued by others or involved caring/ helping others. From an interactional approach, a continuous exchange occurs between cognition, the individual, the activity, and their environment (Toglia, 1992). The social, physical, cognitive, and even cultural factors of the environment influence how well an individual processes and adapts to incoming information, thus mediating the relationship between activity engagement and cognition. In the occupational therapy, occupational sciences and rehabilitation literature, researchers coined the PEOP model (Eakman, 2015), describing the dynamic and complex interactions that occur between an individual, their environment, and the context in which activities are engaged. According to these lines of work, higher cognitive performance is achieved when individuals achieve a state of balance between intrinsic (i.e., personal), and extrinsic (i.e., physical, cultural, social) factors. The nature and quality of social interactions may favor cognition when activities involve close interpersonal interactions; however, according to present analysis when meaningful activities were socially motivated or required greater relational and interpersonal demands, they were more negatively associated with daily cognitive performance. Supporting these agreements, a daily diary study by Neupert and colleagues (2006) showed that on days when individuals experienced more frequent stressors, particularly interpersonal stressors related to close family or friends, they were likely to report memory failures. In sum, multiple features of social engagement (i.e., quality, frequency, meaningfulness) influence the relative associations between meaningfulness and daily cognition. Separating socially rewarding activities from stressful social experiences at the daily level may be especially important going forward. The utilization of longitudinal factor analysis and MLM lagged analysis will be useful analytical tools for modeling daily cognitive performance in relation to varying degrees of meaningful daily experiences.

Activity. For activity, the within-person effect was positive also indicating that on days when individuals had higher-than-usual activity levels, they had worse performance on those same days for the symbol search and location dot memory tasks. The direction of within-person activity effects followed similar trends as meaningfulness factor 2 (i.e., positive directional effect which indicated slower and worse cognitive performance on the present tasks). This contrasts with prior short-term research conducted by Howard and colleagues (2016), which reported that higher engagement in a variety of leisure activities has favorable associations with short-term cognitive ability, measured over one year. Research conducted at the daily level has supported similar favorable associations. Bielak and colleagues (2019a) indicated that participation in various forms of social activity (i.e., unfamiliar, social-private, social-public) positively covaried with changes in weekly processing speed performance (Bielak et al., 2019a); indicating higher activity was associated with greater improvements in performance. Similarly, Allard and colleagues (2014) reported lagged associations between daily intellectual activity engagement (e.g., crossword puzzles, reading) and same-day semantic memory performance.

Differences in the study design and measurement may account for why within-person activity effects had positive associations with cognition in prior research (Bielak et al., 2019a; Whitbourne et al., 2008), whereas negative associations were reported in the present study. Two main incongruencies include, the time over which variables were measured and how activity was operationalized, whether in terms of variety or measured by the frequency of participation in domain-specific activities. In both Bielak et al. (2019a) and Whitbourne et al. (2008), activity and cognition were assessed just once daily for a week, whereas in the present study, activity and cognitive tasks were administered using multiple daily ambulatory assessment over two weeks. Another possible contributing factor is the differences in cognitive assessment techniques used to collect cognitive data. In Bielak et al. (2019a), computerized cognitive tasks were performed at the end of each day for just seven days, whereas Whitbourne et al. (2008) used total daily self-reported memory failures as the cognitive outcome. Other studies have used similar micro-longitudinal periods (i.e., one or two weeks), verifying the reliability and concurrent validity for a wide range of computerized cognitive assessments (Brown et al., 2016; Gamaldo & Allaire, 2016). Here, the use of EMA allowed for performance to be aggregated across several repeated time measurement occasions, collecting daily survey responses and ambulatory assessments 4-5 times a day, over a two-week tablet testing period. Research from the physical activity literature has shown that at the daily level, when individuals reported engaging in higher levels of physical activity, they reported fewer memory failures (Whitbourne et al., 2008). On the other hand, Philips and colleagues (2016) used accelerometers to measure daily physical activity and reported no associations to daily cognition. Importantly, significant differences in the types of cognitive assessments used across these studies limit a more generalizable conclusion but highlight the need for future research to clarify the nature of temporal effects when interpreting the within-person activity effects on cognition.

An alternative consideration accounting for the unexpected direction of within-person activity effects may have been caused by collapsing activity and creating a total daily count rather than separating out domain-specific activity effects. In doing so, the effects of within-person variability based on differences in activity engagement may have been altered (Sliwinski et al., 2018; Weizenbaum et al., 2020), resulting in the negative association found between total daily activity and daily cognition. The unanticipated direction of the effect may have resulted from the mix of different activity types included in the total daily count. In the present study, daily activity was operationalized as the total daily count of activities, calculated by summing all activity "checked" responses at all four beeped survey occasions each day. A higher level of activity was indicated on days when individuals checked more activity responses and served as a proxy for a variety of leisure engagements. In the Bielak et al. (2019a) study, activity summary scores were calculated across the 7 days and EFA and CFA were then performed, resulting in six activity factors used for analysis. My decision to use total daily activity counts was made based on methodological recommendations in the Bielak and Gow (2022) article, which suggested that research conducted at the daily level when using EMA designs may be more useful to use dichotomized (e.g., yes/no) or simple checked lists as an indication of participation in a variety of different daily activities. Although there is considerable overlap in assessments of the variety and frequency of engagement (Bielak et al., 2017), each captures unique information about the activity experience. The lack of positive within-person activity effects reported here possibly resulted because the nature of different types of leisure activity (e.g., social, physical, cognitive) were combined to create an aggregate daily activity total which was operationalized as the variety of daily activity participation. To clarify inconsistencies across studies (Bielak et al., 2019a), differences in the activity domain or type of leisure participation must be considered.

