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ADAPTING TO OBSTACLES: INHIBITION AND CREATIVE POTENTIAL IN A SAMPLE OF SUCCESSFULLY AGING OLDER ADULTS

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Studying older adults who are aging ‘successfully’ (i.e., avoiding disease/disability; maintaining high cognitive and physical functioning; engaging in meaningful interpersonal/social engagement) may offer insight into variables that contribute to cognitive change throughout the lifespan. Successful aging is related to levels of engagement, which may be promoted by the problem solving and reevaluation encouraged by the creative process (Fisher & Specht, 1999). Creative thinking requires the consideration of diverse concepts and strategies (e.g., generating many solutions), as well as the regulated filtering of these possibilities (e.g., neither too permissive nor too narrow when eliminating ideas; Baas, De Dreu, & Nijstad, 2011). Cognitive inhibition is necessary for goal-directed behavior, and may also promote creativity by influencing abilities such as plasticity and innovation. Performance on executive control tasks, especially those that draw on inhibition, are impacted by age. Performance on inhibitory (but not excitatory) tasks may be sensitive to arousal levels that fluctuate with circadian rhythm (synchrony effect).

The current study examined performance on a variety of neuropsychological and creativity measures at two times of the day in a sample of successfully aging adults aged 70-79. Assessments of executive function, inhibition, and creativity (i.e., verbal and non-verbal divergent thinking) were administered to older adults twice, once at a time when inhibitory

performance was expected to be ideal (synchronous) and another at a time when inhibitory performance was expected to be reduced (non-synchronous). We hypothesized that morning testing (synchronous) trials of inhibitory tasks would exhibit lower latency and error rates than evening testing (non-synchronous) trials; morning testing (synchronous) trials of creative potential tasks would exhibit lower fluency, flexibility, and originality scores than evening testing (non-synchronous) trials; and that Need For Cognition (NFC) scores and Information-Orientation ISI subscale scores would be positively correlated with overall (AM + PM) creativity scores (fluency, flexibility, originality). Participants were expected to demonstrate time of day effects on Stroop and TMT performance.

Synchrony effects were not observed in this study. There was a significant relation between creative potential and Need for Cognition scores but not between creative potential and scores on the Information-Orientation subscale of the ISI. The current sample may have compensated with cognitive challenges such as those induced by testing time effects. These findings may suggest that a successfully-aging cohort is not impacted by synchrony effects. No previous research has used synchrony to compare aging trajectories (pathological, usual, successful) on cognitive performance. It is feasible that a successfully aging population would have significant cognitive reserve, brain reserve, or scaffolding strategies to compensate for the additional cognitive challenge of non-optimal testing time (Düzel, Schütze, Yonelinas, & Heinze, 2011; Reuter-Lorenz & Park, 2014). Indeed, a marker of successful aging is to compensate well with age-related changes and demonstrate minimal- to no- deficits in performance (Rowe & Kahn, 1997). Synchrony changes in cognitive performance may not be evident in a successfully aging population. The current study provides evidence that motivates intriguing questions about successful aging, inhibition, creativity, and time of day.

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CHAPTER 1

INTRODUCTION

Improvements in medicine, nutrition, and sanitation have allowed modern humans to live longer than ever before (Olshansky et al., 2005). This does not imply that our older years are free from physical and cognitive disabilities. To the contrary, rates of cognitive pathology such as mild cognitive impairment (MCI) and dementia continue to increase (Roberts et al., 2014). The cause of these disorders is yet unknown, although risk factors can predict susceptibility (e.g., history of depression, diabetes, hypertension, at least 1 APOEε4 allele; Li et al., 2016). Not all older adults will develop impairments in later years. Some exhibit brain structure changes in the absence of corresponding cognitive deficits (Hedden & Gabrieli, 2004). Others live without a physical disability but exhibit declines in working memory and reasoning. Several cognitive aging theories have been proposed to explain the heterogeneity observed in older age (Mitnitski, Howlett, & Rockwood, 2017; Sun & Sun, 2019). These theories and models attempt to describe or predict trajectories of the aging process and mostly concur that lifestyle factors can be protective against pathological age-related changes (Stine-Morrow et al., 2014; Stern, 2012).

Engagement is a lifelong behavior pattern that has been positively associated with healthy aging (Rowe & Kahn, 2015; Stine-Morrow, 2007; Phillips, 2017). For instance, those with mentally demanding jobs exhibit three times lower rates of cognitive impairment than those with mentally light jobs (Adam, Bonsang, Grotz, & Perelman, 2013; Schooler, Mulatu, & Oates, 1999). Attempting to study engagement has proven more challenging than correlating it with health outcomes. Firstly, engagement is a ‘habit of mind’, meaning it overlaps with many other traits and behaviors (e.g., openness to experience, education; Stine-Morrow, Parisi, Morrow, Greene, & Park, 2007). Second, engagement is highly individualized. An intervention designed to induce engagement may be highly stimulating to one individual and insufficient for another (Stine-Morrow, Parisi, Morrow, Greene, & Park, 2007).

The construct of creativity, "the ability to transcend traditional ideas…and to create meaningful new ideas" may be a mediating variable between engagement and healthy aging (Barbot, Lubart, & Besançon, 2016). Creative thinking requires the use of strategy, considering and combining diverse (even unrelated) concepts, avoiding common answers, and using flexible perspectives (Baas, De Dreu, & Nijstad, 2011; Benedek, Jauk, Sommer, Arendasy & Neubauer, 2014). Creativity can promote social interaction, cognitive activity, and a sense of self-worth, all of which are associated with successful aging trajectories (Price & Tinker, 2014; Rowe & Kahn, 2015).

Executive functions are a group of cognitive processes that are utilized in goal-directed behavior (e.g., problem solving, planning; Diamond, 2013). These processes include attentional control, working memory, cognitive flexibility, and inhibition (Diamond, 2013). The prefrontal cortex is primarily (but not solely) implicated in executive function performance (Bettcher et al., 2016; Reuter-Lorenz, Festini, & Jantz, 2016). This brain region exhibits age-related changes in volume and processing speed, even in a typically-aging population (Reuter-Lorenz, Festini, & Jantz, 2016). It is worth noting that changes in executive function are expected with increased age, even in the absence of pathology (Reuter-Lorenz, Festini, & Jantz, 2016). Age-related changes in inhibitory ability are of primary interest in the current study.

Older adults display higher levels of distractibility and perseveration than young adults (Hasher & Zacks, 1988). These behaviors reflect reduced 'inhibition', one of the four aforementioned processes of executive function. Inhibition describes the ability to ignore irrelevant stimuli in favor of target information. Three components form the construct of inhibition: access, deletion, and restraint (Hasher & Zacks, 1988). *Access* directs attention toward only relevant information, *deletion* removes irrelevant information to maximize efficiency, and *restraint* prevents strongly activated information from being immediately utilized (Hasher, Lustig, & Zacks, 2007). Together, these components filter out extraneous stimuli and allow only salient information to access working memory (Hasher et al., 2007).

Inhibition is a cognitively demanding ability. Constant filtering of information requires the coordination of many brain regions and draws heavily on other executive functions, including attentional control (Harnishfeger, 1995). In fact, inhibition may be sensitive to age-related changes due to how many coordinated cognitive resources it requires (Harnishfeger, 1995; May, Hasher, & Stoltzfus, 1993). These coordinated processes are influenced by age and also by physiological arousal (Anderson & Revelle, 1994; May & Hasher, 1998).

Physiological arousal is easily altered via biological and lifestyle variables (e.g., hormones, intoxicants, stress, sleep). Fluctuations in these variables can greatly impact arousal, thus influencing downstream processes such as cognitive performance (Davidson et al., 2006; Herman, Critchley, & Duka, 2018). The human body undergoes regular variations in arousal as part of our circadian rhythm (Aschoff, 1965). This ongoing oscillation of arousal is often overlooked in psychological research, but it can have a significant impact on cognitive task performance (May, Hasher, & Stoltzfus, 1993). In an aged population, the relationship between executive function performance and time of day grows progressively more complex. Older adults exhibit advanced circadian phases (e.g., earlier waking) and decreased circadian rhythm amplitude. Amplitude refers to differentiation between night and day arousal, resulting in older adults being more active at night and less active during the day (Hood & Amir, 2017; Leng, Musiek, Hu, Cappuccio, & Yaffe, 2019). These circadian shifts make the older adult population even more unique and not easy to compare with young adults (May, Hasher, & Stoltzfus, 1993). As such, testing time is a critical variable to consider in research on aging populations (May, Hasher, & Stoltzfus, 1993). Failing to do so may impair motivation and cognitive performance in older adults (May, Hasher, & Stoltzfus, 1993).

The current study explored three primary variables: **inhibition**, **creativity**, and **testing time**. The goal was to determine if there are within-person differences on inhibition and creative performance in a successfully aging sample of older adults when tested at two different times of day. Assuming these performance fluctuations existed, we then aimed to explore measures of creative potential and how these scores may relate to time of day and inhibition. This relationship could illuminate the underlying cognitive mechanisms of creativity. Lastly, the current study sought to better understand how lifestyle, personality and identity relate to inhibition and creative performance in a successfully aging population. Findings, implications, and limitations will be discussed. The following chapter will explore primary concepts (successful aging, inhibition, creativity, testing time), their potential mediators, and correlates.

CHAPTER 2

LITERATURE REVIEW

Adults over 65 display a great deal of inter- and intra- individual variability (Baltes, Smith, & Staudinger, 1992). Humans become increasingly developmentally heterogeneous with age, so that adolescents have more developmentally in common with their peers than seniors do. This variability makes predicting the aging process highly complex. Some adults experience a cognitive and physical decline with age, but do not develop diseases such as Alzheimer's or osteoporosis (Cosco, Prina, Perales, Stephan, & Brayne, 2014; Snowdon, 1997). Others exhibit pathological changes in the prefrontal cortex or white matter but do not exhibit cognitive deficits (Hedden & Gabrieli, 2004). Many factors likely contribute to this heterogeneity, allowing some older adults to thrive into their nineties while others develop pathology in their sixties. Several approaches attempt to explain this variability, the most notable of which will be discussed in the following section.

Aging: A Developmental Perspective

Mary, the first of eleven children, was born in 1892. She received eight years of formal education and did not earn her high school diploma until age 41. In 1993, at age 101, she was administered the Mini Mental Status Exam to assess her cognitive ability. Given her age and education level, her predicted score was 8/30. She scored 27/30 (Snowdon, 1997). Nursing reports and witness accounts indicate that Mary had a clear mind and showed no difficulty grasping explanations and remembering lists of items or events.

The following year, Mary died. Her autopsy report showed extensive neuropathology indicating advanced Alzheimer's disease. Her brain weighed a mere 870 grams. Her hippocampus showed extensive neurofibrillary tangles and both neural and diffuse plaques. Her middle cerebral, internal carotid, and vertebral arteries had atherosclerotic deposits. Sister Mary was one of 678 Catholic nuns who participated in the 'Nun Study of Aging and Alzheimer's Disease' (Snowdon, Greiner, Mortimer, Riley, Greiner, & Markesbery, 1997).

The Nun Study illustrates the complexities in describing, predicting, and understanding human aging. Development is a dynamic, lifelong process (Stowe & Cooney, 2015). As such, it is multidimensional and can be influenced by a wide variety of factors including genetics, lifestyle, cultural events, individual experiences and choices, and a general accrual of physiological changes (Baltes & Baltes, 1990). The following section will discuss four theories that provide unique views on the developmental process. These theories and models attempt to describe the aging process and emphasize contributing factors.

Developmental psychology examines individual development and change from conception until death. Developmentalists assume that change is an ongoing process – one that continues across the entirety of human life. Two dominant models of development have emerged: Lifespan (Baltes, 1987) and Life Course (Elder, 1998). These theories emphasize the influence of context and how historical events can impact future development.

The Lifespan Model (Baltes, 1987) deemphasizes cohort effects and focuses on individual effects of change and multi-directionality (i.e., change can take many directions in the same developmental period). As such, behavior can shift in several directions throughout development (e.g., older adults simultaneously exhibit *increased* crystallized intelligence and *decreased* fluid intelligence; Horn & Cattell, 1967). This assumption underlies the concept of development as a process of gains and losses, rather than a linear process of improvement (e.g., learning to walk is an improvement over crawling). Salthouse (1984) provided support for this model when he observed older typists who had decreased reaction time (loss) but increased accuracy (gain). The Selective Optimization with Compensation (SOC) model emerged from the lifespan perspective (Baltes & Baltes, 1990).

The SOC model posits that successful development is an ongoing practice of maximizing gains and minimizing losses. To increase gains, Baltes and Baltes (1990) suggest that we practice selection, optimization, and compensation. Choosing the most favorable circumstances (e.g., aging hikers may select only paved trails because they are unsteady on uneven terrain) is referred to as *selection*. *Optimization* is the process of augmenting skills to maintain knowledge (e.g., students practice foreign languages over the summer to preserve language skills). Lastly, *compensation* is using new strategies to achieve goals (e.g., recently injured photographers can use a tripod). A unique strength of this model is that it can be applied to both physical (e.g., hiking skills) and psychological (e.g., foreign language ability) tasks. Another model that attempts to describe both physical and psychological contributors to aging is STAC.

The Scaffolding Theory of Aging and Cognition (STAC) model suggests that compensation may delay age-related declines in function (Park & Reuter-Lorenz, 2009). This model proposes that bilateral- and over- activation patterns observed in older adults are mechanisms that assist in maintaining cognitive function despite neural challenges (e.g., atrophy; Park & Reuter-Lorenz, 2009). Neuroimaging studies have described these differences in neural activation between young and older adults (Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000). Relative to young adults, older adults can show broader/narrower (e.g., dedifferentiated) activation or over-/under- activation of neural substrates (Cabeza et al., 2000). Broad (diffuse) activation patterns are identified when older adults display activation of several brain regions while young adults display localized activation (Madden et al., 1999; McIntosh et al., 1999). Overactivation is observed when the region (primarily the prefrontal cortex) is bilaterally rather than unilaterally activated (Cabeza et al., 2000).

These findings are especially puzzling when activation patterns are compared to performance. In many of these neuroimaging studies, there is no significant difference in task accuracy between young and older participants (Cabeza, Anderson, Locantore, & McIntosh, 2002). In other words, older adults are performing just as well as young adults, but they are using different networks or strategies to do so. Low-performing older adults exhibit similar network activation as young adults, but with less efficiency (Cabeza et al., 2002). High-performing older adults display novel network activation, which may suggest plasticity and reorganization of neurocognitive networks (Cabeza et al., 2002). Perhaps these activation patterns demonstrate compensation in older brains (Raz et al., 2005). By functionally changing internal (e.g., rerouting neural networks) and external (e.g., environmental or lifestyle) strategies, older adults may use 'scaffolding' to compensate with age-related changes. The role of lifestyle was expanded upon in the STAC-r model (Reuter-Lorenz & Park, 2014).

The Scaffolding Theory of Aging and Cognition-revised (STAC-r) model addresses life course factors that influence brain health and plasticity. Healthy genetics and lifestyle factors (e.g., adequate nutrition, exercise) may act as 'brain maintenance' by requiring less compensatory scaffolding (Duzel, Schutze, Yonelinas, & Heinze, 2011). STAC-r attempts to predict the outcome of both older adults and middle-aged who require scaffolding at an early age (Reuter-Lorenz & Park, 2014). Protective 'neural resource enrichment' (e.g., participating in exercise, leisure, and social activities) may preserve or enhance brain function. Age-related declines in performance may be accelerated by 'neural resource depletion' (e.g., APOE-4 gene, smoking, obesity) Many models rely on cross-sectional data, whereas the STAC-r model relies on longitudinal research (Reuter-Lorenz & Park, 2014). The STAC-r model also accounts for the role of life experiences, similar to the Cognitive Reserve hypothesis (Stern, 2000).

The Cognitive Reserve hypothesis attempts to describe sources of variability in susceptibility to age-related cognitive change (Stern, 2012). ‘Reserve’ may act as a buffer between pathology and performance, comparable to ‘scaffolding’ as presented by Park and Reuter-Lorenz (2014). Cognitive reserve allows for greater resilience (performance that is maintained or minimally impacted) when presented with a cognitive challenge. Reserve can be classified as either ‘brain’ (e.g., quantitative measure of neurons or brain-derived neurotrophic factor (BDNF)) or ‘cognitive’ (e.g., compensation in processing). Pathology risk is related to measures of executive function and lifestyle factors (e.g., education, occupation, leisure activities).

Older adults who completed less than eight years of formal education had a 2.2-times greater risk of dementia compared to those with more education (Stern, 2012). Each year of education appears to provide additional reserve, with education relating to better cognitive function at any level of pathology (Stern, 2012). Those with low occupational attainment have a similarly increased risk (2.25-times greater). Participating in few leisure activities (less than six in the last month) was also associated with an increased likelihood of dementia diagnosis (Stern, 2012).

A high cognitive reserve may decrease the risk of dementia by as much as 46%, relative to those with moderate to low cognitive reserve (Stern, 2012). While reserve can camouflage cognitive decline, this concealment can lead to a more rapid rate of function loss. Pathology may be more advanced when it begins to manifest in cases of a higher cognitive reserve, indicating less time between onset and loss of function. One way of building cognitive reserve may be to structure the environment to encourage lifelong engagement and learning.

Stine-Morrow (2007) suggests that as we age, our choices about how we engage (or disengage) with the environment will accumulate and influence our rate of cognitive decline. The Dumbledore hypothesis (2007) suggests that vitality is dependent on both how we interact with the demands of our environment and what abilities we learn. This hypothesis promotes using an engagement approach to cognitive training. The engagement model places a participant in complex environments that are socially and intellectually challenging (Stine-Morrow et al., 2014). This engagement model may improve cognition and performance on a wide range of tasks, even without explicit instruction (Stine-Morrow et al., 2014). Engagement is promoted via complexity and ambiguous problems, which require flexibility and self-direction (Schooler, Mulatu, & Oates, 1999).

Participation in social and intellectual activities may buffer age-related declines in cognition (Parisi, Stine-Morrow, Noh, & Morrow, 2009; Stine-Morrow, 2007). One explanation for this benefit is that this kind of challenge requires a diverse range of abilities rather than mastery of one skill (e.g., being a bridge player requires social skills, math abilities, and memory – being a math prodigy alone will not allow you to master the game). Stine-Morrow et al. (2014) compared the traditional 'training' models of cognitive training with an engagement model. Healthy older adults were randomly assigned to a training, engagement, or control condition. The training group completed reasoning training (e.g., sudoku, crosswords) while the engagement condition participated in Odyssey of the Mind (a team competition in creative problem solving), each for 15 hours a week for four months. Older adults demonstrated improvements in constructs similar to the domain they practiced, in this case, measures of inductive reasoning. This is an example of near-transfer benefits. Only the engagement group increased ratings of openness to experience, social network size, and divergent thinking (i.e., creative problem solving; Stine-

Morrow et al., 2014). These traits may change subsequent behavior, such as increased likeliness to approach challenges or novel situations (Stine-Morrow et al., 2014). Comfort with novelty and adequate social efficacy may encourage further engagement, thus building cognitive resilience (Stine-Morrow et al., 2014).

Intervention models are the primary method of investigating lifestyle factors in cognitive aging (Colcombe & Kramer, 2003; Salthouse, 2004; Rebok et al., 2014). As with most research designs, intervention studies have strengths and limitations. Limitations include self-selection bias, as participants who volunteer for these studies are unlikely to be representative of the population. For instance, most older adults would not participate in fifteen hours of brain training or cardiovascular exercise each week for four months. Researchers must also consider selective attrition. If participants who are uninterested or unable to complete the study stop attending, the validity of the study can be threatened.

These four theories of cognitive aging attempt to conceptualize factors that affect how individuals change with age, and why we demonstrate a great deal of variability in our later years (Baltes & Baltes, 1990). Three factors influence this variability: the accumulation of genetic and environmental factors, the effect of individual choices, and pathological disruptions. As one grows older, the cumulative impact of these factors will inform one's interaction with the aging process (Stern, 2012). These theories underscore the importance of lifestyle in promoting resilience to age-related changes (Stern, 2012; Stine-Morrow et al., 2014.). The following section will compare three cognitive aging trajectories: pathological, usual, and successful. The current study examined a sample of older adults classified in the successfully-aging trajectory.

Successful aging

Adults over 65 are often described in terms of averages and expectancies (Rowe & Kahn, 1987). Factors often attributed to age (e.g., hypertension, hypercholesterolemia) are not universal (e.g., agricultural societies exhibit low rates of heart disease). As such, age alone cannot explain the presence of these factors (Rowe & Kahn, 1987). Decreased autonomy (e.g., reduced driving) and high rates of institutionalization (e.g., assisted living) are related to age. While these factors are described as consequences of aging (e.g., “when you get old, you end up in a nursing home”), they can be contributors to cognitive loss (e.g., the assisted living environment may place fewer demands on residents, thus reducing cognitive engagement and thereby promoting cognitive decline; Rowe & Kahn, 1987).

In 1987 Rowe and Kahn challenged this notion by proposing an idea that influenced how gerontologists viewed aging (see summary in Stowe & Cooney, 2014). They would suggest that functional declines in older adulthood are due to an accumulation of lifestyle or psychosocial factors (Rowe & Kahn, 1997). Disease and disability in advanced age are one of many possible trajectories, not fate (Rowe & Kahn, 1997). This seminal article proposed that aging adults should be considered a heterogeneous group with several trajectories of aging (i.e., pathological, usual, successful) rather than a reflection of average loss (Rowe & Kahn, 1987). In other words, cognitive decline is not a direct consequence of the aging process (Stowe & Cooney, 2014). The following section will describe aging Americans through the framework of Rowe & Kahn’s (1987) trajectories, starting with ‘pathological’ aging.

An accumulation of lifestyle factors (e.g., smoking) may influence functional outcomes (e.g., lung cancer) but that effect is not necessarily due to age as much as an accumulation of the effect (e.g., the increase in lung cancer risk can be attributed to smoking for 20 years, not aging 20 years; Rowe & Kahn, 1997). Some older adults develop disease and disorders as they age – common pathologies include cancer, heart disease, and dementia. The looming threat of these pathologies leads many individuals over 65 to be concerned about losing their independence. Thankfully, fears about forced early retirement, revoked driver's licenses, and assisted living facilities are mostly unfounded. Alzheimer's and other dementias are widely known, but only 8.8% of Americans over age 65 have this diagnosis (Langa, Larson, Crimmins, Faul, Levine, & Kabeto, 2016).

Dementia is a neurodegenerative disease characterized by deterioration in cognitive ability (Prince, Bryce, Albanese, Wimo, Ribeiro, & Ferri, 2013). Dementia is an umbrella term that encompasses accelerating cognitive impairment due to Lewy bodies, vascular occlusion or disease (e.g., Alzheimer's, Parkinson's, Creutzfeldt-Jacob; Prince et al., 2013). While not widespread in the population, dementia is a devastating, progressive condition with severe consequences for the patient and families. Current treatment for dementia includes acetylcholinesterase inhibitors or NMDA antagonists, with no cure (Jessen, 2014). The majority of older adults will not develop dementia. A more common diagnosis is that of Mild Cognitive Impairment (Eshkoor, Hamid, Mun, & Ng, 2015).

Approximately 32% of older adults will experience Mild Cognitive Impairment (MCI; Eshkoor, Hamid, Mun, & Ng, 2015). MCI is a condition in which a person exhibits cognitive deficits, but these deficits are subclinical for a diagnosis of dementia (Prince et al., 2013). Individuals with MCI report disturbance to normal cognition, but without impairment to daily function. MCI is not always a prodromal symptom of dementia, but it does signify an increased risk of diagnosis (Langa & Levine, 2014). Approximately 10-15% of clinic patients with MCI convert to dementia within a year (Langa & Levine, 2014).

There are no medications available for the treatment of mild cognitive impairment, although interventions aimed at aerobic activity, social engagement, and cognitive activity may decrease the risk of further decline (Langa & Levine, 2014). Current best practice is to maintain healthy biomarkers and implement preventative behaviors such as high levels of social and cognitive engagement (Phillips, 2017; Rowe & Kahn, 2007; Stine-Morrow, 2007). Older adults who participate in increased leisure activities and regular mental engagement display a 50% lower incidence of dementia even after controlling for age, health, cerebrovascular disease, education, and occupation (Fabrigoule et al. 1995; Fratiglioni et al. 2000; Scarmeas et al. 2001; Verghese et al. 2003; Wang, Karp, Winblad, & Fratiglioni, 2002; Wilson et al. 2002).

Age-related pathology (e.g., dementia, MCI) may occur in older adults, but it is not typical. Alzheimer's and other dementias are diseases that occur with higher frequency in the older population, but they should not be viewed as an expected part of the aging process (Birren, Schaie, Abeles, Gatz, & Salthouse, 2006). Non-pathological adults can be classified into two additional categories – usual and successful agers. The most common trajectory for an older adult is classified as usual aging (Rowe & Kahn, 1987). The following section will describe the usual cognitive aging process and what age-related changes can be expected in a typical adult.

Changes in cognition (e.g., speed of processing, attention) are typical even in non-pathological aging. These declines in function may be accompanied or even driven by structural changes in the brain and neural networks associated with aging (Raz, 2000). Neuroimaging studies have demonstrated neural changes concurrent with cognitive changes - for instance, reduction in hemispheric volume is related to global declines in performance on executive function tasks (Schneider, Pichora-Fuller, Craik, & Salthouse, 2000).

Brain regions sensitive to age include frontal white matter (Salat, Kaye, & Janowsky 1999), cerebellar structures (Raz, Dupuis, Briggs, McGavran, & Acker, 1998; Schneider, Pichora-Fuller, Craik & Salthouse, 2000) and the prefrontal cortex (PFC; particularly the dorsolateral region implicated in motivation and attention). In addition to cortical volume changes, older adults exhibit differences in neural activation. Older adults show less posterior activation relative to young adults and declines in amygdala activation (particularly when viewing negative stimuli; Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011; Mather & Carstensen, 2005; Navarro & Gonzalo, 1991). Brain regions associated with working memory also change with age, which can influence the maintenance and rehearsal of goals, immediate information, and processing strategies (Moscovitch & Winocur, 1992; Salthouse, 1994).

Other age-associated neurological changes include white matter hyperintensities. These are evident in normal aging but prolific in pathological aging (Schneider, Pichora-Fuller, Craik, & Salthouse, 2000). Neuronal loss may occur in specific regions (Kemper, 1994), while other structures demonstrate signs of neurogenesis (Gross, 2000). These structural changes appear to be influenced by lifestyle factors such as exercise, diet, and engagement (Jonasson, Nyberg, Kramer, Lundquist, Riklund, & Boraxbekk, 2017).

This section described both pathological and usual trajectories of aging. What follows is a description and review of the third trajectory, successful aging, which is relevant for the current study. Aging can be classified as usual when the aging process is intensified by extrinsic factors such as diet and exercise (e.g., no pathology but high risk). Conversely, successful aging is when extrinsic factors have a neutral or positive interaction with the aging process (e.g., no pathology, low-risk, high functioning; Rowe & Kahn, 1987).

Previous gerontological perspectives had largely, if not entirely, ignored this group of viable and engaged seniors (Stowe & Cooney, 2015). This first attempt at defining successful aging has been passionately debated and since modified. Rowe and Kahn revised this successful aging model in 1997 to further operationalize successful aging. Rowe and Kahn (1997) posit that successful aging is indicated by three markers: 1) avoiding disease/disability, 2) maintaining high cognitive and physical functioning, and 3) engaging in meaningful interpersonal/social engagement. To age well, one should not only avoid disease but also be low risk for acquiring disease (e.g., the absence of heart disease *and* healthy cholesterol levels). Cognitive and physical functioning can be evaluated on two dimensions: what you can do (e.g., run a mile) and what you are doing (e.g., running a mile each day). Lastly, meaningful engagement is operationalized as interpersonal and constructive activity (e.g., volunteer work). Critics of this model argue that biological and sociological research is mostly excluded from this definition of successful aging (Rowe & Kahn, 2015).

Aging trajectories can be predicted with moderate accuracy by several biological (e.g., fasting glucose, forced expiratory volume), health (e.g., smoking, inactivity) and social (e.g., income, stress, education) factors (Lara et al., 2013; Sowa, Tobiasz-Adamczyk, Topór-Mądry, Poscia, & La Milia, 2016). Despite a large body of research, no single factor or approach (e.g., biomedical, psychosocial) has provided a robust prediction model (Sowa et al., 2016). Recent models correctly classify participants into aging trajectories between 50% and 70% of the time (Jonkman et al., 2018; Sowa et al., 2016).

Clearly, these models leave much to be desired when explaining an outcome as complex and heterogeneous as human aging. The strength of using a developmental perspective is to broaden the understanding of aging as a *process* (Blane, 2006). This process is constantly being influenced throughout the lifespan, where formative circumstances and experiences diverge into lifestyle and social paths (Kuh, 2007). These paths lead to an accumulation of experiences so that factors throughout development impact outcomes into adulthood (Blane, 2006; Kuh, 2007). Under this approach, aging outcomes can be understood by considering lifelong patterns.

There are limits to the application of Rowe and Kahn's (1997) model of aging. This model heavily emphasizes the role of individual autonomy and personal agency in the aging process (Rowe & Kahn, 2015; Stowe & Cooney, 2015). Rowe and Kahn (1997) believe that identifying dispositional factors that affect cognitive aging may empower individuals to take personal responsibility for successful aging. While individuals do not have control over the genes they inherit, they may be able to make choices within the environment that can contribute positively to sustained cognitive performance (Cooper, Sommerlad, Lyketsos, & Livingston, 2015). Of course, nutrition, exercise, and other lifestyle factors do contribute to aging outcomes (Berkman et al., 1993). This should not disregard the many extrinsic forces that impact the aging process, including personal biology and genes.

Foremost, biological and psychosocial variables (e.g., personality, resilience, socioeconomic status) should be acknowledged as key factors in aging, as they impact physiological outcomes (e.g., reduced cardiovascular risk factors, reduced risk-taking behavior, moderation in alcohol use; Rowe & Kahn, 1987). The Swedish Adoption/Twin Study of Aging (SATSA) provides complementary evidence for Rowe and Kahn's model (Pedersen, McClearn, Plomin, Nesselroade, Berg, & DeFaire, 1991). Aging twins were examined to determine heritability for disease. Findings were threefold – 1) both intrinsic (e.g., genetics) and extrinsic (e.g., lifestyle) factors significantly impacted aging, 2) genetic factors were less influential in later life, and 3) trajectories for aging were predicted by extrinsic factors (Pedersen et al., 1991; Rowe & Kahn, 1997).

Any interpretation of Rowe and Kahn's (1997) model of aging should consider limitations and view the model as one of many perspectives on the complexities of human aging and behavior. A sensible way of doing this is to consider Rowe and Kahn's (1997) successful aging criteria as continuums rather than dichotomies (Whitley, Popham, & Benzeval, 2016). This approach acknowledges the heterogeneity exhibited by older adults in how they experience disease/disability, perform on cognitive and physical measures of function, and engage in meaningful interpersonal/social activities (Rowe & Kahn, 1997).

North American stereotypes about aging are overwhelmingly negative, portraying old age as a time of frailty, loneliness, dependency, and decreased mental and physical functioning (Dionigi, 2015). These sociocultural beliefs often embellish the age-related changes attributed to physiological aging (Dionigi, 2015). Older adults cope with a great deal of developmental variability, both interpersonal and intrapersonal. Some find themselves relatively healthy into their eighties, only to exhibit a rapid decline in ability. Others may be diagnosed with disease much earlier than their peers, but then maintain function for many decades. Yet others live to become vibrant and healthy centenarians. American views of aging tend to focus on cognitive and physical pathology, which are not destined stages of the developmental process. The current study was conducted in a sample of older adults who demonstrated criteria in the successful aging trajectory.

Rowe and Kahn (1997) proposed one of several cognitive aging theories that attempt to describe the developmental heterogeneity observed in older age (Mitnitski, Howlett, & Rockwood, 2017); Sun & Sun, 2019). Many of these studies find relationships between lifestyle factors and lower rates of pathological aging trajectories (Stern, 2012; Stine-Morrow et al., 2014). Some older adults develop impairments, some exhibit brain structure changes or risk factors in the absence of corresponding deficits, and some seem largely unaffected by the aging process (Hedden & Gabrieli, 2004). Engagement is a behavior that reoccurs in healthy aging literature (Stern, 2012; Stine-Morrow et al., 2014; Reuter-Lorenz & Park, 2014).

Describing, defining, and studying engagement has proven challenging. Engagement is a lifelong behavior pattern and is therefore difficult to disentangle from other lifespan variables (e.g., personality, socializing; Rowe & Kahn, 2007; Stine-Morrow, 2007; Phillips, 2017). Engagement is described as a ‘habit of mind’, meaning it overlaps with many other traits and behaviors (e.g., openness to experience, education; Stine-Morrow et al., 2007). Engagement is also inter- and intra- individually variable. An engaging activity may be highly stimulating for one person and insufficient for another (Stine-Morrow, et al., 2007). Intra-individually, an activity that is engaging at one time point may be inadequate at a different time point. Identifying the underlying components of ‘engagement’ may help to focus the research and advance our understanding of the construct. A lifelong ability that may relate to engagement is creativity.