Activity & Meaningfulness Combined. Like the between-person combined effects, the within-person effects also weakened when both activity and meaningfulness were combined, suggesting considerable functional overlap exists between these constructs. Separating the predictive effects of daily activity and the psychological context (e.g., meaningfulness) in which activity occurred did not strengthen the model as predicted, but instead weakened model fit, demonstrating that although operationally these constructs may overlap, different directional patterns may have cancelled out and/ or weakened the combined predictive effect. A recent report by Zhaoyang and colleagues (2021), using a similar 14-day EMA design, reported that on days when individuals engaged in more social interactions, they had higher same-day cognition. Similarly, Bielak et al., (2019a) found that on days when older adults engaged in more social activities, especially with close social partners, they had better performance on memory and processing speed tasks. On the other hand, Allard et al., (2014) reported no association between daily experiences and mobile cognitive performance, finding that daily participation in social activities was unrelated to same-day semantic memory performance. In sum, these studies provide some support for the associations between daily activity and cognition, but are specific to engagements that involve social interaction, and pertain to involvement with close friends and family.

Temporal associations vary based on the level and frequency of measurement and future research should consider the lagged associations between other forms of daily leisure engagement (e.g., social, and cognitive) to clarify and disentangle same-day vs. next-day effects. Within-person coupling has been used to describe the temporal patterns of individual-level associations between daily physical activity and a variety of health-related outcomes (Phillips et al., 2016). Research by Conroy and colleagues (2011) showed delayed associations between physical activity intentions and engagement in daily physical activities. Weekday but not weekend physical activity engagement was predicted by the overall strength of intentions (averaged across the week). In sum, supplementing activity counts with additional experiential information, such as intent or meaning, has allowed researchers to better classify and discriminate the relative association with specific activities on daily cognitive outcomes. Studies evaluating different psychological and contextual aspects related to activity engagement, in addition to the frequency, such as the variety of participation and perceived situational/ social support are needed.

To summarize, the direction of within-person effects for the meaningfulness factors and activity were unexpected. Overall, findings demonstrated that meaningfulness was a stronger predictor of cognitive performance than daily activity level. When both activity and meaningfulness were combined as predictors, the predictive value of the model weakened suggesting that considerable overlap may exist between these constructs. Other considerations accounting for the lack of combined effect include how activity was operationalized as a total daily count. These findings suggest that future research should consider factoring activity into specific domains to better understand how meaningfulness overlaps with engagement in particular types of social, physical and activities, at the daily level. For example, the unique contribution of socially meaningful daily activities on performance may depend upon individual motivational pursuits and the level of perceived challenge, or intrinsic benefit of the situation. These additional contextual modifiers are discussed in more detail in the next section as they represent potential avenues for future researchers aiming to extend upon the present findings. Future investigations may also consider the interactive effects between external modifiers and sociodemographic characteristics that might explain more of the variance in daily performance and help to better clarify how these dynamic processes operate at the daily level.

Other Contextual Modifiers. In addition to activity and meaningfulness, other potential modifiers of cognition include internal state-based factors (e.g., affect and motivation), and external environmental factors (e.g., time of day, sleep). These attributes often characterize and motivate engagement and may provide additional insight into potential modifiers that influence cognitive performance at the daily level (Stine-Morrow et al., 2020). Emotional processing research has shown that the positive and negative valence of an individual's momentary affect impacts domains of cognition, particularly working memory (Allard et al., 2014; Brose et al., 2014; Verhagen et al., 2019). At the within-person level, Allard et al. (2014) reported that on days when the positive affect was higher, individual working memory performance was stronger and task-related motivation was higher. Brose et al. (2014) reported similar trends for negative affect and poorer same-day working memory performance, and Sliwinski et al. (2006) identified within-person associations between higher daily stress and slower RT on a daily working memory task. The effects of daily stress, sleep, and worry or anticipation on daily cognitive performance have been well-documented (Curtis et al., 2018; Hyun et al., 2019; Qian et al., 2014), suggesting multiple mediating effects. For example, Qian et al. (2014) reported that the degree to which the frequency of daily stress influenced cognition was partially mediated by positive affect and the allocation of leisure time. Like stress, the effects of chronic pain, depression, and sleep have all been documented to influence cognition at the daily level, as well as present lagged associations (e.g., late-day and next-day effects) (Hyun et al., 2019).

Motivational influences are more difficult to capture in the moment-to-moment daily environment, due to variations in affective processing, available cognitive resources and task demands, and practice effects (Pessoa, 2009; Tomporowski & Pesce, 2019). For example, the degree to which engagement is considered cognitively challenging may depend upon having adequate stress-coping resources and available leisure time (Qian et al., 2014). Unfortunately, very few studies have considered task difficulty or measured the degree of momentary challenge when attempting to describe how motivation might exert influence on the relationship between daily activity and cognition (Salthouse et al., 2006). Therefore, the extent to which naturally occurring fluctuations in state-based motivation influences engagement in meaningful activity on any given day and how these factors impact daily cognitive performance remains unknown. Future research examining the effects of mood, motivation, and meaningfulness on cognition using real-time self-reported mobile assessments will certainly clarify how these internal factors relate to and interact with one another.