Creativity

Creativity, the capacity to produce useful and novel ideas, is a multifaceted construct in psychological research (Amabile, 2018). This term can be applied to a variety of behaviors, from novel thinking to revolutionary inventions. When considering ‘creative individuals,’ renaissance painters and ancient Greek sculptors may come to mind. While these examples are creative archetypes, there are many more instances of creative expression (Amabile, 2018). The following section will provide a definition for creativity, describe theories behind the construct, discuss how it is measured, and end with a section on how creativity may relate to other variables of interest in the current study.

Creativity can be categorized into three forms: artistic, scientific, and hybrid. These forms of creativity vary in goals, structure, and how much personal expression they display (Amabile, 2018). For instance, artistic creativity tends to exhibit a great deal of the creator’s personality, needs or perceptions (Gomez, 2007). In contrast, scientific or technological creativity is detached from individual personality and encourages the development of novel and useful ideas (Gomez, 2007). Hybrid creativity promotes both environmental problem solving and artistic personality expression in fields such as architecture (Gomez, 2007).

Artistic creativity is loosely structured and personal, whereas scientific creativity relies on protocol and does not necessarily express the creator's individuality (Feist, 1998). In other words, painters and composers rely on subjective creative structure, whereas engineers and scientists follow prescribed protocol when creating (Feist, 1998). For example, poetry is an expression of artistic creativity whereas the Tesla battery is an expression of scientific creativity. Various theories have attempted to describe 'creativity,' a construct that encompasses behaviors as vast as products from Andy Warhol, theories from Stephen Hawking, and cooking without a recipe.

On a micro-level, creativity can be described on two dimensions: originality and functionality (Amer, Campbell, & Hasher, 2016). These criteria can be applied to individual performance differences or to single creative products (Amer, Campbell, & Hasher, 2016). Describing individual performance would be considering how original and functional Steve Jobs' concepts were, whereas describing single products would be considering how original and functional the new iPhone is.

At a macro-level, creativity can refer to daily acts of individual creative adaptation (i.e., Little-c creativity) as well as innovative alterations to well-established concepts (i.e., Big-C creativity; Kersting, 2003). The former describes 'everyday innovation' in problem solving at work and home, such as substituting a barrette for a paper clip or the ability to decorate a cake. The latter refers to eminent works of creative genius, such as the development of solar technology and the creation of the Impressionism movement.

While several descriptions of creativity exist, multiple methods have been used to assess the construct. Beyond the micro- and macro- perspectives of what creativity *is*, there are a variety of measures used to quantify it. These assessments attempt to isolate and quantify a single expression of creativity such as creative achievement, everyday creativity, or creative potential. The following paragraphs provide definitions and examples of the three expressions of creativity.

'Creative achievement' refers to real life outcomes that are frequently measured by self-report, using measures like the Creative Achievement Questionnaire. These assessments require the participant to rank accomplishments and achievements (Carson, Peterson, & Higgins, 2005). For instance, a participant is asked 'Have you composed a piece of music', and they respond on a scale from 'I have not been recognized in this area' to 'My compositions have been critiqued in a national publication'. These creative achievement assessments measure production, but not everyone can equally express creativity (Jauk, Benedek, Dunst, & Neubauer, 2013). Opportunities to produce may be limited by factors like exposure to art, access to education, financial resources, and corporate career constraints.

While some individuals may be limited in the ability to produce creatively, everyone has equal chance to practice everyday creativity. 'Everyday creativity' implies that creativity can be practiced 'at work and leisure across the diverse activities of everyday life' (Richards, 2010). Assessments of everyday creativity require participants to indicate the frequency of several creative behaviors (e.g., made your holiday decorations, drew a doodle; Jauk, Benedek, Dunst, & Neubauer, 2013). Measures that assess everyday creativity, such as the Lifetime Creativity Scale, provide insight into how one has practiced creativity but does not give an instantaneous measure of creativity. Consider an older adult who can indicate several behaviors on this measure but may not have performed them for several years. Creative potential measures can provide a current and functional assessment of creativity.

The cognitive ability to generate unique and useful ideas is referred to as ‘creative potential.’ Creative potential tasks require respondents to consider and combine unrelated concepts, avoid common answers, and use flexible perspectives (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014). Assessments of creative potential may use problem solving, divergent thinking, or deductive and inductive reasoning tasks (Karwowski, 2016). These all require spontaneous creation that draws on underlying cognitive processes such as executive function and inhibition. As such, a creative potential task was utilized in the current study.

The process of creation is twofold: ideas must be generated and they must be subsequently evaluated. For example, when asked to list words that begin with the letter ‘N’ one must generate ideas (name, knight, narrow, number, knife) and evaluate them for accuracy (thus excluding ‘knight’ and ‘knife’). While the ability to generate is related to measures of fluid intelligence and category switching, the ability to evaluate is related to scores of sustained attention, alertness, and attentiveness (Bass, DeDreu, & Nijstad, 2011; Benedek, Franz, Heene, & Neubauer, 2012). As is evident from these findings, creative potential tasks draw heavily on cognitive resources.

Some researchers classify creativity as a disinhibition syndrome, suggesting a lack of restraint is necessary for creative production (Eysenck, 1995; Martindale, 1999). The construct of disinhibition is used to describe a variety of disorders including manic states and hypersexuality. While these comparisons may be tantalizing, the majority of empirical work suggests that creativity requires both constraint (Carson, Peterson, & Higgins, 2003) and freedom (Benedek et al., 2014). Cognitive processes contribute to creativity by suppressing interference of inappropriate solutions and persevering beyond initial ideas (Benedek, Franz, Heene, & Neubauer, 2012). Initial responses are typically more common answers, whereas unique responses take longer to be generated. Inhibition serves to restrain initial or common responses, essentially blocking the path of least resistance and allowing for subsequent evaluation of new, unique ideas (Benedek et al., 2014; Cassotti, Agogue, Camarda, Houde, & Borst, 2016).

While inhibition assists in generating ideas, intelligence may be responsible for the uniqueness of ideas (Benedek, Franz, Heene, & Neubauer, 2012). Intelligence (both fluid and crystallized) can allow one to connect disparate concepts and associate remote elements (Benedek, Franz, Heene, & Neubauer, 2012). Researchers have debated the role of intelligence in creativity for decades, with two main hypotheses emerging: the threshold hypothesis and the Dual Pathway to Creativity Model (DPCM).

The threshold hypothesis proposes that the relationship between intelligence and creativity depends on intelligence level (IQ). For example, individuals with high intelligence demonstrate a full range of creativity (low to high scores), whereas individuals with low intelligence demonstrate mostly low and some moderate creativity scores (Benedek et al., 2014). The relationship between intelligence and creativity is predictive until a threshold IQ of 120 is reached, after that the prediction is not as strong (Benedek et al., 2014). In addition to finding statistical support for an IQ threshold of 120, Karwowski (2016) found personality and identity traits predict creative production. That is, while intelligence is necessary for creativity, it is not sufficient (Karwowski, 2016).

Cognitive factors and personality traits may mediate the relationship between intelligence and creativity (Nijstad, DeDreu, Rietzschel, & Baas, 2010). The Dual Pathway to Creativity

Model (DPCM) describes the role of dispositional and situational variables in creative performance (Baas, Roskes, Sligte, Nijstad, & DeDreu, 2013; Nijstad, DeDreu, Rietzschel, & Baas, 2010). Traits like openness and extraversion relate to approach behavior while traits like neuroticism and negative affectivity are related to avoidance behavior. The suggested underlying framework for DPCM is that approach-related traits predict higher cognitive flexibility and avoidance-related traits predict higher cognitive persistence. As such, situational factors that influence cognitive flexibility, persistence, or both will subsequently impact creative production (Baas, Roskes, Sligte, Nijstad, & DeDreu, 2013; Nijstad, DeDreu, Rietzschel, & Baas, 2010). Together, inhibition and intelligence can predict performance on creative potential tasks (Benedek, Franz, Heene, & Neubauer, 2012).

Creative Potential: Personality and Developmental Influences

Avoiding activities that are cognitively stimulating will not beget creative thinking (Dollinger, 2003). Creativity necessitates broad, abstract thinking and problem solving. Personality traits such as conscientiousness, neuroticism, and openness to experience may influence how one expresses creativity (Silvia, Beaty, Nusbaum, Eddington, Levin-Aspenson, & Kwapil, 2014). Beliefs about the self can also drive creative achievement, with those who emphasize self-reflection demonstrating better creative performance (Dollinger & Clancy Dollinger, 2017). While many traits may influence creative expression, the most predictive personality trait is openness to experience (Feist, 1998).

Openness to experience is a dimension in the Five Factor Model personality inventory that describes “the recurrent need to enlarge and examine experience” (McCrae & Sutin, 2009). Individuals scoring high in openness tend to exhibit active imaginations, aesthetic sensitivity, attentiveness to internal emotions, preference for variety, and intellectual curiosity (Connelly, Ones & Chernyshenko, 2014). Openness also mediates the association between higher gray matter volume and creativity, suggesting that the personality trait may influence creative expression (Li et al., 2014). Openness and creativity share traits like imagination, curiosity, challenge, and risk taking (Li et al., 2014).

Openness to experience has two subcomponents –experiencing openness (i.e., sensation seeking) and intellectual openness (i.e., need for cognition; Connelly, Ones, & Chernyshenko, 2014). Sensation-seeking is a subcomponent of openness to experience and is discriminable from need for cognition (Roberti, 2004). Sensation-seeking is comprised of four traits: thrill/adventure, experience seeking, disinhibition, and boredom susceptibility (Zuckerman, Eysenck, & Eysenck, 1978). While related to openness, sensation-seeking shows no direct relation to creativity (Ravert et al., 2013). In contrast, ‘need for cognition’ is related to creative thinking (Ivcevic & Brackett, 2015; Kaufman et al., 2016). The personality variable ‘need for cognition’ describes how apt one is to participate in effortful thinking (Cacioppo & Petty, 1982). Need for cognition is related to problem solving, participation in debate, high elaboration, and thinking as an end goal (Mussell, 2010).

High rates of openness are associated with decreased cognitive decline, even after controlling for education and disease (Sharp, Reynolds, Pederson, & Gatz, 2010). Openness contributes to cognitive reserve and has an even greater effect at low levels of education (Franchow, Suchy, Thorgusen, & Williams, 2013). While openness to experience is related to successful aging trajectories (Gregory, Nettelbeck, & Wilson, 2010; Levy & Langer, 1999; Sharp, Reynolds, Pedersen, & Gatz, 2010), most studies have not explicitly examined the subcomponent of need for cognition. Need for cognition influences how actively one interacts with the environment, perhaps increasing lifelong engagement and creativity (Stine-Morrow, 2007). Aging interventions that use creative problem solving have shown increased rates of need for cognition (Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012; Stine-Morrow et al., 2007). In young adults, need for cognition predicts creativity (Dollinger, 2003). The current study examined this association in older adults for the first time.

Openness and creativity are also related to one's view of self, or identity (Berzonsky & Sullivan, 1992). The term 'Identity' refers to many self-beliefs, but in this context, refers to Berzonsky's social-cognitive decision making styles. Berzonsky (1994) describes three styles of processing when faced with stressors or difficult choices. An information orientation refers to those who are open to self-reflection and actively find and evaluate relevant information (Berzonsky, 1994; Berzonsky & Sullivan, 1992). A normative orientation is used to describe those who are primarily influenced by the expectations and standards of family and peers (Berzonsky, 1994; Berzonsky & Sullivan, 1992). Lastly, a diffuse orientation is used to characterize those who procrastinate or avoid making choices and may ultimately remain uncommitted (Berzonsky, 1994; Berzonsky & Sullivan, 1992).

Identity processing styles are related to measures of creativity (Dollinger & Clancy Dollinger, 2017). Young adults who utilize an information orientation score higher on measures of creativity, whereas those with normative orientations tend to score lower (Dollinger & Clancy Dollinger, 2017). Creativity requires a breadth of information and developing novel ideas. Identity processing styles describe how one utilizes information and comfort with unconventional ideas (Dollinger & Clancy Dollinger, 2017). For instance, those with a normative orientation value the opinions and expectations of friends and family (Berzonsky, 1994; Berzonsky & Sullivan, 1992). These values may influence ability or willingness to engage in unconventional thinking. Emphasizing personal identity (information orientation) is associated with higher rates of creativity, but ones focus on personal identity shifts across the lifespan (Sneed & Whitbourne, 2003).

The topic of lifespan creativity has primarily explored the construct in young adults using correlational designs. By focusing on creativity only in early- or mid- life, the lifelong interaction between creativity and aging is overlooked. Old age is a time of transition and change, with disruptions in life situations such as loss of social support, relocations, and shifting social roles (Rossen, Knafl, & Flood, 2008). Successful aging is enhanced by adaptability and coping that may be promoted with the flexibility that comes from living a creative life (Fisher & Specht, 1999).

A few studies have examined aging and creativity, mostly through structured interviews with artists (Cohen-Shalev, 1989; Fisher & Specht, 1999). Creativity may facilitate successful aging by playing a role in how creative individuals manage everyday activities (Fisher & Specht, 1999). The creative process requires reevaluation and is often challenging. Older adults report feeling a sense of 'purpose' during creative production (Fisher & Specht, 1999). Creative individuals tend to vary environments (Levy & Langer, 1999), seek out productive engagement (Park, Gutchess, Meade, & Stine-Morrow, 2007), and live longer than the general population (Lindauer, 1998). Creative activities can promote social interaction, cognitive activity, and a sense of self-worth (Price & Tinker, 2014). As such, creativity may provide a compensatory advantage for neurological challenges, like those from cognitive decline (Franchow et al., 2013).

Executive Functions

Executive functions are used to organize thoughts and behavior. These processes are crucial for daily tasks like socializing and driving. Impaired executive functioning is the best predictor of functional decline in older adults (Bherer, 2015). The following section outlines the cognitive constructs known collectively as 'executive functions' and describes how they may change during cognitive aging.

Several models have been proposed to describe how executive functions operate and are hierarchically organized. The Limited Capacity Model (Kahneman, 1973) assumes that executive functions are controlled by a finite amount of cognitive resources. Cognitive resources are distributed across necessary systems as goals are introduced and completed (e.g., allocating attention to take the proper dose of medication). This distribution of finite resources is reflected in the label 'limited capacity model.' Kahneman (1973) suggested that cognitive resources cannot be used simultaneously across systems (e.g., while focusing on medication dosage, one cannot simultaneously do the math necessary to balance a checkbook). Exemplifying this model, older adults exhibit declines in performance on dual-attention tasks (Bherer, 2015). Aging may influence cognitive resource availability, as changes in cognition are typical even in non-pathological aging.

Executive functions are a group of coordinated cognitive processes that cue and direct goal directed behavior. Most models include four processes: attentional control, working memory, cognitive flexibility, and inhibition. These constructs can be isolated, but function additively (Diamond, 2012). Reasoning, problem solving, and planning (i.e., higher-order tasks) require the simultaneous organization of executive functions. Each process of executive function and how it relates to age-related changes will be explored throughout this section.

Attentional control, or 'selective attention,' is utilized when filtering through information to attend to relevant information (Rogers, 2000). This process can be quite efficient, as demonstrated by the cocktail party effect. This phenomenon is exhibited when attention is inadvertently redirected upon hearing one's name being spoken in a crowded room (Cherry, 1953). While selective attention can be assessed using auditory paradigms, visual search is a more commonly used measure. These tasks require participants to find a target object amidst many distractor objects, as in the popular children's book series "Where's Waldo." Older adults take longer to find the target in complex visual search tasks (Plude & Doussard-Roosevelt, 1989; Rogers, 2000). Both practice and cues (e.g., look in the bottom left quadrant) facilitate performance in older adults (Madden, 1983).

Working memory is critical for efficient processing of target information (Baddeley, 1986). There are individual differences in the capacity of working memory, but ultimately the amount of information that can be held is limited. Working memory capacity is related to behaviors like reading, following directions, and even SAT performance (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Carpenter, Just, & Shell, 1990; Kyllonen & Christal, 1990). Digit span tasks are used to assess the capacity of working memory, with average capacity equaling seven chunks, plus or minus two (Miller, 1956).

When utilizing working memory, the participant must both remember and process the information (e.g., while taking medicine, recalling what medication to take and how to take it). Older adults exhibit age-related declines in both manipulation and capacity (e.g., slower information processing and fewer simultaneous items; Salthouse 1991). The Working Memory theory suggests that reductions in processing speed may account for up to 40% of age-related deficits (Salthouse & Babcock, 1991).

Age-related changes in processing speed may also impact performance on switching tasks that draw on the 'cognitive flexibility' process of executive function. Cognitive flexibility (i.e., mental flexibility, attention/set shifting) refers to one's willingness and ability to adapt or 'switch' – whether that is changing a strategy or developing new beliefs (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). This process is inherently complex, as it requires simultaneously inhibiting previous perspectives and activating new ones in working memory. As such, cognitive flexibility emerges later in development as it builds on other executive functions (e.g., working memory; Diamond, 2012). Performances on task switching, perspective taking, fluency, and creativity measures are related to cognitive flexibility and hindered by mental rigidity (Miyaki et al., 2000).

This section introduced and described three constructs of executive function (attentional control, working memory, and cognitive flexibility). These processes can be studied individually, but often operate in a coordinated fashion to achieve goals (Diamond, 2012). The final process of executive function (inhibition) is implicated in age-related differences observed in older adults. Inhibition is particularly relevant to the current study and will be discussed in detail in the following section.

Inhibition and Aging

Inhibition works in concert with attentional control, working memory, and cognitive flexibility to logically prioritize thoughts (Hasher, Lustig, & Zacks, 2007). The presence of stimuli initiates (either explicitly or implicitly) neural activation (May & Hasher, 1998). Cognitive inhibition allows activation to be down-regulated during speech/language production, memory, and social interaction (May & Hasher, 1998; Hasher, Lustig & Zacks, 2007). Disrupted inhibition may allow irrelevant information to enter working memory, subsequently slowing the processing of target information due to excitation or distraction from stimuli (May & Hasher, 1998). Efficient inhibitory ability can enhance attentional control, declutter working memory, and aid cognitive flexibility.

Attentional control draws heavily on inhibitory processes to prevent distractions from the intended target (Hasher, Zacks, & May, 1999). Hasher and Zacks (1988) proposed three mechanisms of inhibition: *access*, *deletion*, and *restraint*. These mechanisms assist in goal focused thoughts and behavior, by ignoring extraneous information (e.g., background noises, intrusive thoughts). The 'access' mechanism of inhibition prevents disruptive or irrelevant information from accessing working memory (e.g., does the unusual noise in the background warrant attention?; Hasher et al., 1999). The 'deletion' mechanism erases the processing or awareness of no longer relevant information (e.g., the phone number we just dialed; Hasher et al., 1999). Lastly, the 'restraint' mechanism holds back strong or impulsive responses to analyze them for appropriateness (e.g., when asked what goes in a toaster, preventing 'toast' from being said before the correct answer, 'bread'; Hasher et al., 1999).

Deficits in inhibitory ability contribute to distractibility, forgetfulness, and delays in completing goal directed behaviors (Hasher et al., 1999). Inhibitory processes are utilized in novel tasks, as they limit distraction and enhance attention. Well practiced material benefits from automaticity and draws from excitatory (or 'activating') processes. Individuals with reduced inhibitory mechanisms will be more distractible, respond inappropriately, and forget more frequently than those with healthy inhibitory control (Hasher & Zacks, 1988). Many older adults consistently display this pattern of behavior, which may stem from an inhibitory deficit and is evident in behavioral performance as well as on laboratory tasks (Hasher & Zacks, 1988). For instance, older adults typically take longer to complete the Stroop procedure than young adults (Spieler, Balota, & Faust, 1996). Extraneous 'noise' or distractions in the environment may intensify this deficit and negatively impact performance. Low accuracy on inhibitory tasks is also linked with mood disorders and degenerative diseases (Hasher, 2007).

Mechanisms of inhibition may be differentially sensitive to age-related changes

(Feyereisen & Charlot, 2008). That is, older adults may experience a decline in inhibitory *access* while performance on inhibitory *deletion* tasks remains consistent. Laboratory tasks that draw heavily on one component (e.g., access) may lead to performance differences that are interpreted as global decline (McDaniel & Einstein, 2000). Hasher and Zacks (1988) were the first to suggest that performance on executive functioning tasks may be linked to the control of attentional resources. These findings may have important consequences for the study of activities of daily living such as language production and memory (Kim, Hasher, & Zacks, 2007).

As described in the previous section, age-related deficits in cognitive performance are seen in usually aging adults. Several theories have been proposed to account for these outcomes, including the Generalized Slowing Hypothesis (Salthouse, Mitchell, Skovronek, & Babcock, 1989) and the Inhibitory Deficit Hypothesis (Hasher & Zacks, 1988). The Generalized Slowing Hypothesis posits that a small number of interrelated variables may influence age-related changes in cognitive performance.

Salthouse (1992) used statistical path methods to control for perceptual speed on a pattern comparison task performed by participants aged 18-81. The inter-individual variance was significantly reduced by merely controlling for age. Increased reaction time may indicate slowing in the central nervous system. Mechanisms of this model were proposed in the subsequent, and expanded, Processing Speed Theory (Salthouse, 1996). Slow processing can significantly lower performance when task performance is determined by the number of responses in a specified time (e.g., 'one minute to provide as many words as possible that begin with the letter 'A'') or when there are concurrent demands on processing (e.g., Waldo must be wearing glasses, a hat, *and* a red and white sweater; Salthouse, 1980; Somberg & Salthouse, 1982; Verghese et al., 2002). Salthouse (2004) estimated that up to 75% of age-related changes in performance could be attributed to central nervous system slowing, with the remaining 25% unexplained.

The Inhibitory Deficit Hypothesis complements the Generalized Slowing Hypothesis (Hasher & Zacks, 1988). Reduced inhibition in older adults may allow extraneous information to enter working memory (Zacks & Hasher, 1994). As a result, the working memory system may have less capacity and perform slower than someone with healthy inhibitory control (Zacks & Hasher, 1994). While some domains of cognition decline with age, not all components of that domain necessarily decline equally.

It is likely that inhibition contributes some variance to creativity (Benedek, Franz, Heene, & Neubauer, 2012). While evidence indicates a robust relationship between inhibition and creativity, there have been different interpretations of how these variables interact (Benedek, Franz, Heene, & Neubauer, 2012). Inhibitory ability may allow greater cognitive flexibility by promoting divergent thinking and novel responses. Inhibitory capabilities may promote performance on tasks that require creativity and divergent problem solving (e.g., generating novel solutions). While appropriate attentional functioning depends on inhibitory mechanisms, the role of inhibition in creativity is not well understood.

Creative individuals tend to score higher on measures of impulsivity and engage in more risky health/safety behaviors (Benedek, Franz, Heene, & Neubauer, 2012; Tyagi, Hanoch, Hall, Runco, & Denham, 2017) than individuals scoring low on creativity measures. Some theories posit that creativity is a ‘disinhibition syndrome’ (Eysenck, 1995). A body of neuropsychological evidence provides evidence that these observations are likely not related to cognitive inhibition. Instead, these behaviors are likely due to personality traits such as risk orientation and unconventional attitudes (Amabile & Sensabaugh, 1992).

Creative performance relies on both excitative and inhibiting processes, personality traits, and cognitive factors . With this multitude of mediating factors, creativity has many possible trajectories across the lifespan. Evaluative processes are driven by cognitive abilities such as sustained attention, alertness, and attentiveness. These abilities tend to decrease in older adults, which may reduce creative potential (Barbot, Lubart, & Besancon, 2016). An alternative interpretation of this decline is that older adults' broader bandwidth of attention may allow for more information and thus may benefit performance on divergent thinking tasks (Healey, Campbell & Hasher, 2008; Baird, Smallwood, Mrazek, Kam, Franklin, & Schooler, 2012).

Circadian Rhythm

This section will begin with an exploration of physiological and cognitive effects of circadian rhythms. While circadian rhythms dictate arousal patterns, other factors may influence one's ability to adhere to these patterns. Circadian rhythms refer to the chronobiological measurement of bodily rhythms, and the term chronotype refers to interindividual differences in preference of sleep/wake cycles (Duffy, Dijk, Hall, & Czeisler, 1999). For example, your job may start at 8am but ideally, you'd wake up at 9am. As such, the interaction between Morningness/Eveningness and circadian rhythms (i.e., 'synchrony') will be discussed. Contributing variables and proposed effects of the synchrony effect are explored. Finally, this section concludes with evidence on the overlap between synchrony, executive function, and aging.

Circadian rhythms are biological patterns that are endogenously driven and are consistent with a 24-hour day (Panda, Hogene, & Kay, 2002). This cycle is referred to colloquially as an 'internal clock.' Both biological (e.g., blood pressure, body temperature) and hormonal (e.g., melatonin and cortisol) phase markers can be used to track circadian phases. Human chronobiology refers to biological functions (e.g., sleep/wake cycles, blood pressure, body temperature, and hormone excretion) that are influenced by circadian rhythms (Panda, Hogene, & Kay, 2002). These bodily cycles are chronobiological, and thus unchanged. For instance, testosterone secretion is highest at 9am, regardless if you sleep in on the weekend (Duffy et al., 1999).

While an individual can elect to override the preferred sleep/wake cycle, endogenous rhythms require time to adapt. External cues from the environment, called zeitgebers (German for 'time givers'), promote a 24-hour cycle (Hut & Beersma, 2011). Zeitgebers can be naturally occurring (e.g., light levels, ambient temperature) or self-directed cues (e.g., exercise, eating patterns; Hut & Beersma, 2011). Humans rely heavily on zeitgebers to regulate circadian rhythms, and disrupted zeitgebers (e.g., daylight savings time) can be disorienting or stressful until this rhythm is retrained (Wirz-Justice, Bromundt, & Cajochen, 2009). Jet lag is one example of the discomfort experienced due to circadian rhythm disruption ('circadian dysrhythmia'). A lack of synchronization between sleep cycle and circadian rhythm is linked with alterations in biological and physiological functions (e.g., metabolism, hormone production; Potter, Skene, Arendt, Cade, Grant, & Hardie, 2016). These changes have many implications downstream that may include fluctuations in cognitive functioning. Executive functions draw heavily on cognitive resources that may fluctuate in availability and efficacy with arousal patterns, glucose accessibility, and blood oxygen supply (Davidson et al., 2006). Incongruency between waking times and circadian rhythms are related to declines in cognitive performance as well as adverse health outcomes.

Both humans and non-human animals that undergo frequent changes of circadian rhythm demonstrate higher rates of cancer, digestive disorders, diabetes, and impaired cellular regeneration (Davidson et al., 2006). These disorders may arise from the lack of synchronization between zeitgebers and the internal rhythms previously established. These disparate signals may disrupt natural body signals, leading to disturbed sleep, poor sleep quality, and increased fatigue (Davidson et al., 2006).

Circadian rhythm dysfunction is symptomatic in many disorders (e.g., diabetes, Alzheimer's, Multiple Sclerosis), perhaps due to functions controlled by the endogenous cycle (Zelinski, Deibel, & McDonald, 2014). Many physiological functions (e.g., metabolism, blood pressure, hormone output) rely on circadian rhythms. Processes downstream from these functions similarly depend on a regular sleep/wake cycle (e.g., lipid and carbohydrate metabolism, glucose regulation, glucocorticoid metabolism, immune activity; Sookoian et al., 2007). Those who experience chronic circadian dysrhythmia exhibit high body-mass-index, increased fasting insulin levels, and higher triglycerides and leukocyte (cells implicated in immune functioning) counts than those with consistent circadian rhythms (Sookoian et al., 2007).

In contrast to physiological phase markers for circadian rhythm, self-report measures are used to assess chronotype (Horne & Östberg, 1977). Interindividual preferences in rising and sleeping times are referred to as chronotypes (Curtis, Burkley, & Burkley, 2014). Chronotype (i.e., Morningness/Eveningness) is distinct from circadian rhythms although often related (Duffy et al., 1999). Morningness/eveningness is colloquially referred to as being an 'early bird' or 'night owl.' Self-report measures allow researchers to compare circadian fluctuations against personal preferences in the sleep/wake cycle (Horne & Ostberg, 1975). These preferences differ both inter- and intra- individually across the lifespan.

Sleep/wake cycles change throughout development, with infants typically exhibiting a morning-type arousal pattern (Gunnar & Donzella, 2002). Between two weeks and three months of age, infants demonstrate a quantifiable arousal cycle, verified by salivary levels of cortisol and melatonin (Brooks & Canal, 2013; de Weerth, Zijl, & Buitelaar, 2003). Arousal gradually shifts toward an intermediate- to evening- type arousal pattern in adolescence (Crowley, Acebo, & Carskadon, 2007). A phase shift to later waking is related to increased caffeine intake, subjective poor sleep quality, and later bed- and waking- time on weekends (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002). Bioregulatory systems undergo drastic restructuring starting with puberty and lasting throughout adolescence. This may influence behavioral decisions and the ability to adjust to a fluctuating schedule (Carskadon et al., 1998; Crowley et al., 2014).

Preference for early rising begins around middle age (35-45 years of age) and continues well into late adulthood (May et al., 1993). Although the mechanism behind this change is yet unclear, it may be related to changes in glucose utilization within the suprachiasmatic nucleus (Wise, Cohen, Weiland, & London, 1988). Increased age is related to increased preference for both early sleep and early waking. Older adults reported feeling most active and focused early in the day, as well as rising sooner than younger counterparts (Cavallera, Boari, Giudici, & Ortolano, 2011). This shift in chronotype may be an important factor to consider because it has implications for both cognitive performance and physical health changes in late adulthood (Cavallera et al., 2011). As older adults begin to shift toward morning-type arousal, they should be cognizant of scheduling social events, cognitively demanding tasks (e.g., driving) and medical appointments at synchronous times of the day.

Synchrony

Performance on executive function tasks can fluctuate across the day in accordance with arousal levels (May & Hasher, 1998). The synchrony effect is the association between peak arousal and testing time (May et al., 1993), and incongruity between these factors may impair cognitive performance (May et al., 1993). Chronotype and testing time can be synchronous (e.g., morning chronotype tested between 6am and 12pm) or non-synchronous (e.g., morning chronotype tested between 12pm and 6pm; May & Hasher, 1998). Synchrony affects arousal, executive function performance, and availability of cognitive resources (Anderson, Campbell, Amer, Hasher, & Grady, 2014).

Non-synchronous testing time may impair select executive functions such as inhibitory processes (May, Hasher, & Foong, 2005). This impairment may be due to changes in resource availability, as described by the Limited Capacity Model (Kahneman, 1973). Novel responses require inhibitory processes, whereas well-rehearsed responses draw on excitatory processes, with each requiring different amounts of cognitive resources (May, Hasher, & Foong, 2005). Evidence supporting a synchrony effect on inhibitory processes is robust, but there is less support for an effect on excitatory processes (Yoon, May, & Hasher, 1999). Performance on inhibitory tasks is decreased at non-synchronous testing times. That is, when a participant is tested at a non-optimal time of day, they are less effective at inhibiting (e.g., increased latency, more error).

This effect is observed across the lifespan, with older adults exhibiting an increased sensitivity to time of day effects (Hasher, Zachs & May, 1999; Park & Schwartz, 2000; Yoon, May & Hasher, 1999). Usually aging adults experience decreased inhibition, even at synchronous times of day. This effect is amplified by non-synchronous testing times, as there are fewer cognitive resources to ‘buffer’ the reduced cognitive arousal (Hasher, Zachs, & May, 1999). In other words, a younger adult will have few errors at a synchronous testing time, and some errors at a non-synchronous testing time. An older adult will have some errors at a synchronous testing time and relatively more errors at non-synchronous testing times (Hasher, Zachs, & May, 1999).

While older participants report preferring morning testing times, many psychological studies on college campuses are conducted in the afternoon when college students are available to participate (May & Hasher, 1998). May, Hasher and Stoltzfus (1993) examined typical testing times in aging studies by administering a questionnaire to cognitive aging researchers. They reported that 71% of young and 62% of older participants were tested in the afternoon (e.g., 12pm to 6pm; May, Hasher, and Stolzfus, 1993). May et al. (1993) questioned if testing participants on this schedule was effective at controlling for time of day effects on performance. The researchers they surveyed believed that they *were* controlling for time of day effects by limiting testing to a strict time window. To the contrary, by testing different age groups during the same time window they may exacerbate age-related differences in performance (May & Hasher, 1998; May et al., 1993; Yoon, May, & Hasher, 1999).