Externally, time of day may represent another important environmental modifier influencing between-person differences in cognition. Most notably, differences in cognitive performance have been linked to individual differences in peak circadian arousal periods (Schmidt et al., 2007). The literature suggests however that the relationship between time of day and cognition seems to rely mostly on intraindividual differences in alertness (West et al., 2002). In one study, West et al. (2002) compared self-reported alertness between younger and older adults and found that alertness was higher for older adults in the mornings. To account for potential individual differences in arousal and alertness in the present study, the timing of daily testing was determined based on participants self-reported waking and sleep schedules. In the mornings, the first beeped survey was set to alarm three to four hours after self-reported waking time. The use of mobile assessment was particularly useful for capturing time stamps of each assessment and identifying responses that were outside of the scheduled time frame for everyone. An alternative approach could be to collect subjective and/or objective measures of alertness/ arousal at the time of the ambulatory cognitive assessment. Eventually, passive forms of alertness that use touch screen latencies to measure other biometric responses (e.g., heart rate, eye movements) may be used in conjunction with cognitive assessments.

Conclusion. With the emergence of mobile technologies (i.e., EMA) researchers can examine daily contextual factors in real-time to quantify associations with cognitive performance using short-term longitudinal analysis. The results of Study 2 supported the predictions that daily meaningfulness and daily activity were related to performance on ambulatory assessments of processing speed and working memory. Between-person level effects for activity and meaningfulness emerged only on the intercept, predicting differences in initial starting performance between people; neither differences in activity nor meaningfulness (between-person level effects) predicted performance day-to-day change on any of the three cognitive outcomes. At the within-person level, individually the frequency of meaningfulness and activity showed same-day coupling with performance on daily tasks of processing speed and working memory, but only when predictors where isolated from one another.

Cognitive research must consider using alternative and multiple metric approaches to fully capture and better categorize daily activity experiences. It may be helpful for researchers to collect additional contextual information that provides more insight into the engagement experience from a psychological perspective. In the OT literature, several engagement-based surveys have been designed to capture the subjective experiences that describe everyday activity engagement (Eakman, 2012; Eakman et al., 2010a; Eakman et al., 2010b). To disentangle the short-term associations between activity and cognition, studies utilizing experiential assessments to gain a broader perspective of the role that subjective experiences play in relating to the external environment are extremely valuable. Because daily patterns of engagement fluctuate in response to the internal state-based and external (i.e., environmental) context, research is needed that conceptualizes leisure activity both in terms of quantifying the amount of activity (i.e., daily count) as well as describing the psychological context in which activities are embedded. Future research will benefit from using multi-measurement assessment approaches that quantify the relative impact that subjective internal psychological processes have on real-time, everyday cognition. Understanding daily patterns of performance and factors of the physical environment that support engagement and promote cognitive health will aid in the development and customization of personalized prevention programing for aging adults.

CHAPTER 5: CONCLUSION

This dissertation presented two studies examining the relationship between activity engagement, meaningfulness, and cognition in a sample of healthy middle-aged and older adults. The first study used a cross-sectional design; mediational analysis tested several different structural arrangements linking the three constructs. The results of the first study revealed a significant direct effect of meaningfulness on activity but failed to associate either meaningfulness or activity with cognitive performance at baseline. Building on these results, the second study then examined the day-to-day fluctuations in activity and meaningfulness using a short-term longitudinal design that involved EMA and MLM to separate between and within-person effects. The analysis revealed significant between and within-person effects of daily meaningfulness and daily activity on cognition, particularly for the SST, a measure of visual-processing speed. Contrary to hypothetical predictions however, the direction of these effects was surprising; particularly for meaningfulness factor 2, the within-person effect was positive, indicating that on days when individuals had higher activity counts and had higher-than usual factor 2 scores, they performed significantly worse on the SST that same day (i.e., had slower RTs). Interestingly, when meaningfulness and activity were tested separately as independent predictors of cognition, the magnitude of between and within-person effects for both predictor variables were larger compared to when predictors were entered concurrently in the final model. One explanation for the weakened combined effect may be due to functional similarities existing between these constructs.

At the most basic level, these findings suggest that meaningfulness and activity are conceptually and empirically linked, with meaningfulness as the more favorable predictor. Meaningfulness was a stronger predictor of activity engagement than vice versa, and meaningfulness also more strongly predicted cognition, albeit directionally the effects at the daily level were unanticipated. The present studies expanded the literature on activity engagement and cognition in several important ways: Theoretically in Study 1, by demonstrating that directionally, the meaningfulness of an activity was more strongly related to social activities at baseline; and analytically in Study 2, showing meaningfulness more strongly predicted cognition over daily activity. Furthermore, both studies described here emphasize the role that psychological factors such as the purpose or meaning assigned by an individual to an activity (i.e., meaningfulness) as an important predictor of engagement and cognition over different timescales. Consistent with occupational theories by Eakman (2016), when leisure activities are personally meaningful, they contribute to a greater sense of psychological well-being and sustained engagement throughout adulthood.

The need for more research utilizing multi-method approaches has been stated by other cognitive aging researchers. Bielak and Gow (2022) highlighted the necessity of using both cross-sectional and short-term longitudinal analysis to better describe the dynamic and temporal associations between activity and cognition. This dissertation employed both cross-sectional and longitudinal designs and utilized multiple forms of assessment across varying timeframes to better understand the influence of an individual's participation in every day meaningful leisure activities on cognitive performance, both at the structural (Study 1) and daily level (Study 2). By converging models from two different paradigms: theories of occupational therapy (Eakman, 2018), and models of cognitive rehabilitation (Skidmore, 2014; Toglia, 1992) and leisure recreation (Iso-Ahola, 1980; Khloeher et al., 2011), the present research utilized a range of analytical techniques to expand and improve current conceptualizations of how lifestyle engagement relates to cognitive functioning in adulthood.