Older adults tend to reach peak cognitive arousal in the morning (6 am to 12 pm) compared to young adults who prefer afternoon (12 pm to 6 pm; English & Carstensen, 2015; May, Hasher, & Foong, 2005; Schmidt, Peigneux, & Cajochen, 2012). To illustrate this point, 74% of older adults report being ‘moderate to definitely’ morning type whereas 44% of young adults report being ‘moderate to definitely’ evening type. As such, the current study examined only ‘moderate to definitely’ morning type older adults. Few older adults are ‘moderate to definitely’ evening chronotypes (approximately <2%; May & Hasher, 1998). As such, a fully-crossed design using Age (young/older) X Chronotype (Morningness/Eveningness) was not feasible as results from older adults who are evening chronotypes would not be generalizable.

Far less evidence is available for the interaction between synchrony and creativity. A review of the literature with the keywords “time of day” or “synchrony” combined with “creativity” or “divergent thinking” revealed two studies – one on morningness-eveningness and creative thinking in young adults who play recreational sports (Cavallera, Boari, Labbrozzi, & Bello, 2011) and two relevant studies on chronotype and creativity (Giampietro & Cavallera, 2007; Roeser, Riepl, Randler, & Kubler, 2015).

In the first of these studies, volunteers aged 19 to 76 were tested on measures of creativity and given a morningness-eveningness assessment (Giampietro & Cavallera, 2007). Relations between the two scores suggest that evening type participants provide high numbers of unique and unusual answers. Researchers suggest this may be a reflection of nocturnal types’ originality and unconventional lifestyles (Giampietro & Cavallera, 2007). Evening types view themselves as clashing with social norms and exhibiting non-conventional attitudes (Giampietro & Cavallera, 2007). While innovative, this study evaluated pre-existing variables without experimental control. Additionally, this study was not deliberate in the recruitment of age groups (Giampietro & Cavallera, 2007).

In the second study, undergraduate and graduate participants were tested in either the morning or evening on measures of creativity (Roeset, Riepl, Randler, & Kubler, 2015). Scores of both generation (number of responses) and evaluation (diversity of responses) were collected. Older age, female gender, and morningness significantly predicted higher generation scores, but not evaluation scores (Roeset, Riepl, Randler, & Kubler, 2015). This study used an experimental approach and is relevant to the current research question, but it did not take place in an exclusively aging population, nor did it include assessments of executive function.

Current Study

The current study examined cognitive and lifestyle correlates of successful aging and expands preexisting literature by specifically including engagement in a successfully aging sample of older adults. Inhibitory resources were manipulated and performance assessed on creative potential tasks. Specifically, the relations between executive functions, personality traits, and creativity were explored in a successfully aging group of older adults.

Previous studies have considered the role of testing time, but few systematically examined the influence it had on other variables. This study examined relations between inhibition and creative potential using synchrony (time of day effect) as an independent variable. Testing time was manipulated to impact cognitive resource availability. Varying resource availability was hypothesized to lead to differences in inhibitory performance across testing times. By examining this effect in an aging population, inhibitory deficits were exaggerated. Older adults are sensitive to synchrony effects, particularly on tasks which require greater cognitive resources. This research can illuminate an underlying relationship between inhibitory performance and creative potential performance.

Creative potential performance was compared against inhibitory performance to understand more about the relationship between these two constructs. This relationship was clarified by examining peak arousal performance vs non-peak arousal performance. Previous studies have examined creativity, but few used experimental methodology, and none have done so in a sample of older adults. An experimental design provides insight into the underlying mechanisms of creativity.

Historically, aging research has focused on pathological or usually aging populations. The current study was performed with successfully aging adults who 1) self-report well managed disease or disability, 2) scored at or above the 50th percentile on executive function measures, and 3) reported participation in four or more social events within the last month. Many aging studies examine between-groups effects, rather than intra-individual differences. This study utilized a within-subjects approach to minimize variability due to inter-individual differences. Measures were administered twice, once at a time when inhibitory performance was expected to be ideal (synchronous) and another at a time when inhibitory performance was expected to be reduced (non-synchronous).

Hypotheses

Hypothesis 1: The synchrony effect posits that older adults have better resource availability and arousal in the morning. As such, morning testing (synchronous) trials of inhibitory tasks will exhibit lower latency and error rates than evening testing (non-synchronous) trials.

Hypothesis 2: The benefits of distractability hypothesis suggests that creative problem solving benefits from diffuse attentional abilities. As such, morning testing (synchronous) trials of creative potential tasks will exhibit lower fluency, flexibility, and originality scores than evening testing (non-synchronous) trials.

Hypothesis 3: Need For Cognition (NFC) scores and Information orientation ISI subscale scores will be positively correlated with overall (AM + PM) creativity scores (fluency, flexibility, originality).

CHAPTER 3

METHOD

Participants

Participants included older adults (70-79 years old) recruited from a large suburban community and surrounding rural areas in the Northwestern region of the United States. Older adults were recruited from convenience samples of community organizations using flyer advertisements. Snowball sampling was utilized via word of mouth. Using G-Power (ANOVA: repeated measures, within factor, 2 groups, 4 measurements, $\eta 2 = .28$), an estimated total sample size of 38 was deemed sufficient to produce the desired effect.

Participants were primarily recruited from suburban areas outlying a large city in the Northwest. Initial phone screening was conducted with 79 volunteers. Only those who met criteria for successful aging (no chronic or unmanaged disease/disability, no reported cognitive or physical limitations, and regular engagement in interpersonal/social functions; Rowe & Kahn, 1997) were scheduled to participate. Forty-four percent of those interviewed via phone were scheduled for in-person screening and administration. Forty-five older adults participated in the current study. Three participants were excluded after additional in-person screening was conducted (two for cognitive performance and one for a previously undisclosed head injury). One was removed as an outlier (described below). Two participants had incomplete data due to completing only one testing session. The remaining 39 participants were included in analyses for the current study.

The average age of participants was 73.56 years (SD = 5.88). All participants identified as Caucasian/white, and the majority were female (n = 34). Half (50%) of females reported taking hormone replacement therapy. Participants were moderately morning type, averaging an

18.2 on the Morningness Eveningness Questionnaire (range = 12, SD = 3.00). The cutoff for inclusion in the study was an MEQ score of <15. The current sample was well educated, with 87.5% having at least some college. Of those who completed degrees, 17% completed Bachelors, 20% completed Masters, and 5% completed PhD. Participants were generally healthy, with none reporting 'poor' health and 85% self-reporting 'good' or 'very good' health. The most common health complaint was arthritis, 50% of participants reported being diagnosed with this condition. The second most common health complaint was a reported diagnosis of depression, with 35% of participants reporting this condition. 84% of participants were retired. This sample of older adults were highly active, self-reporting an average of '6 or more' social activities per month and '4 to 5' activities for others per month. Morning testing sessions occurred most often (46%) at 10:00am, evening sessions most often (63%) at 4:00pm. See Table 1 for descriptive statistics.

Design

The current study utilized a repeated-measures design. This design allows for greater statistical power and a reduction in variance associated with individual differences. Limitations of a repeated measures design, including carryover and practice effects, were considered. Potential threats to the validity of this study were factored into the design. Participants were tested on the same measurements twice, so assessments were selected to be appropriate for repeated testing. Counterbalancing was utilized to reduce carryover and testing effects.

The current study required an estimated total sample size of 38 participants. Data collection included oversampling (N =45) to ensure enough data was collected to account for possible attrition. Attrition was addressed with the following considerations: testing was limited to one hour, participants were sent reminders twice, and incentives were provided (Brueton et al., 2011). Differential attrition was monitored and was not a significant concern (see Results).

Contact with participants took place via email, phone call, and face-to-face meetings. The battery of assessments utilized in the current study was carefully selected to not exceed one hour of testing (See Figure 1). All measurements were appropriate for use in older adults and were provided in font size 14+ to minimize eye strain. After completion of both conditions, incentives were provided in the form of gift bags worth $5. Gift bags included a large-print Sudoku book, a large-print crossword book, and a large-print word search book as well as a pamphlet about healthy aging.

A fully-crossed design using Age (young/older) X Chronotype (Morningness/Eveningness) was not feasible. As such, only morning type older adults (age 70-79) were recruited. Participants completed measures of executive function and creativity at both peak (8am-12pm) and non-peak (4pm-8pm) times. Eligible participants were assigned to one of two conditions – 1) initial testing at peak time with subsequent testing at off-peak time, or 2) initial testing at an off-peak time with subsequent testing at peak time.

The current study examined three variables: inhibition, creativity, and time of day. See Figure 2 for a conceptual map of these variables. The sample of participants was drawn from a group who were successfully aging, quantified by self-reported well managed disease or disability, scoring at or above the 50^{th} percentile on executive function measures, and participation in four or more social events within the last month (measured with the Florida Cognitive Activities Scale). Inhibitory skills were assessed by performance on the Trails and Stroop tasks. Creativity was measured by performance on verbal and non-verbal creative potential measures from the Torrance Tests of Creative Thinking. Lastly, synchrony was manipulated by assessing Morningness/Eveningness with the MEQ-SA and controlling for testing time.

Procedure

Potential participants were contacted over the phone and verbally administered the Morningness-Eveningness Questionnaire Short Answer (MEQ-SA). If participants scored in the intermediate to evening range (15 or less), they were thanked for their time, provided with educational materials, and excluded from participating. If participants scored in the morning range (>15), they were assigned to a condition (initial testing time synchronous or non-synchronous) via block randomization. Testing times were scheduled accordingly, with morning testing completed between 8 and 11am and evening testing completed between 4 and 7pm. Participants self-selected testing time within the selected block. This allowed for consideration of schedule and driving preferences (e.g., some opted not to drive during rush hour or after dark). Participants were offered the choice of two testing locations: the library meeting room or their house. The majority of participants (53%) were tested at the library and the remaining (46%) were tested at their house.

At testing time, participants completed an Informed Consent form followed by additional screening measures. All participants were screened for cognitive impairment using the SLUMS (see Measures section for parameters). Participants were given a standard Snellen vision test and tested for color blindness. Color blindness was included as a screening measure because the Stroop test (discussed under Executive Function measures) is administered in full color. Participants were asked to complete the Ishihara Color Blindness Test. Six plates from the test were used (plates 1, 2, 8, 11, 12, 13) and participants had to correctly identify all six plates to be eligible. Those who scored below threshold on SLUMS, misidentified an Ishihara plate, or were unable to complete the vision test with a Snellen score of 20/50 or better (with corrected vision) were excluded from the current study.

Participants completed personality, identity, engagement and demographic (see Appendix A) forms only once. Participants completed the executive function measures and creativity assessments twice, once per session (i.e., peak and non-peak times). See Figure 1 for a timeline of the study.

After the initial meeting, participants were scheduled for a follow-up meeting within 14 days. Average completion time was 120 minutes or 60 minutes per condition. After completion of both conditions, participants were thanked for their time and effort and debriefed on the study. They received literature on healthy aging, information on the possible benefits of scheduling activities at ‘peak’ arousal time, and gift bags (containing sudoku, crossword, and word find puzzle books).

Materials

Screening Measures

All cognitive screening assessments were administered on paper.

<u>Horne-Östberg Morningness/Eveningness Questionnaire (MEQ-SA)</u>

Performance on executive function and inhibitory tasks fluctuate with circadian arousal (May & Hasher, 1998; May, Zacks, Hasher, & Multhaup, 1999). Arousal patterns may influence performance on the tasks administered in the current study, so Morningness/ Eveningness was assessed to evaluate this effect. The MEQ-SA was used to assess Morningness/Eveningness. Participants were contacted via phone and asked five multiple choice questions regarding sleeping and waking habits (Horne & Ostberg, 1975), see Appendix B. Scores were based on a continuous scale from evening type (low scoring) to morning type (high scoring; Horne & Östberg, 1977).

The MEQ-SA demonstrates high validity when compared to peak body temperatures and heart rate that fluctuate throughout the circadian cycle. Scores on the MEQ-SA correlate (.95) with other measures of Morningness/Eveningness such as the Torsvalland Akerstedt measure (Smith, Reilly, & Midkiff, 1989). The Horne-Östberg measure is the most widely used measure to assess Morningness-Eveningness (Smith, Reilly, & Midkiff, 1989). Due to the format of questions (e.g., "How do you feel after being awakened in the morning?") the MEQ-SA is not recommended for use with night shift workers. As such, any participant who reported a history of night shift work was excluded from participating. The MEQ-SA is appropriate for administration in an older adult population (Biss & Hasher, 2012; May & Hasher, 1998; May, Zacks, Hasher, & Multhaup, 1999; Rowe, Valderrama, Hasher, & Lenartowicz, 2006).

Saint Louis University Mental Status

The Saint Louis University Mental Status (SLUMS) was developed to screen older adults for mild cognitive impairment and dementia (Tariq, Tumosa, Chibnall, Perry III, & Morley, 2006). The SLUMS is an alternative to the more traditional Mini-Mental Status Exam (MMSE), which may not detect mild cognitive impairment or dementia at lower thresholds (Tariq et al., 2006). For those without a high school education, mild cognitive impairment is indicated at a score of 23.5 (sensitivity value 0.92, specificity value 0.81) and dementia is indicated when scoring at 19.5 or below (sensitivity value 1.0, specificity value 0.98; Tariq et al., 2006). For those who have completed high school, mild cognitive impairment is indicated at a score of 25.5 (sensitivity of .95, specificity value 0.76) and dementia is indicated when scoring below 21.5 (sensitivity of .98, specificity value 1.0; Tariq et al., 2006).

Florida Cognitive Activities Scale (FCAS)

The FCAS is composed of 25 activities (e.g., taking a course, walking/driving in familiar environments, playing board games; Schinka, Mcbride, Vanderploeg, Tennyson, Borenstein, &

Mortimer, 2005). This list is provided to participants who are instructed to read the list and think about how often in the last year they did each activity. For each of the statements, they are asked to provide a score between one (never) and five (every day) to indicate the frequency of participation. Each participant was walked through the scale, with examples for each number value (i.e., two is once every few months, three is monthly, four is about weekly; Schinka et al., 2005). Participants were encouraged to ask questions if they were unsure of how to score for this measure. There was no time limit for completion of this task.

Three scores can be derived from this measure, a sum of all 25 activities as well as two subscales (Higher Cognition, Frequent Activities; Dotson, Schinka, Brown, Mortimer, & Borenstein, 2008). These subscales indicate the relationship between the FCAS questions and cognitive abilities. These subscales weren't utilized in the current study as they are experimental and have low sensitivity (Schinka et al., 2005). The overall scale demonstrates acceptable levels of internal consistency (.65) and a method for quantifying engagement in activities in an older adult population (Schinka et al., 2005). The Demographics form merely asked about overall frequency of social activities. The FCAS was administered to gather more information about the kinds of activities participants reported engaging in, and to quantify level of activity.

Executive Function Measures

All executive function assessments were administered on paper.

<u>Trail Making Test</u>

The Trail Making Test (TMT) test consists of two parts (TMT-A, TMT-B), each with 25 numbers or letters (Reitan, 1958). The initial test, TMT-A, consists of only numbers. Participants must connect these numbers in sequence (i.e., 1, 2, 3…) as rapidly as possible. Upon completion of this trial, the second test is administered. TMT-B consists of both numbers and letters, which the participant must connect in an alternating pattern (i.e., 1, A, 2, B…) as rapidly as possible. Time-to-complete each section is measured as the dependent variable. By subtracting time-to-complete TMT-A (e.g., 20 seconds) from time-to-complete TMT-B (e.g., 50 seconds), an overall measure of performance (e.g., 30 seconds) is obtained (Tombaugh, 2004).

Participants were shown a sample of TMT-A and then provided a copy, face down. Participants were instructed to connect numbers (i.e., TMT-A) or numbers and letters (i.e., TMT-B) without lifting the pencil from the paper. The administrator timed each trial from start to finish using a stopwatch, hitting 'start' when the participant turned the paper over. Per standard administration, errors were pointed out immediately and participants were allowed to self-correct. The Trail Making Test is sensitive to dementia (Cahn et al., 1995) and is a reliable measure across time. In a sample of older adults, reliability drops after one year (TMT-A, .53-.64; TMT-B, .67-.72) but is still adequate (Strauss, Sherman, & Spreen, 2006).

<u>Stroop Task</u>

The Stroop task was developed in 1935 as an assessment of cognitive interference (Stroop, 1935). It quickly and accurately assesses inhibition and cognitive flexibility (Scarpina & Tagini, 2017). Participants read three lists of words as fast as possible (Scarpina & Tagini, 2017). All lists are made of names of colors (e.g., yellow, green). One is printed in congruent colors (e.g., 'yellow' in yellow ink) and one is printed in incongruent colors (e.g., 'yellow' in red ink; Scarpina & Tagini, 2017). On each trial, participants are asked to say the color of the word instead of reading the word itself. In the congruent condition, this is automatic. In the incongruent condition, participants experience cognitive interference when the color and word do not match.

Participants were provided with a copy of the congruent and incongruent list. They were asked to read the congruent list aloud as quickly as possible, followed by the incongruent list. The administrator timed each trial from start to finish using a stopwatch. Gardner et al. (1959) proposed scoring as a measure of (total time + (total time/100)) x number of errors. Alternatively, speed and accuracy can be used for scoring each independent trial and is an accurate reflection of inhibitory errors (Scarpina & Tagini, 2017). As a result, scoring for the current study was based on both speed and accuracy (errors). Scores provide a measure of cognitive flexibility, inhibition, and processing speed (Scarpina & Tagini, 2017).

Personality and Identity Measures

All personality and identity assessments were administered on paper.

Identity Style Inventory (ISI-5)

The ISI-5 is a brief self-report measure of identity processing styles (subscales: informational, normative, diffuse). Identity processing style refers to decision making styles (Berzonsky, 1994). Information orientation refers to those who are open to self-reflection and actively find and evaluate relevant information. Normative orientation is used to describe those who are primarily influenced by the expectations and standards of family and peers. Diffuse orientation is used to characterize those who procrastinate or avoid making choices and may ultimately remain uncommitted. Participants are asked to use a five-point Likert scale to describe how "like them" each question is ('not at all like me' to 'very much like me'; Berzonsky, Soenens, Luyckx, Smits, Papini, & Goossens, 2013). The ISI-5 is comprised of 36 questions, with a subscale for each identity processing style. There is no time limit for completion of this task.

Scoring is totaled for each subscale (informational, normative, diffuse), with high values indicating greater evidence of these traits (Berzonsky et al., 2013). Reliability varies from .74 to

.86 (informational, M = .79); .75 to .82 (normative, M = .79); and .71 to .89 (diffuse-avoidant, M = .83). Test–retest reliability ranges from .77 to .83.

<u>Big Five Inventory (BFI-S)</u>

The BFI-S (Hahn, Gottschling, & Spinath, 2012) is a shortened version of the 44-item BFI personality inventory. This short assessment is reliable for older adults when completed as a self-assessment with pencil and paper. It was designed to allow efficient measurement of five personality dimensions (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism; Lang, John, Ludtke, Schupp, & Wagner, 2011). In this task, participants were shown 15 statements (e.g., I see myself as someone who is talkative). For each statement, they were asked to rate how much they agree with the statement using a five-point Likert scale (strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree). There was no time limit for completion of this task.

Scoring was totaled for each dimension with high values indicating greater evidence of these traits. Validity evidence includes convergent and divergent agreement with other Big Five inventories as well as with peer ratings (Lang, John, Ludtke, Schupp, & Wagner, 2011; Rammstedt, 2007).

<u>Need For Cognition Scale (NFC)</u>

The NFC (Need For Cognition) scale is a personality style inventory (Cacioppo & Petty, 1982). This assessment was revised for length (Cacioppo, Petty, & Kao, 1984) and quantifies one’s tendency to seek cognitive challenge and engage in intellectually complex activities. In this task, participants were shown 18 statements (e.g., I only think as hard as I have to; I usually end up deliberating about issues even when they do not affect me personally) and asked to rate on a five-point Likert scale how much that statement is characteristic of them. There was no time limit for completion of this task.

Half of the questions are reverse coded. Scoring is the sum of all 18 questions, with high values indicating a greater motivation for seeking intellectual stimulation. This measure has been used with older adults and remains stable across the lifespan with high internal reliability (.89) and test-retest stability (.75; Soubelet & Salthouse, 2017).

Creativity Measures

The following assessments were tasks utilized in the Torrance Tests of Creative Thinking (TTCT). This set of tests is comprised of 17 assessments, sorted into three categories. Categories are organized by two criteria: the type of stimuli provided to the participant and the kind of response required of them (Torrance, Ball, & Safter, 2003). Categories include verbal stimuli requiring verbal responses, non-verbal stimuli requiring verbal responses, and non-verbal stimuli and responses. While indicated as ‘verbal’ responses, participants often write lists of answers rather than delivering them out loud (Torrance, Ball, & Safter, 2003). The TTCT and Guilford’s Structure of Intellect tests have been in use since the 1960’s and are the most common assessments of creativity (Kim, 2006). The TTCT is the most widely used and referenced of the two, having been normed four times since its conception (1974, 1984, 1990, 1998; Kim, 2006). As such, information on norms and validity are readily available. The TTCT demonstrates convergent validity with measures of creative achievement and giftedness, as well as with teacher, peer, and self-ratings (Kim, 2006). All creativity assessments were administered on paper.

<u>Alternative Uses Task – verbal response using verbal stimuli</u>

This task was adapted from the Guilford Brick uses task (Guilford, 1959). The Guilford task provided only one item for consideration, a brick. The TTCT adapted this task to be used across the lifespan. In the adapted task, the administrator can select from a short list of items. For instance, Torrance hypothesized that children might be more adept at giving uses for a cardboard box than they would a brick. Other items include a tin can and a rope.

Participants were given one item per trial and asked to think of as many possible uses for it as they could. Participants were instructed to write responses down, be creative, and continue trying even after ideas become infrequent (Baer, 2017). Traditional testing takes place for three minutes (Nusbaum & Silvia, 2011). In the current study, administration time was expanded to five minutes to accommodate processing speed changes in older adults. Scoring is described in the following section.

Product Improvement Task - verbal response using non-verbal stimuli

This task was adapted from the Guilford Apparatus test (Guilford, 1959). The Guilford task focused only on children, and thus provided them with toys. Torrance adapted this task to be used across the lifespan. In the adapted task, the administrator can select from a short list of items (e.g., telephone, remote control).

Participants were given one item per trial and asked to think of as many possible improvements for the item as they can, so that the item would be more fun for a child to play with. Participants are instructed to write responses down, be creative, and continue trying even after ideas become infrequent (Baer, 2017). They are instructed not to consider the cost of the improvement, whether it is possible to implement the improvements they are suggesting, and only to brainstorm ideas (Carroll, 1993). Traditional testing takes place for three minutes (Nusbaum & Silvia, 2011). In the current study, administration time was expanded to five minutes to accommodate processing speed changes in older adults. Scoring is described in the following section.

Incomplete Figures Task - non-verbal response using non-verbal stimuli

This task was adapted from the Drawing Completion Task (Barron, 1958). The stimulus consists of a white piece of paper with six subsquares. Each subsquare has a different stimulus (e.g., a series of lines, circles, or other shapes). Participants are asked to sketch a novel object or design around the provided stimulus (see Appendix C). Participants are instructed to sketch as much as they want and to be creative (Torrance, 2000). Traditional testing takes place for five minutes (Nusbaum & Silvia, 2011). In the current study, administration time was expanded to eight minutes to accommodate processing speed changes in older adults. Scoring is described in the following section.

Scoring of Creativity Measures

Scoring on the TTCT varies from task to task. When assessing creativity, some scoring techniques are subjective and require a great deal of inter-rater training to reach reliability (Bart, Hokanson, & Can, 2017). Even with agreement among raters, reliability on some tasks may vary. As such, the measures selected for the current study demonstrate the most quantifiable scoring (Bart, Hokanson, & Can, 2017).

The Alternative Uses and Product Improvement tasks are scored on three dimensions: fluency (total number of responses), flexibility (distinct response categories), and originality (uniqueness scoring using a novelty formula; Torrance, Ball, & Safter, 2003). See Appendix D for rubric (Yamamoto, 1964). For example, a participant is asked to provide as many responses as possible for how they could use a brick. Fluency is described as a raw number of acceptable responses. Flexibility is assessed by the number of categories (e.g., all responses using the brick to build count in one category, all responses using the brick as a weapon count in a different category). Finally, scoring for originality compares each response to the total responses from all participants. Answers provided by 10% or less of the group are unusual (1 point), whereas responses provided by 5% or less of the group are rare (two points; Zeng, Proctor, & Salvendy, 2011). The Incomplete Figures Task is scored on vividness (detail, the depiction of motion) originality (uniqueness scoring) and transformativeness (multiplying an element of the image, distorting proportions; Jankowska & Karwowski, 2015). All creativity assessments were administered on paper.

A panel of three peer experts were recruited to score the creativity measures. This panel was composed of three retired older adult artists. The panelists all identified as artists (bead work, paint, sketch), with each earning money in exchange for sale of their art. Panelists were recruited via word of mouth and had previous experience judging art competitions and jurying for art shows. Panelists were compensated with a paid lunch of their choice from a local restaurant. Lunch was delivered to the panel at their meeting location, a panelist's house. The panel convened after all participants had been tested. The administrator explained the general purpose of each creative task and the criteria for scoring. The panel then discussed characteristics of interest in each creative measure and scored practice data individually. Panelists compared scores and discussed criteria again. Panelists were retrained until interrater reliability was reached (.9). The panel spent one day scoring all creative measures, formally breaking once for lunch.

Analyses

Hypothesis one examined whether executive function performance at morning testing (synchronous) trials exhibited lower latency and error rates than evening testing (non-synchronous) trials. A repeated measures ANOVA was used to explore this hypothesis. Hypothesis two examined whether creative potential performance as assessed with fluency, flexibility, and originality scores differed from morning testing (synchronous) trials to evening testing (non-synchronous) trials. A repeated measures MANOVA was used to explore this hypothesis. Finally, hypothesis three used a multiple regression analysis to predict creative potential scores from Need For Cognition (NFC) scores and Information-Orientation ISI subscale scores.

CHAPTER 4

RESULTS

Multiple statistical analyses were utilized to assess group differences between morning and evening performance. The current study examined how measures of executive function, personality, identity, and creativity relate to one another, and how time of day relates to creative and inhibitory performance. A brief overview of the assumptions of within-subjects ANOVA and multiple regression will be outlined. Descriptive data as well as all analyses will be presented.

Preliminary Analyses

Univariate z-scores, box plots, and Mahalanobis distances were examined to detect outliers. One participant was removed for extreme z-scores, they scored high on several measures. Remaining data met the assumption of normality. Skewness and kurtosis were evaluated for all dependent variables, which met the assumption of homogeneity of variance.

Primary Analyses

Hypothesis 1: Morning testing (synchronous) trials of inhibitory tasks will exhibit lower latency and error rates than evening testing (non-synchronous) trials. A repeated measures ANOVA with one within-subjects factor was conducted to test the effect of time of testing (morning, evening) on executive function task performance (Stroop, Trail Making Test). There was no need to examine Mauchly's test for sphericity, as there are only two levels of the factor; therefore the hypothesis test was evaluated without adjustment. Time of day did not significantly impact performance on the Trail Making Test, $F(1, 37) = 2.76$, $p = .10$, or performance on the Stroop task $F(1, 37) = .07$, $p = .80$. See Table 1 for ANOVA table.

Hypothesis 2: Morning testing (synchronous) trials of creative potential tasks will exhibit lower fluency, flexibility, and originality scores than evening testing (non-synchronous) trials. A repeated measures MANOVA with one within-subjects factor was conducted to test the effect of time of testing (morning, evening) on creative potential performance (fluency, flexibility, originality). The result showed no difference between morning and evening testing on creative fluency, flexibility, or originality $F(3, 34) = 1.01$, $p = .11$, $\eta^2 = .08$. Univariate tests also indicated no time of day effect on a participant's fluency performance, $F(1, 36) = .88$, $p = .35$, $\eta^2 = .02$, flexibility performance $F(1, 36) = 2.63$, $p = .11$, $\eta^2 = .07$, or originality performance $F(1, 36) = .52$, $p = .48$ $\eta^2 = .01$. See Table 1 for MANOVA table.

Hypothesis 3: Need For Cognition (NFC) scores and Information-Orientation ISI subscale scores will be positively correlated with overall (AM + PM) creativity scores (fluency, flexibility, originality). Tests to see if the data met the assumption of multicollinearity indicated that the variables did demonstrate significant multicollinearity (Fluency and Originality $r = .94$; Fluency, Tolerance = .09, VIF = 11.20; Flexibility, Tolerance = .61, VIF = 1.66; Originality, Tolerance = .09, VIF = 10.52). Furthermore, during assumption testing the predictor variable of Information-Orientation score was not correlated with the dependent variables at a level above .3, see Table 4 for correlation table. As a result, multiple regression analysis was not a good fit for this data.

A Pearson correlation was conducted to explore the relationship among Need for Cognition scores, Information-Orientation ISI subscale scores, and performance on creative potential tasks (fluency, flexibility, originality). Scatterplots indicate the data met assumptions for homoscedasticity and linearity. Data met the Shapiro-Wilk test of normality. Need for cognition scores demonstrate a significant positive high correlation with all three scores of creative potential including fluency, $r(37) = .43$, $p = .01$, flexibility, $r(37) = .34$, $p = .04$, and originality $r(37) = .43$, $p = .01$. Information-orientation score was not significantly correlated with fluency, $r(37) = .11$, $p = .53$, flexibility, $r(37) = .08$, $p = .62$, and originality $r(37) = .17$, $p = .32$. See Table 5 for full Pearson correlation results.

CHAPTER 5

DISCUSSION

The current study aimed to determine if there are synchrony effects on within-person performance on inhibition and creative potential tasks. The research was conducted with a sample of older adults who met criteria for a trajectory of successful aging. Older adults display a great deal of developmental heterogeneity (Mitnitski, Howlett, & Rockwood, 2017; Sun & Sun, 2019). Given this, a repeated-measures design was utilized to minimize between-subjects error. The current study also assessed lifestyle, personality, and identity variables to validate representativeness of the sample.

The sample of older adults in the current study did not demonstrate synchrony effects on expected tasks. This may indicate that a sample of older adults demonstrating a successfully-aging trajectory of aging may not be impacted by synchrony effects. That is, time of day may be an insufficient manipulation to influence performance on executive function and creative potential tasks in this sample. This may indicate that successfully aging older adults are able to compensate for a testing time manipulation via the use of strategy or cognitive reserve. The following section will interpret this effect using lifespan development models.

Some aspects of the current study were novel while others replicated previous work. Novel combinations included the relationship between need for cognition and creativity in a sample of older adults, examining synchrony effects on executive function in a successfully aging sample, using a repeated-measures design, and manipulating testing time with measures of inhibition and creativity. This is also the first study to examine creative potential performance using experimental methods in a sample of successfully aging older adults. Findings, implications, and limitations of the current study will be discussed in the following sections.

Findings and Implications

Hypotheses one and two predicted within-person differences of performance on measures of inhibition, executive function, and creative potential. Participants were expected to demonstrate time of day effects on Stroop and TMT performance. Stroop and TMT assess inhibition, which was expected to have greater latency in the afternoon relative to morning. As demonstrated in the cognitive aging literature, reduced executive function performance was expected at off-peak times of day (e.g., 4pm-7pm), relative to on-peak times of day (e.g., 8am-11am; English & Carstensen, 2015; May et al., 1993; May et al., 2005; Schmidt, Peigneux, & Cajochen, 2012).

Consistent with the necessary condition hypothesis, creative potential performance was expected to fluctuate with executive function and inhibition levels (Baas, Roskes, Sligte, Nijstad, & DeDreu, 2013; Nijstad, DeDreu, Rietzschel, & Baas, 2010). As such, it was predicted participants would score higher on measures of creative potential when inhibitory performance was less efficient. Older adults demonstrate time of day effects, with evening testing demonstrating poor inhibitory skills (English & Carstensen, 2015; May et al., 1993; May et al., 2005; Schmidt, Peigneux, & Cajochen, 2012). Therefore, higher creative potential scores were predicted at off-peak times of day.

Synchrony effects were not observed in this study. A repeated measures ANOVA showed no significant difference in performance on executive function measures between morning and late afternoon testing. These findings suggest that performance remains constant from morning until late afternoon, which does not support hypothesis one which predicted that morning testing trials of inhibitory tasks would exhibit lower latency and error rates than evening testing trials. This is inconsistent with previous synchrony literature, which found that older adults demonstrate a decline in performance on cognitive tasks as the day progresses (English & Carstensen, 2015; May et al., 1993; May et al., 2005; Schmidt, Peigneux, & Cajochen, 2012).

Similarly, a repeated measures MANOVA showed no significant difference in creative potential performance between morning and late afternoon testing. Results from this analysis suggest that participants performed similarly from morning to late afternoon on measures of creative potential including fluency, flexibility, and originality. This does not support hypothesis two which predicted morning testing trials of creative potential tasks would exhibit lower fluency, flexibility, and originality scores than evening testing trials. It is difficult to interpret the implications of this second finding without significant results for hypothesis one. Creative performance could be compared against inhibitory performance if one of these variables demonstrated time of day effects. As neither showed significant synchrony effects, no dissociation is possible. These findings may be consistent with the threshold hypothesis of creativity, which suggests that creative potential does not rely on underlying cognitive mechanisms such as inhibition (Benedek et al., 2014).