As prior investigators have stated, the type of assessment, length of assessment time, and method of how the questionnaire is administered may all contribute to differences across studies (Bielak, 2017), highlighting the need for more research that uses multiple types of assessments over varying time-periods. Here, the predictive effects of meaningfulness and activity on cognition only emerged in Study 2, when daily scores were averaged across the two-week period. When variables were factored based on assessments conducted at a single time-point (i.e., Study 1) they were non-predictive of baseline cognitive performance. From an analytical perspective these findings point to possible inadequacies when measuring cognition at a single time point. Another important distinction is that different cognitive assessments were used across Study 1 and Study 2; some researchers believe that when ambulatory cognitive assessments are administered via mobile technologies, they may be more sensitive to detecting subtle performance fluctuations than traditional paper-and-pencil and even computer-administered forms of testing (Bielak et al., 2017). This dissertation illustrated how utilizing different timeframes and assessment periods resulted in different interpretations of how these constructs were related to cognition. In the following sections I provide a thorough discussion of the overall project's strengths and limitations. Suggestions for future research are provided and theoretical considerations are explored. The major findings from both studies are examined within the broader paradigm of successful aging. Finally, remarks are made on the significance and impact of this research for aging individuals and society.

Strengths

This project had many theoretical and statistical strengths, as it provided a comprehensive, translational approach using diverse cross-sectional and longitudinal methodology. Because relatively few studies have used repeated measurements over shortened periods, this study adds significantly to the existing body of literature. The short-term longitudinal approach used in Study 2 expanded the analytical opportunities by employing repeated measurements, which allowed for real-time performance to be evaluated within an individual's everyday environment. The purpose of including both cross-sectional and longitudinal research designs studies was to determine whether daily activity patterns and their association to contextual factors, such as meaningfulness, functioned differently in relation to cognition, at baseline compared to at the daily level. The results from Study 1 differed from Study 2 in several important ways. The structural pathways hypothesized between activity and meaningfulness as predictors of baseline cognition were not supported by the cross-sectional analysis, yet in Study 2, the between-person components for both activity and meaningfulness predicted initial cognitive performance. These differences do not represent replication failure but instead suggest that by varying the level of measurement, different depictions of how the structural and associational relations between these constructs emerged. Furthermore, distinctions in general versus temporal meaningfulness may partially explain the lack of meaningfulness effects on baseline cognition. Whereas, in Study 2, meaningfulness was specific to the last three to four hours, this indication may have influenced individuals' interpretation of activity experiences as more generally in Study 1, versus more temporally specific in Study 2, which emphasized meaningful engagement over the past few hours.

This project established directional and temporal relationships between cognitive performance and two performance modifiers, the internal or subjective psychological state (i.e., meaningfulness), and the external engagement with one's environment (i.e., activity). No prior study has evaluated meaningfulness in relation to activity and cognition, thus strengthening the theoretical importance of these findings. Further, this study combined theories across multiple different social science paradigms, including cognitive aging, leisure activity and recreation research, social psychology, occupational health, and cognitive rehabilitation. Using a translationally informed theoretical model to guide study design and analytical procedure provides further notation for the impact of this work. Conceptually, evaluating meaningfulness as a psychological attribute of activity and an underpinning of cognitive performance was novel and provides fruitful evidence of the importance of observing contextual patterns of behavior.

Lastly, from an analytical perspective, the utilization of factor analysis (FA) in both Study 1 and Study 2 provided significant novelty to this investigation. No other research has performed exploratory and confirmatory analysis on the EMAS at the daily level, but prior studies have confirmed a 2-factor structure in various clinical and non-clinical populations (Eakman et al., 2010b; Prat et al., 2019). Interestingly, it seems that subjectively, the underlying characteristics describing meaningfulness fluctuated between baseline and daily assessment, providing interesting implications about how this assessment is perceived over varying timescales. These findings may have relevance for occupational frameworks as an extension to the PEOP model (Baum et al., 2015; Eakman, 2015), which states that when people are performing tasks they are also inherently interacting with their environment, producing a reciprocal relationship. Based on the differing conceptualizations for meaningfulness that emerged, it seems that certain relational aspects of meaningfulness, particularly caring for or engaging in helping others, may inherently interact with subjective interpretations of the engagement. Although the cross-sectional results showed support for greater meaningfulness being associated with more frequent engagement, particularly social activity, these positive associations did not extend to baseline cognitive performance. However, at the daily level, when cognition was assessed over a shorter period, positive cognitive outcomes emerged, suggesting that meaningfulness is an important contextual factor influencing the relationship between activity and cognition, however further elucidation of why meaningfulness is perceived differently across different timeframes is required. As this dissertation exemplified, disentangling these contextual nuances is a complicated endeavor and represents an important focus for future research, one that will be aided by multidisciplinary projects that use translational frameworks across multiple social science disciplines to guide future research development.

Limitations

Overall, the sample of 81 participants used for Study 1 and Study 2 analysis did not lend itself easily to generalizability to the larger population of healthy middle-aged and older adults. The sample had little racial or ethnic diversity (92.6% self-reported they were White), and was highly educated, with 85.2% of participants holding bachelor’s degrees or higher. In this sample, 37.1% of the participants reported earning more than $75,000 a year. According to the U.S. Census Bureau (2019), the median earnings for adult males 65 and older was $56,850, and for adult females 65 and older, $41,200 annually. The characteristics of this sample demonstrated that the individuals who participated in this study were not representative of the larger middle-aged and older adult population, as they were more educated, primarily White, and reported earning a higher income than population studies in the U.S. have suggested.

Due to reliance on convenience sampling as the method of recruitment and the differences in demographic characteristics between these participants and the larger population, the generalizability of these findings may be limited. Furthermore, observations may be affected by selection bias, such that individuals with higher cognitive functioning may be attracted to this type of social research that evaluated their performance on cognitive tests, thus influencing the level of participation. Future research should aim to recruit larger, more diverse samples of individuals that are more representative of typical middle-aged and older adult populations, across various geographical regions in the U.S. and beyond. It seems probable that the nature of leisure varies greatly depending upon available environmental resources and cultural influences across different regions of the world. Future research should examine the associations between leisure activity and cognition cross-culturally, as differences in western and eastern cultures likely display different lifestyle patterns based on cultural values towards leisure activity.

In addition to these sample characteristics, another notable limitation of this project is the subjective, self-reported nature of activity and meaningfulness. Advancements in mobile technologies have allowed for the inclusion of some objective-based forms of measurement, particularly for physical activity. However, there is great difficulty in objectively measuring other forms of leisure such as social recreation and personal cognitive activity. Some lines of work suggest that using real-time self-reported daily assessments may reduce the amount of reporting an error or cognitive bias in reported activity-related information (Hatt et al., 2021). However, even at the daily level, short-term reports of activity and meaningfulness are still subject to reporting biases and there is still no way for cognitive or social activities to be assessed objectively in real-time. Future research should consider employing simultaneous biobehavioral measurements that capture multiple features of the contextual environment either actively or passively through sensory detection devices. Lastly, given the nature of EMA, timing of the beeped surveys may have resulted in an interruption to cognitive functioning. This explanation relies on the argument of divided attention and distractions in work-flow processes, which may have resulted in lower cognitive functioning if the beeped survey disrupted a cognitive flow state. As an example, in occupations involving intense scientific reading and writing (i.e., academia), often subtle distractions of sound and tasks that divert attention unwantedly may be detrimental to cognitive functioning in real-time. More consideration of external factors involved with tablet testing technologies is warranted so that EMA can be incorporate individual preferences, ensuring the validity of assessments while minimizing tablet distractibility that may inherently disrupt prior cognitive processes (Csikszentmihalyi et al., 2005; Payne et al., 2011; Stine-Morrow et al., 2020). Applying EMA across multiple different workplace settings (e.g., on-site, remote, hybrid) will enable researchers to better adapt EMA technologies to be more specific to the needs and response preferences of the individual within their work environment.

Research Recommendations

High-frequency measurement approaches are key for understanding the dynamic and temporal associations between constructs and the context in which they are assessed. Understanding these short-term, micro-processes should be used in conjunction with longer-term longitudinal analysis, given that the relations between engagement and cognition differ across various timescales (e.g., daily, weekly, yearly). The integration of short-term biobehavioral measures and momentary assessments of stress and affect will advance the current state of cognitive aging research. Translational models that involve cognitive and emotional explanations for the complex, bi-directional associations between lifestyle engagement, psychological health, physical functioning, and cognitive aging are beginning to emerge from various streams of literature but much more inquiry into these multidimensional processes will be required going forward.

The potential coupling of EMA methods with other physiological recordings may be recommended, as studies suggest a considerable overlap between multiple behavioral, affective, and cognitive responses (Cain et al., 2009). The incorporation of smartphone-based sensors, like accelerometers, GPS, and microphones to capture auditory engagement may all offer potential for cognitive aging research. For example, sensory detection devices and ambient audio recordings can be combined with self-reported EMA. This would allow for both passive and active monitoring of an individual's real-world environment. This data can then be used to make personalized recommendations based on the characteristics of that environment (Deimary et al., 2020; Weizenbaum et al., 2020). Researchers may identify more accurate patterns of individual activity by observing how people interact with others and with their environment. This may include: the distance and frequency of walking and sedentary behaviors throughout the day; the frequency and type of social conversations (i.e., text messaging, phone calls, video-chats); and the geographical patterns of movement in one's environment (i.e., GPA location data). By observing movement patterns in the environment and aggregating this with self-reported social and cognitive activity, future research may better detect abnormal fluctuations in performance and make real-time recommendations for behavioral or lifestyle modification. These multi-modal approaches to cognitive assessment have begun to emerge in prevention research as well as across various clinical settings (Moore et al., 2017). Broadly, the goal of mobile assessments in clinical contexts is to monitor clinical impairment in cognition; early monitoring techniques may give rise to prevention strategies aimed at reducing cognitive decline. A review by Moore et al. (2017) identified 12 studies that reported using self-administered mobile cognitive assessments with various age groups and clinical populations. Authors reported high adherence rates (80% on average), like that reported in Study 2 (79.5%), however very few of these studies included real-time self-reported measurement of other temporally dynamic contextual variables in addition to cognition. Further, several studies reported sampling cognition only once per day (Moore et al., 2017).

One prominent direction for future research will be to evaluate using adaptations of EMA for use in the cognitively impaired population. Another option lies in offering personalized activity-based programs for aging adults, especially those involved in frequent family caregiving activities. As the findings from Study 2 suggest, there was considerable variability in cognitive performance based on engagement in socially meaningful daily activities. Utilizing EMA to study cognitive health strategies in populations of adult caregivers may provide information about stress-coping mechanisms and daily contextual factors that promote resilience and reduce neglectful behaviors (Pickering et al., 2020). In the context of aging and occupational health, the quality of performance at work may fluctuate depending upon the nature of leisure and the state of individuals at home-life. When more time is spent engaging in activities that are directed at others (i.e., family caregiving), the level of cognitive performance may be affected, resulting in downstream associations with other psychological factors such as reduced quality of work. There is a need for programs that promote adequate work-life balance, and the use of EMA will provide insight into the individual-level psychological processes and patterns of daily activity that contribute to equanimity and lead to more successful aging outcomes.