In the current study, no synchrony effects were found. Synchrony effects were examined on inhibitory and creative potential performance within-subjects across time of day. Testing time impacts cognitive performance, including measures of inhibition and executive function (Hasher, Zachs & May, 1999; Park & Schwartz, 2000; Yoon, May & Hasher, 1999). Young and middle-aged adults exhibit time of day effects in performance (English & Carstensen, 2015; May, Hasher, & Foong, 2005; Schmidt, Peigneux, & Cajochen, 2012). Older adults are most sensitive to synchrony effects and should demonstrate the greatest difference in performance across time of day (Hasher, Zachs, & May, 1999). Only 'moderate to definitely' morning type older adults were included in this study, consistent with previous work on morningness and aging (Biss &

Hasher, 2012; May & Hasher, 1998; May, Zacks, Hasher, & Multhaup, 1999; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). A sample of evening type older adults may allow for greater insight into this synchrony effect. Less than 2% of the older adult population identify as 'moderate to definitely' evening type (May & Hasher, 1998), which presents a considerable recruitment challenge. Additionally, interpretation of this data would not generalize to most of the older adult population.

The lack of synchrony effects observed in the current study may have been influenced by scheduling. The mode (46%) for morning testing session was 10am, the opening time at local libraries. Many participants were tested at these locations, preventing earlier start times for morning testing sessions. The mode (63%) for afternoon testing was 4pm. Anecdotally, many older adults were unwilling to schedule testing later than 4pm. Participants often drove to meet at the testing location and selected hours they were willing to travel (e.g., don't want to drive during rush hour, or after dark). Some participants noted that they were tired after dinner or in the evenings, so they requested earlier evening appointments. It may be that self-selection bias influenced this testing time, in that participants chose a time that would utilize the least amount of cognitive effort. They may have anticipated poorer performance if tested later in the evening.

Inclusion criteria may have influenced scheduling availability. Utilizing a repeated measures design provides methodological advantages, but is more demanding on participants (Leary, 2004). Successfully aging adults are often very active even in retirement. To this point, selection criteria for the current study mandated that participants engage in regular social activities every month. While a successfully aging sample has better mobility and cognition, they may also have more family, community, and social commitments (Reichstadt, Depp, Palinkas, & Jeste, 2007). As a result, schedules are restricted and they may be more selective with participation time.

Results may also reflect the unique sample used in the current study. Participants were required to exhibit a ‘successfully aging’ trajectory for inclusion (Rowe & Kahn, 1997). Most developmental aging research is done with pathologically or usually aging adults (Rowe & Kahn, 1987). A search of ‘testing time’ or ‘synchrony’ and ‘successfully aging’ returned no results. It could be that the current study offers a novel contribution to the research field in that it examines a documented phenomenon (e.g., synchrony) in usually aging adults and applies that paradigm to a successfully aging sample. These findings may suggest that a successfully-aging cohort is not impacted by synchrony effects. No previous research has used synchrony to compare aging trajectories (pathological, usual, successful) on cognitive performance.

It is feasible that a successfully aging population would have significant cognitive reserve, brain reserve, or scaffolding strategies to compensate for the additional cognitive challenge of non-optimal testing time (Düzel, Schütze, Yonelinas, & Heinze, 2011; Reuter-Lorenz & Park, 2014). Indeed, a marker of successful aging is to compensate well with age-related changes and demonstrate minimal- to no- deficits in performance (Rowe & Kahn, 1997). Inclusion criteria of the current study required that participants demonstrate well managed self-reported disease or disability, score at or above the 50^{th} percentile on executive function measures, and report participation in four or more social events within the last month. Thus, this sample may be capable of compensating with cognitive challenges such as those induced by testing time effects. It may be that synchrony changes in cognitive performance are not demonstrated in a successfully aging population. Future studies may attempt to verify this by including a comparison group of usual- or pathologically- aging older adults.

It is possible that a successfully aging population would use strategy to overcome performance limitations posed by testing time. Results of the current study can be interpreted through the Selective Optimization with Compensation (SOC) model (Baltes & Baltes, 1990). This model posits that successful development is an ongoing practice of maximizing gains and minimizing losses (Baltes & Baltes, 1990). As such, the results of the current study would not be viewed as a limitation but rather as a reflection of hallmark performance within a successfully aging sample of older adults. In order to maximize gains and minimize losses, participants may have opted into the study only if they felt it was within their abilities (*selection*). Participants were allowed to select their testing time within the given window of options (AM = 8am-11am; PM = 4pm-7pm). As such, participants could choose the testing time they believed would minimize performance deficits (e.g., earlier in the PM window) (*optimization).* Participants may have modified their behavior (e.g., take a nap, eat a snack) or used aids (e.g., caffeine) to maximize their performance. These strategies would help participants adapt to the demands of the task and compensate for the manipulation of testing time.

Sampling may also have impacted the results of the current study. For instance, the sample used in the current study was not racially diverse and was primarily (>85%) female. It is possible these trait variables are importantly linked to synchrony or cognitive performance. As such, effects may not have been detectable using this paradigm with ethnically homogenous and primarily female participants. Older adults are highly heterogeneous, which makes predicting performance challenging (Mitnitski, Howlett, & Rockwood, 2017; Sun & Sun, 2019). Perhaps these results should not be a surprise, and rather should be viewed as a reflection of the wide variety of differences in performance in an older adult population.

Hypothesis three predicted relationships between personality and identity measures and creative potential performance. Consistent with the necessary condition hypothesis, creative potential performance was expected to be related to personality and identity factors levels (Karwowski, 2016). High scores on Need for Cognition and the Information orientation subscale of the ISI were hypothesized to predict higher scores on creative potential tasks. The Pearson correlation showed a significant relationship between creative potential and Need for Cognition scores, but not between creative potential and scores on the Information orientation subscale of the ISI. This partially supports hypothesis three.

Many studies that explore identity do so in the young adult stage of development. This may be the developmental stage when identity is most predictive. Few studies have examined identity in older adults, so these findings may be typical for this developmental group (Sneed & Whitbourne, 2001; Sneed & Whitbourne, 2003). The Identity Style Inventory attempts to describe personal view of self and how information is incorporated into decision making (Berzonsky, 1994; Berzonsky & Sullivan, 1992). While this is the most prolific measure of identity, it is rarely used in an aging population (Fadjukoff & Kroger, 2016). Studies that examine identity in older adults are often qualitative in nature (Fadjukoff & Kroger, 2016).

Creative potential may not be the form of creativity that is strongly associated with identity. The current study included measures of creative potential, which assess instantaneous creative performance. A wider variety of creative measures (e.g., creative performance, creative interests) would allow for greater comparison and contrast between identity measures and creative scores. It may be that only creative performance (e.g., being in a magazine) or creative interests (e.g., a love of music) would align with identity but not creative potential performance (Karwowski, 2016; Karwowski & Kaufman, 2017).

Findings of the current study can be applied to clinical or education applications, personal use, and future research. This study contributes empirical evidence to the field of creativity and inhibition and may provide a basis for future research in successfully aging populations. Successfully aging older adults are capable of compensating with age-related changes (Düzel et al., 2011; Reuter-Lorenz & Park, 2014). The current study provides evidence that older adults may also compensate for time of day differences in performance. Identifying lifestyle factors that relate to engagement may motivate future research on aging trajectories and serve as a basis for intervention work in at-risk populations of older adults (Rowe & Kahn, 1987). Lastly, it is unclear what lifespan and arousal factors may impact creative potential. Very little creativity research is done quantitatively and rarely focuses on an aging population, much less a successfully aging one. This study may suggest that a successfully aging trajectory buffers age-related changes in a variety of domains, including creativity.

Limitations

Overall, results from the current study are unexpected but can be supported by models in the literature. The previous section highlighted issues with sampling, scheduling, and assessment. This section will discuss limitations regarding methodology, design, and operationalization. Repeated measures design allows for reduced interindividual error, an important consideration for a highly heterogeneous population like older adults (Leary, 2004; Mitnitski, Howlett, & Rockwood, 2017; Sun & Sun, 2019). However, this methodology may have influenced recruitment and contributed to bias.

Testing time and synchrony have been explored in cognitive aging research, but are not well-defined variables (Hasher, Zachs, & May, 1999; Park & Schwartz, 2000; Yoon, May, & Hasher, 1999). This may have reduced the power of the current study to detect time of day differences in performance. Finally, creativity is a vast construct and is primarily analyzed with qualitative methods (Bailey, White, & Pain, 1999). This presented unique challenges in measuring and defining creativity. This section will discuss the limitations in understanding and applying the results of the current study, as well as provide a foundation for constructing follow-up studies.

This study exhibits limitations due to the nature of the experimental design, including demand characteristics, self-selection bias, and a lack of experimental control. The use of a repeated measures design was beneficial for reducing interindividual error, but it placed increased demands on participants. Only select participants are willing to participate in psychological research, and even fewer are willing to commit to two hour-long sessions. The design of the current study demanded time, resources, and attention. Participants may have had to rearrange daily schedules when assigned to a testing condition (AM or PM). Length of assessments and measures had to be considered to account for session duration. A repeated measures design also introduces greater possibility of demand characteristics (Leary, 2004).

The current study took steps to minimize demand characteristics, including concealing the condition (e.g., time of day was not discussed as a condition) and not discussing expectations about performance or time of day effects with participants. However, the study was not blind and participants were informed in advance that two testing sessions were required. The time of day manipulation was obvious to participants, as recruitment notified them that scheduling was required in both the morning and the late afternoon.

Older adults exhibit demand characteristics and are highly motivated to outperform expectations, particularly on cognitive tasks (Green, 1981). A successfully aging sample often embody the ‘good participant’ role, wishing to overcome any expectancy effects or stereotypes about aging. Having a single experimenter may have increased demand characteristics (Leary, 2004), as this person was responsible for recruitment and met with participants at both testing sessions. This interpersonal contact may increase both participant and experimenter expectancy effects. These factors make it challenging to interpret any directional relationships between variables.

Only older adults who met criteria for a successfully aging trajectory were recruited in the current study. Criteria for disease and disability in the current study was rated on a continuum (Whitley, Popham, & Benzeval, 2016). Participants with less than two diagnoses were included, given those conditions were well-managed. Perhaps on a continuum these participants were on the lower end of successfully aging. For instance, many diseases (e.g., high blood pressure, high cholesterol) are markers associated with inflammation which may predict cognitive risk factors (Yaffe et al., 2004).

Statistical comparison may have been improved with a reduced range of age-since-retirement. Participants were primarily retired (84%). The current study had age-related inclusion criteria (i.e., age 70-79), but several artists reported still working. Of those who were retired, some remain active in producing and selling their work (e.g., painting, crafts, sewing, photography). Due to snowball sampling, several older artists asked to participate or share experiences. One person wanted to participate who was 89 and still creating daily.

Creativity research is primarily conducted in school-age populations and is often done with qualitative methods (Torrance, 1987). There were several challenges in translating this work to an older adult population. The TTCT is a well-documented measure of creativity and provides robust norms and clear scoring procedures (Torrance, 1987). A panel of peer experts scored the measure using a rubric and achieved interrater reliability (.9). Despite these considerations, error or bias may have been introduced during scoring. It may be that a different measure of creative potential or a different measure of creativity (e.g., creative performance, creative interests) would have related to the variables and constructs assessed in the current study. Finally, the TTCT is primarily used to assess individual creativity: for example, in students who are being tested to meet the Gifted Program requirements (Torrance, 1987). As such, using the TTCT for group comparisons is relatively novel and may not have translated well. Despite these challenges, the current study provides insight into creative potential in older adults and shows how it is distributed in a successfully aging sample.

Future Directions

The current study may motivate intriguing questions about successful aging, inhibition, creativity, and time of day. Limitations in the current study can be addressed to expand the research about these constructs. For instance, the size of the sample and overlap between variables restricted the ability to make predictions. Larger sample sizes would allow for greater use of inferential statistics. Additionally, the methodology did not allow for causal effects between the variables of interest.

It is yet unclear what attitudes, behaviors, or genes may contribute to successful aging, versus which are expressed in older years as a result of someone living to that age. For instance, high social interaction is associated with successful aging. However, conclusions cannot be drawn about whether social interaction somehow encourages healthy aging, or if those who age without significant disease and disability are more mobile and cognitively able as a result of fewer limitations. Furthermore, the relationship between successful aging and synchrony is left unclear. It may be that individuals with initial compensatory abilities are capable of aging well, or the above variables combine in some additive way to support successful aging. Questions of causality are left unanswered by the current study, providing many possibilities to future researchers wishing to expand on this work.

Future studies can ameliorate these issues by using longitudinal designs and interventions. For instance, understanding a causal relationship between creativity and successful aging would require longitudinal research. Future work may answer these questions more definitively. Usually aging older adults are less susceptible to synchrony effects than a pathologically aging population (Hasher, Goldstein & May, 2005; Li, Hasher, Jonas, Rahhal, & May, 1998; Yoon, May, & Hasher, 1999). Perhaps a trend can be inferred here, suggesting that successfully aging older adults are less susceptible to synchrony effects than a usually aging population. If this is true, a successfully aging population would require a significantly more powerful time of day manipulation to induce synchrony effects than their typically-aging counterparts. This information would be vital to understand before conducting synchrony research on this population in the future.

Previous synchrony literature does not explicitly operationalize the hours between testing sessions, instead providing only testing windows (i.e., 8am-12pm; May et al., 1993; May & Hasher, 1998; Yoon, May, & Hasher, 1999). The relatively short period between testing sessions in the current study (AM Mode= 10am, PM Mode = 4pm) may not have been significantly powerful to capture synchrony differences in performance. It is possible that an 8, 10, or 12-hour window would have produced significant effects to dissociate time of day and performance. This is an investigation for future studies, to better delineate the window of time necessary for time of day performance differences. This could be done using a between-group design where participants are randomly assigned to testing windows. Unfortunately, the parameters of the current study did not allow for required participation times to be designated.

It is also possible that a six-hour window is sufficient to show time of day performance differences but that this window would need to be skewed to earlier or later in the day (e.g., 8am-

2pm; 12pm-6pm). These possibilities hold intriguing and important implications for future time of day research in an aging population. This highlights the need for clearly defining and communicating an operational definition of morning and afternoon testing moving forward, so that future research can more precisely design studies that can be compared to one another.

In the current study, time of day was not sufficiently powerful to influence either inhibition performance or creative potential performance. This may suggest there is an underlying relationship between the two, or they may be unrelated. As such, no firm conclusions can be drawn about the impact of time of day on inhibition, time of day on creativity, and thus no relationship between inhibition and creativity. Future studies should do repeated validity checks to confirm that testing time is sufficiently powerful to influence inhibitory performance, thus allowing conclusions to be drawn about any relationship between inhibition and creativity.

Future research is open to many possibilities, questions, and directions. This document outlines a few that are relevant to the constructs examined here, such as creativity, successful aging, and time of day. Given the challenging nature of this research, perhaps a cross-longitudinal design or an intervention approach would be more appropriate to a successfully aging older adult population. Future research should continue to expand the literature on time of day to include traits like creativity. While some research examines creativity as trait, much of it views creative performance as a skill. The use of greater experimental control and more rigorous standards for participants could improve empirical work on the construct of creativity. This could be applied to retirement centers and senior centers to increase creative programs for residents.

Concluding Remarks

Research can always build on itself, just as this study provides a starting point for a new line of inquiry into the relationships between creativity, executive function, and their roles in successful aging. The current study contributes empirical evidence to the field of creativity and inhibition and may provide a basis for future research in successfully aging populations. Identifying lifestyle factors that relate to engagement may clarify future research on aging trajectories and serve as a basis for intervention work in at-risk populations of older adults.

Much of the research in aging attempts to treat pathology associated with old age, such as arthritis, dementia, heart disease, and cancers. A smaller amount of aging research is dedicated to understanding what typical aging looks like and determining influences and markers for typical development and trajectories for the full human lifespan. There is much to be learned from those in the remaining group of agers, those who age well and defy disease, disability, and the expected outcomes associated with aging. These individuals give us insight into the healthiest of humanity and give us hope for our own futures. They exhibit strength, poise, and clarity that many of us strive towards in our older years.

Understanding how these individuals cope with or compensate for age-related challenges may provide insight for each of us to have tools, not only in how to cope with aging but in how to cope with challenges in a healthy and adaptive way. Many of these successful agers attribute health outcomes to creativity and a sense of purpose in life, both of which are loosely understood constructs in the empirical literature. The current study attempted to shine light on this area, better understanding the complex links between traits, behaviors, and aging. This study explored the link between successful aging outcomes and time of day that has not yet been examined in the literature, generating even more research questions about aging and lifespan development.