Lastly, from a clinical research perspective, mobile mental health technologies and ambulatory cognitive assessments are now being used to augment traditional psychiatric care (Torous et al., 2021), providing clinicians new treatment opportunities. The use of remote and just-in-time adaptive intervention (JITAI) designs offer promising potential for research aimed at improving psychological health through behavior modification (Nahum-Shani et al., 2018). Unsupervised digital cognitive testing has also been used in patients with preclinical AD (Papp et al., 2021), however the use of ambulatory cognitive assessments in adjunct with JITAIs have not been fully explored in patients with milder cognitive impairment.

Closing Remarks

Throughout the COVID-19 pandemic, older adults experienced disproportionately adverse effects. Due to social distancing practices and limited caregiver and family access, there has been a considerable concern for older individuals who were isolated at home and in residential care facilities (Vahia et al., 2020). However, counter to expectations, research has reported that older adults engaged in more socially connected types of leisure and recreation activities than any other age group (Rivera-Torres et al., 2021). Another qualitative study drew similar thematic conclusions, suggesting that older adults seemed to adapt more positively to leisure constraints throughout the pandemic, a manner aligned with the SOC model (Chung et al., 2021). Unfortunately, the influence of leisure activity on cognition seems largely dependent upon sociodemographic and individual differences. The extent to which these characteristics enhance or diminish the likelihood of engagement-related cognitive benefits depends upon whether the individual has adequate cognitive resources, and stable psychological functioning (Mejia et al., 2017; Yoon et al., 2021). The same leisure mechanisms involved with successful aging seem to have contributed to better mental health outcomes for older adults throughout the pandemic (Chung et al., 2021).

In conclusion, this dissertation provided strong evidence on how contextual factors such as meaningfulness are associated with activity participation and cognitive functioning. However, much more research is needed to fully disentangle the mechanisms responsible for these associations. Understanding how individual-level cognitive and emotional processes promote better psychological health for aging adults may shed light on certain lifestyle attributes and psychological contexts that encourage resiliency in response to current challenges and the COVID-19 pandemic. An important focus for future investigations will be to explore how meaningfulness conceptually changed during the pandemic and whether individuals successfully adapted leisure activities to be cognitively favorable. The integration of psychological contextual factors to the study of cognitive aging will greatly expand current conceptualizations of activity engagement broadly, as well provide clarity about how these processes specifically change and fluctuate across the adult lifespan. As more studies come forward utilizing multi-method approaches, a greater understanding of the temporal and dynamic lifestyle processes involved with the maintenance of cognitive performance across adulthood will emerge. Although the psychological nature of activity-cognitive associations is informative for prevention and intervention programming, more long-term research is needed to fully understand what drives habitual activity patterns in healthy adults and how relational factors differentiate between short and long-term gains in cognition. Translationally, the implications of mobile cognitive testing extend beyond aging research and offer enormous potential for improving current conditions by shortening the length of assessment time and providing more accessible and affordable options. Lastly, as more technological opportunities for web-based activities emerge, future research must consider how to sufficiently tailor mobile intervention programs to the specific needs and preferences of the individual (Cohen-Mansfield et al., 2021). Using adaptive technology to detect and modify age-related cognitive concerns, in real-time and in the comfort of individuals homes, represents an important endeavor for future aging research, one that will require considerable ethical consultation. This dissertation addressed significant gaps in the current literature by clarifying contextual attributes of engagement that are particularly important for healthy cognitive development. Helping to push the successful aging agenda forward, this dissertation represents a novel psychological lens through which lifestyle can now be explored.

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APPENDICES

Appendix A: Victoria Longitudinal Study (VLS-AQ) Activity Questionnaire

Date: _____ / _____ / _____ Participant #:_______________________
d m y

ACTIVITIES QUESTIONNAIRE

Our lives are organized to a great extent by the types of activities we participate in. In this questionnaire, you will find a list of activities that different people do in their everyday lives.

You may never have participated in some of these activities. Others you may have participated in several years ago. In this questionnaire, we would like you to tell us how many of these activities you have participated in within the last two years.

You will be asked to indicate about how often you engage in each activity. Do not worry if you cannot give an exact figure. **Circle** the letter that **MOST NEARLY** describes the frequency with which you have done the activity during the past two years. Here is an example:

I go shopping at a mall or downtown:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

Let's assume that you go to a mall or downtown once or twice a month most of the time. There may have been a month when you did not go at all, or there may have been a month when you went more often. But once or twice a month most nearly describes what you usually have done over the last two years. Thus alternative **f** is circled.

For each of the activities listed on the following pages, please **circle** the number that most nearly describes the frequency with which you have participated in them during the last two years.