EXHIBITS

Table 1. Descriptive statistics.

Descriptive Statistics

	N	Mean	Std. Deviation
Age	41	73.5610	5.88663
MEQ-SA	41	18.20	3.084
AMTestTime	39	1002.56	89.552
PMTestTime	39	1614.02	130.121
Valid N (listwise)	39		

Table 2. Repeated Measures ANOVA for hypothesis one.

Tests of Within-Subjects Contrasts

Source	Measure	Time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Stroop	Linear	4.207	1	4.207	.068	.796	.002
	Trails	Linear	1256.980	1	1256.980	2.767	.105	.070
Error(Time)	Stroop	Linear	2292.244	37	61.953			
	Trails	Linear	16810.563	37	454.340			

Table 3. Repeated Measures MANOVA for hypothesis two.

Tests of Within-Subjects Contrasts

Source	Measure	Time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Fluency	Linear	17.514	1	17.514	.882	.354	.024
	Flexibility	Linear	19.514	1	19.514	2.636	.113	.068
	Originality	Linear	21.622	1	21.622	.517	.477	.014
Error(Time)	Fluency	Linear	714.486	36	19.847			
	Flexibility	Linear	266.486	36	7.402			
	Originality	Linear	1506.378	36	41.844			

Table 4. Assumption testing for hypothesis three.

Correlations

		Information Orientation	Fluency	Flexibility	Originality
Pearson Correlation	Information Orientation	1.000	.106	.084	.167
	Fluency	.106	1.000	.629	.944
	Flexibility	.084	.629	1.000	.590
	Originality	.167	.944	.590	1.000
Sig. (1-tailed)	Information Orientation	.	.266	.310	.162
	Fluency	.266	.	.000	.000
	Flexibility	.310	.000	.	.000
	Originality	.162	.000	.000	.

Assumption testing for multicollinearity and predictor/dependent variable correlation on information orientation score and creative potential outcomes (Fluency, flexibility, originality).

Correlations

		Need For Cognition	Fluency	Flexibility	Originality
Pearson Correlation	Need For Cognition	1.000	.434	.341	.433
	Fluency	.434	1.000	.629	.944
	Flexibility	.341	.629	1.000	.590
	Originality	.433	.944	.590	1.000
Sig. (1-tailed)	Need For Cognition	.	.004	.019	.004
	Fluency	.004	.	.000	.000
	Flexibility	.019	.000	.	.000
	Originality	.004	.000	.000	.

Assumption testing for multicollinearity and predictor/dependent variable correlation on Need For Cognition score and creative potential outcomes (Fluency, flexibility, originality).

Table 5. Correlation table for hypothesis three.

Correlations

		Need For Cognition	Information Orientation	Fluency	Flexibility	Originality
Need For Cognition	Pearson Correlation	1	.554**	.434**	.341*	.433**
	Sig. (2-tailed)		.000	.007	.039	.007
	N	39	39	37	37	37
Information Orientation	Pearson Correlation	.554**	1	.106	.084	.167
	Sig. (2-tailed)	.000		.532	.620	.324
	N	39	39	37	37	37
Fluency	Pearson Correlation	.434**	.106	1	.629**	.944**
	Sig. (2-tailed)	.007	.532		.000	.000
	N	37	37	37	37	37
Flexibility	Pearson Correlation	.341*	.084	.629**	1	.590**
	Sig. (2-tailed)	.039	.620	.000		.000
	N	37	37	37	37	37
Originality	Pearson Correlation	.433**	.167	.944**	.590**	1
	Sig. (2-tailed)	.007	.324	.000	.000	
	N	37	37	37	37	37

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

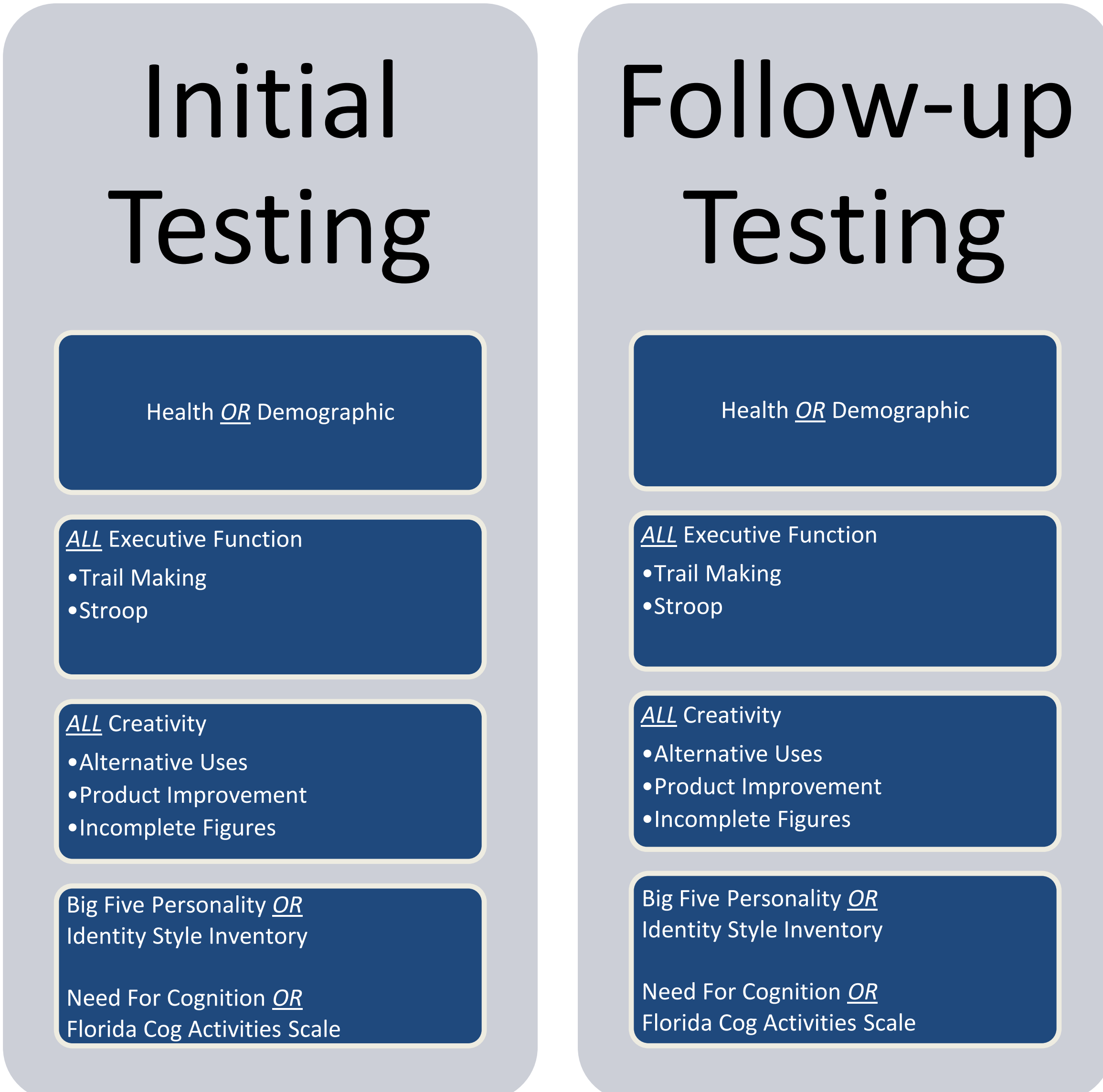

Figure 1: Timeline of research procedure. Morningness/Eveningness is administered over the phone, at which time participants are randomized to condition (initial testing at morning or evening).

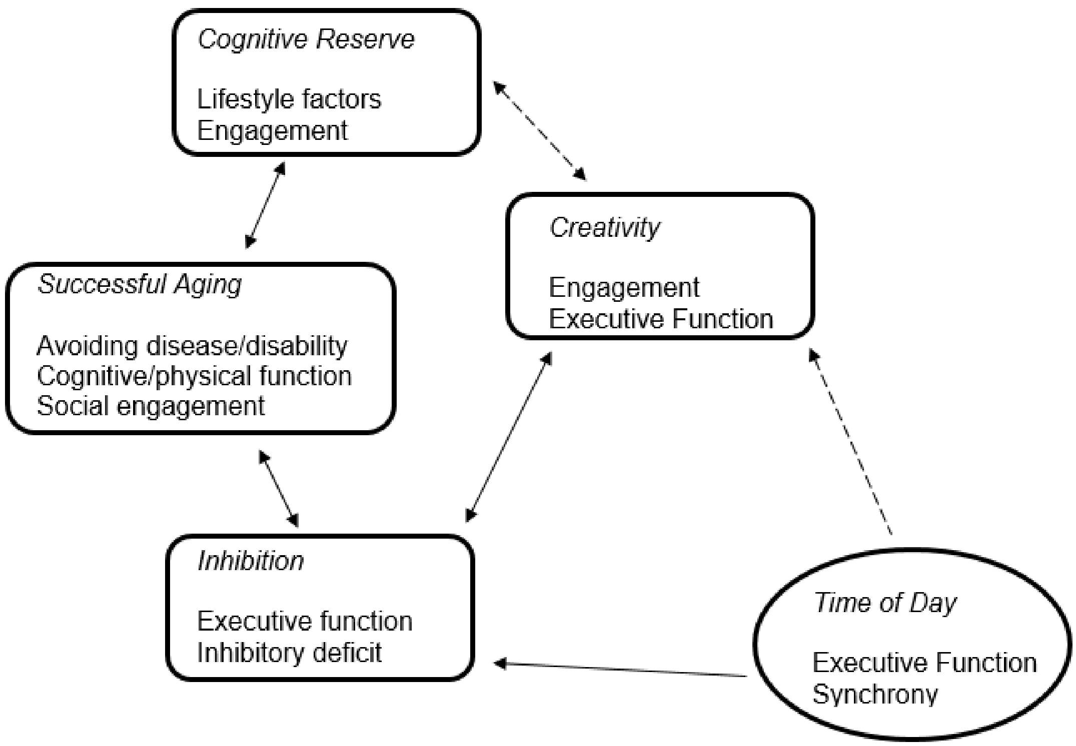

Figure 2: Concept map of primary variables

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APPENDIX A

DEMOGRAPHICS

Are you a woman or a man? Participant #___________

☐ Woman
☐ Man

If female, have you taken hormone replacement therapy?

☐ Yes
☐ No

How do you describe your ethnicity?

☐ Asian
☐ Black/African American
☐ Spanish/Hispanic/Latino
☐ Middle Eastern
☐ White/Caucasian
☐ Other________________

What is your marital status?

☐ Never Married
☐ Married
☐ Divorced
☐ Widowed

What language was spoken in your childhood home?

____

Do you speak more than one language?

☐ Yes → What language(s)? _____________________________

☐ No

What is the highest level of school you have completed?

☐ Some high school
☐ High school degree
☐ Some college
☐ Associates Degree
☐ Bachelor's Degree
☐ Some graduate school
☐ Master's Degree
☐ M.D./Phd

Are you retired?

☐ Yes → What was your profession? ___________________What year did you retire? ______

☐ No

Which of the following categories best describes your employment status?

☐ Employed, working part-time (<30 hours a week)
☐ Employed, working full-time (>30 hours a week)
☐ Disabled/not able to work
☐ Not employed, not looking for work

In an <u>average month</u>, how often do you participate in social events (e.g., family meals or gatherings, visiting with friends, attending events with others)?

☐ Never ☐ 4-5 times
☐ 1-2 times ☐ 6+ times

In an <u>average month</u>, how often do you participate in activities for others (making meals, providing physical help (e.g., doing chores) or transportation, giving them money, or creating gifts or goods for them)?

☐ Never ☐ 4-5 times
☐ 1-2 times ☐ 6+ times

In an <u>average month</u>, how often do you have a drink containing alcohol?

☐ Never ☐ 4-5 times (about once a week)
☐ 1-2 times ☐ 6+ times (multiple times a week)

In an <u>average month</u>, how often do you use recreational drugs (including marijuana)?

☐ Never ☐ 4-5 times (about once a week)
☐ 1-2 times ☐ 6+ times (multiple times a week)

Do you nap regularly

☐ Yes → How many times a week? _____ How long is your average nap? _____
☐ No

Do you exercise regularly?

☐ Yes → How many times a week? How long is your average workout?
☐ No

In general, would you say your physical health is:

☐ Poor
☐ Fair
☐ Good
☐ Very Good

Compared to one year ago, how would you rate your physical health now?

☐ Much worse
☐ Somewhat worse
☐ Same or similar
☐ Somewhat better
☐ Much better

Have you been diagnosed with any of the following medical conditions?

Arthritis
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Cancer
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Breathing conditions (including emphysema, COPD)
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Depression (including Seasonal Affective Disorder)
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Diabetes
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

High Blood Pressure
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

High Cholesterol
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Heart conditions (including heart disease, congestive heart failure)
☐ Yes → Are you on medication? ☐ Yes ☐ No
☐ No

Other major conditions not listed?
☐ Yes → Describe:____
Are you on medication? ☐ Yes ☐ No
☐ No

APPENDIX B

MORNINGNESS EVENINGNESS QUESTIONNAIRE

Instructions:
Please read each question very carefully before answering.
Please answer each question as honestly as possible.
Do NOT go back and check your answers.

Do you work night shift? Yes_____ No_____

1. What time would you get up if you were entirely free to plan your day?

_______ am/pm

2. During the first half-hour after you wake up in the morning, how tired do you feel?

____ Very tired
____ Fairly tired
____ Fairly refreshed
____ Very refreshed

3. At what time of day do you feel you become tired as a result of need for sleep?

____ 8:00 – 9:00 PM
____ 9:00 – 10:15 PM
____ 10:15 PM – 12:45 AM
____ 12:45 – 2:00 AM
____ 2:00 – 3:00 AM

4. At what time of the day do you usually feel the best?

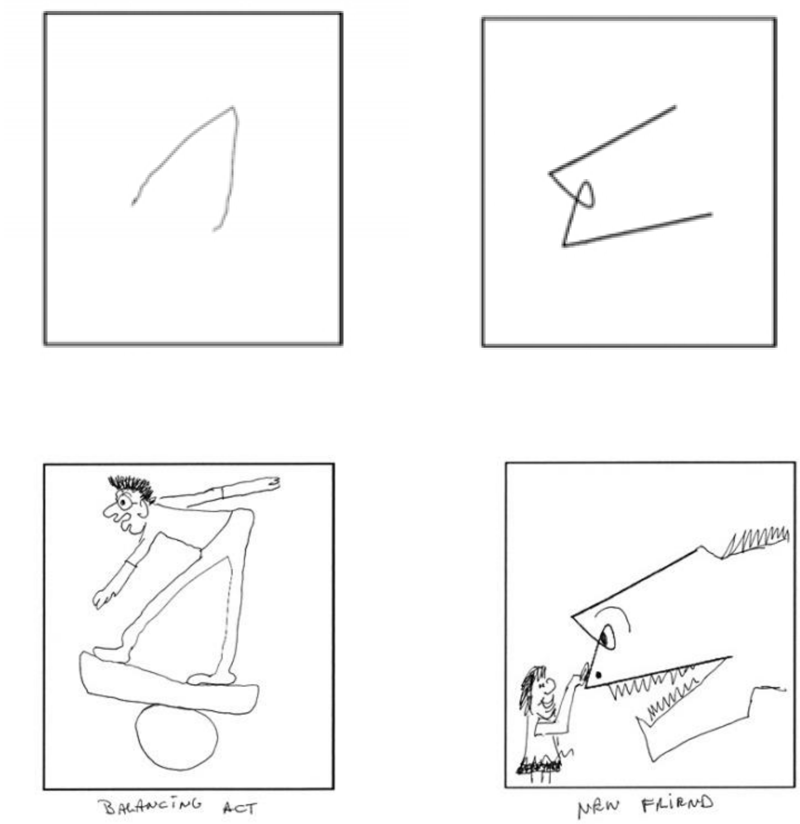
____ 5:00 – 8:00 AM
____ 8:00 – 10:00 AM
____ 10:00 AM – 5:00 PM
____ 5:00 – 10:00 PM
____ 10:00 PM – 5:00 AM

5. You may have heard about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

____ Definitely a "morning" type
_____ Rather more a "morning" than an "evening" type
____ Rather more an "evening" than a "morning" type
____ Definitely an "evening" type

APPENDIX C

INCOMPLETE FIGURES TASK



Incomplete Figures Task; the top images are provided to participants, and the bottom images are sample responses.

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