1. I engage in weight lifting, strength or calisthenics exercises:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

2. I engage in aerobic activities such as cardio, fitness, or working out:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

3. I engage in flexibility activities such as stretching, yoga, or tai chi:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

4. I engage in outdoor activities such as sailing, fishing, or backpacking:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

5. I engage in exercise activities such as jogging, bicycling, or swimming:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

6. I engage in recreational sports such as tennis, bowling, or golf:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

7. I repair a mechanical device:
   a. Never
   b. Less than once a year
   c. About once year
   d. 2 or 3 times a year
   e. About once a month
   f. 2 or 3 times a month
   g. About once a week
   h. 2 or 3 times a week
   i. Daily

8. I do household repairs:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

9. I do woodworking or carpentry:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

10. I buy a new item requiring set-up:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

11. I play word games:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

12. I play knowledge games:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

13. I play board games:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

14. I play jigsaw puzzles:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

15. I do cross-word puzzles:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

16. I play card games:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

17. I watch comedy or adventure programs on television:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

18. I watch game shows on television:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

19. I watch documentaries on television:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

20. I watch news programs on television:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

21. I go out with friends:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

22. I visit friends or relatives:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

23. I attend parties (e.g. birthday):
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

24. I talk to (a) friend(s) on the phone:
a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

25. I give a dinner for friends:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

26. I play jigsaw puzzles:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

27. I eat out at a restaurant:

a. Never
b. Less than once a
ear
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

28. I give a public talk:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

29. I attend club meetings:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

30. I attend organized social events:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

31. I volunteer:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

32. I attend church services or synagogue:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

33. I engage in prayer or meditation:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

34. I travel out of town:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

35. I travel out of state:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

36. I travel abroad:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

37. I engage in business activities not related to my job:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

38. I collect stamps, coins, dolls, etc.:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

39. I read for leisure:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

40. I read newspapers:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

41. I garden indoors or outdoors:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

42. I write letters:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

43. I engage in sewing, knitting, or needlework:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

44. I read books as part of my job:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

45. I attend a public lecture:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

46. I enrol in a course at a university:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

47. I engage in creative writing:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

48. I go to the library:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

49. I study a foreign language:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

50. I engage in an on-the-job training program:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

51. I attend movies:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

52. I use computer software:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

53. I use an electronic calculator:

a. Never
b. Less than once a year
c. About once year
d. 2 or 3 times a year
e. About once a month
f. 2 or 3 times a month
g. About once a week
h. 2 or 3 times a week
i. Daily

54. I do arithmetic calculations:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

55. I engage in photography:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

56. I play an instrument:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

57. I prepare my own income taxes:

a. Never	d. 2 or 3 times a year	g. About once a week
b. Less than once a year	e. About once a month	h. 2 or 3 times a week
c. About once year	f. 2 or 3 times a month	i. Daily

Appendix B: Engagement in Meaningful Activities Survey (EMAS)

Participant Number: ________________

Engagement in Meaningful Activities Survey

Below is a list of twelve statements about your day to day activities. Please read each one carefully and choose the answer that best describes to what extent each statement is true for you. Take your time and try to be as accurate as possible.

---

1. The activities I do help me take care of myself.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

2. The activities I do reflect the kind of person I am.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

3. The activities I do express my creativity.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

4. The activities I do help me achieve something which gives me a sense of accomplishment.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

5. The activities I do contribute to my feeling competent.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

6. The activities I do are valued by other people.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

7. The activities I do help other people.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

8. The activities I do give me pleasure.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

9. The activities I do give me a feeling of control.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

10. The activities I do help me express my personal values.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

11. The activities I do give me a sense of satisfaction.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

12. The activities I do have just the right amount of challenge.

☐ Rarely ☐ Sometimes ☐ Usually ☐ Always

Appendix C: Beeping Schedules

5am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 4:00 am and 5:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
6:45 am	6:15 am	7:25 am	5:55 am	7:00 am	6:40 am	7:40 am
9:05 am	8:50 am	9:30 am	8:25 am	9:10 am	8:55 am	10:10 am
11:30 am	11:05 am	12:25 pm	10:55 am	12:05 pm	11:10 am	12:35 pm
2:25 pm	1:50 pm	3:05 pm	1:30 pm	2:55 pm	2:00 pm	3:20 pm
5:15 pm	4:25 pm	5:45 pm	4:10 pm	5:40 pm	4:35 pm	5:55 pm

6am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 5:01 am and 6:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7:45 am	7:15 am	8:25 am	6:55 am	8:00 am	7:40 am	8:40 am
10:05 am	9:50 am	10:30 am	9:25 am	10:10 am	9:55 am	11:10 am
12:30 pm	12:05 pm	1:25 pm	11:55 am	1:05 pm	12:10 pm	1:35 pm
3:25 pm	2:50 pm	4:05 pm	2:30 pm	3:55 pm	3:00 pm	4:20 pm
6:15 pm	5:25 pm	6:45 pm	5:10 pm	6:40 pm	5:35 pm	6:55 pm

7am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 6:01 am and 7:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
8:45 am	8:15 am	9:25 am	7:55 am	9:00 am	8:40 am	9:40 am
11:05 am	10:50 am	11:30 am	10:25 am	11:10 am	10:55 am	12:10 pm
1:30 pm	1:05 pm	2:25 pm	12:55 pm	2:05 pm	1:10 pm	2:35 pm
4:25 pm	3:50 pm	5:05 pm	3:30 pm	4:55 pm	4:00 pm	5:20 pm
7:15 pm	6:25 pm	7:45 pm	6:10 pm	7:40 pm	6:35 pm	7:55 pm

8am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 7:01 am and 8:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
9:45 am	9:15 am	10:25 am	8:55 am	10:00 am	9:40 am	10:40 am
12:05 pm	11:50 am	12:30 pm	11:25 am	12:10 pm	11:55 am	1:10 pm
2:30 pm	2:05 pm	3:25 pm	1:55 pm	3:05 pm	2:10 pm	3:35 pm
5:25 pm	4:50 pm	6:05 pm	4:30 pm	5:55 pm	5:00 pm	6:20 pm
8:15 pm	7:25 pm	8:45 pm	7:10 pm	8:40 pm	7:35 pm	8:55 pm

9am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 8:01 am and 9:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
10:45 am	10:15 am	11:25 am	9:55 am	11:00 am	10:40 am	11:40 am
1:05 pm	12:50 pm	1:30 pm	12:25 pm	1:10 pm	12:55 pm	2:10 pm
3:30 pm	3:05 pm	4:25 pm	2:55 pm	4:05 pm	3:10 pm	4:35 pm
6:25 pm	5:50 pm	7:05 pm	5:30 pm	6:55 pm	6:00 pm	7:20 pm
9:15 pm	8:25 pm	9:45 pm	8:10 pm	9:40 pm	8:35 pm	9:55 pm

10am Profile: This alarm schedule is used for participants who report typically waking up on weekdays between 9:01 am and 10:00 am.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
11:45 am	11:15 am	12:25 pm	10:55 am	12:00 pm	11:40 am	12:40 pm
2:05 pm	1:50 pm	2:30 pm	1:25 pm	2:10 pm	1:55 pm	3:10 pm
4:30 pm	4:05 pm	5:25 pm	3:55 pm	5:05 pm	4:10 pm	5:35 pm
7:25 pm	6:50 pm	8:05 pm	6:30 pm	7:55 pm	7:00 pm	8:20 pm
10:15 pm	9:25 pm	10:45 pm	9:10 pm	10:40 pm	9:35 pm	10:55 pm

Appendix D: Tablet Training Handout

HOW TO USE YOUR TABLET

PROTECTING THE TABLET: Keep the tablet protected from water. Keep your tablet separate from your keys, water bottle, and sharp objects in your bag or pocket.

THE SCREEN: Only use your finger to *tap* the very *sensitive* screen. **DO NOT** use pens, pencils, or any other object to touch the tablet because this may permanently damage the screen.

TO TURN ON THE SCREEN: Lightly press the button on the top right side of the tablet or the 'home' center bottom button. The screen will light up and you will see the water drop image. Slide one finger across the screen from left to right to unlock the screen. You should see the home screen with the raindrop on it and the two green logos for the survey. If you don't see the home screen, press the middle button at the bottom of the screen.

THE HOME BUTTON: This is a button located at the bottom of the tablet screen, and means home. If you are ever on a screen that you do not recognize, press the home button and it will take you back to the home screen (i.e., the water-drop background).

HOW TO SELECT THE EXERCISES OR BEDTIME SURVEY: Tap the "Launch Survey" icon at the top of the screen. It is a white and green icon that takes you to the REACT survey menu screen. Select your survey from this screen. If you are answering a beeped survey while the tablet is beeping, it will take you directly to the survey.

FILLING OUT THE SURVEY: Think of each screen on the tablet as a page. The directions on each page will explain how to make your response to the question. If you do not answer a question, you will get a message asking whether you meant to skip the question before going to the next page. If you did not complete the noted activity, you may tap "YES". When you complete a page tap the "**Next**" button. To go back one page, tap **"Previous"** and you will return to the previous page.

AT THE END OF THE SURVEY: You will see the message "Your data is being finalized." This means that your answers are being saved and sent. Sometimes this is very quick, sometimes it takes a little longer.

HOW TO ADJUST THE VOLUME: If you will be somewhere where a loud beep would not be appropriate (e.g., meeting, class, theatre), you can adjust the volume by pressing the volume button below the top right button that turns the screen on and off. The tablet will beep, and the volume will appear on the screen. Press the small cog or wheel to the side of the volume box and this will open more volume options. You can turn down the beeps by touching the bar or sliding the volume for Media. Make sure to only do this when absolutely necessary to ensure you don't forget that the volume is turned down low and then miss later beeps. When you are done with the event, you can do the same steps to turn the volume back up.

Daily Schedule

When You Wake Up in the Morning:

Remember to keep your tablet with you during the day to fill out the Beeped surveys!

WHEN THE TABLET BEEPS:

A short piece of music plays for a few seconds. You will see a screen that says "Please take a Beeped Survey now." Tap the "Do Survey" button to go directly to the survey.

1) **Complete your Beeped survey** and THEN…
2) **Tap "Launch Survey" icon and choose "Exercises".** Complete the Brain Exercises.

You will be "beeped" 4 times a day, approximately every 3 and a half hours. The times vary each day.

BEFORE YOU GO TO BED AT NIGHT:

About 30 minutes before your typical bedtime (as reported to us), an alarm on your tablet will go off to remind you to take the bedtime survey. Shut off the alarm by touching the red X circle and slide this to the right or left. Then, complete your Bedtime survey. Tap the "Launch Survey" icon and select the "Bedtime" survey.

Plug in the tablet near your bed so you remember to keep the tablet with you during the next day. It is critical that you do NOT let the battery run out. The program will not run properly after the tablet runs out of battery, even after it is fully charged. Please do NOT shut off the tablet unless instructed to do so, as the program will not run properly afterwards.

OTHER NOTES:

What if I miss a beep?

If you are not able to respond to a beep immediately (for example, while driving or in a meeting), try to respond as soon as you can. If the survey is not attended to when it beeps, it will continue to play the music every 25 seconds for the next 4 minutes.

If the survey screen is still on when you are able to get to the tablet, please complete the survey. If the survey screen is not on when you are able to get to the tablet (i.e., only the home screen with the waterdrop appears), please wait until the next beep to do the survey.

If you know you will be attending a quiet event during a time for which the tablet is scheduled to beep, you may choose not to bring it with you if you think it will be disruptive. This should be done **very rarely**, only under special circumstances.

If you notice that more than 4 hours of the day have passed without a beep PLEASE CALL US IMMEDIATELY AT 970-491-2804 or email: chhs-hdfs_activity_study@mail.colostate.edu