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The Impact Of Time Of Day, Sleep, And Nutrition On Age-Related Changes In Cognitive Performance

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THE IMPACT OF TIME OF DAY, SLEEP, AND NUTRITION ON AGE-RELATED CHANGES IN COGNITIVE PERFORMANCE

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This thesis, submitted by Jaclyn Reckow in partial fulfillment of the requirements for the Degree of Master of Arts from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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ABSTRACT

The present study examined how sleep, nutritional intake, and time of day moderate age-related cognitive changes. Research indicates there are cognitive changes associated with healthy aging. Many studies comparing young and older adults have tested participants at the same time of day. More recently, research has revealed certain cognitive tasks produce a synchrony effect, in which participants perform better during their preferred time of day. Older adults tend to prefer morning activities while younger adults prefer afternoon or evening. Forty-eight young adults, ages 18-35 (M = 20.7) and 25 older adults, ages 60-84 (M = 71.4) completed the Pittsburgh Sleep Quality Index, the Block 2005 Brief Food Questionnaire, the Repeatable Battery for Assessment of Neuropsychological Status (RBANS), and prose passage recall. Synchrony effects were supported for RBANS List Recognition, Figure Copy, and Figure Recall. No synchrony effect was observed for prose recall. Additionally, sleep indices and nutritional intake did not significantly account for age-related differences in cognitive performance.

CHAPTER I

INTRODUCTION

Research has investigated cognitive decrements in aging individuals by comparing younger and older adults on a variety of cognitive tasks. Older adults have more difficulty in working memory and in retrieving newly learned information. Craik and McDowd (1987) examined age differences in recognition and recall memory. Younger and older participants were visually presented lists of 12 words, and then asked to complete a cued-recall or recognition retrieval task. During the recall and recognition trials, participants performed a secondary reaction time task. The secondary reaction time task visually presented one of four classes of alphanumeric characters and participants pressed a corresponding response key as quickly as possible. Longer latency of reaction times during the retrieval tasks represented more cognitive resources being used in the word retrieval. Craik and McDowd (1987) found a significant interaction between age and test. Older and younger adults had slower reaction times during the recall task compared to the recognition task, and this difference was significantly larger in older adults than younger adults. These results suggested that recall demanded more processing capacity than recognition and that the additional demands on processing capacity during recall were larger for older adults than younger adults.

In addition to word lists memory, age related declines in passage memory have been observed. For example, Dixon et al. (1984) looked at the effects of verbal ability and text structure on age differences in text recall. Participants were young, middle-aged, and older adults. Each age group was divided into low and high verbal ability based on Part I of the Advanced Vocabulary Test from The Kit of Factor Referenced Cognitive Tests. Participants were presented six short texts that were 98 words in length. Texts varied in number of arguments (main points) and in text levels. Text levels were rated for their importance to the main point of the texts. The superordinate proposition levels represented themes within the texts while subordinate levels represent details. Scores on a recall task revealed a three-way interaction between age, verbal ability and propositional level. In low verbal ability adults, younger adults recalled more propositions at all text levels than older adults. In higher verbal ability adults, there was no age difference in recall of superordinate (Level 1) propositions. However, younger adults recalled more at subordinate levels (Levels 2, 3, 4) than older adults. Higher verbal older adults showed age differences at the detail level, while lower verbal older adults showed age decrements at all levels of text (Dixon et al., 1984).

Petros et al. (1989) examined the impact of text characteristics and verbal ability on age differences in prose memory. Petros et al. predicted that verbal ability and passage type would moderate the size of age differences observed. High and low verbal younger and older adults listened to six stories that were 200-220 words in length. Three of the passages were narrative in organization while three were expository. The stories were presented at either a slow, medium, or fast rate and each presentation was followed by an immediate recall. Each story contained units at three levels of importance. Results showed younger adults recalled more than older adults, and high verbal individuals recalled more than low verbal. Narrative passages were recalled more than expository across age and verbal ability. There was a significant interaction between verbal ability, passage type and age; low verbal subjects showed greater age differences on expository passages than narrative passages and the magnitude of this difference was larger for low verbal than high verbal participants (Petros et al., 1989).

One of the cognitive components involved in prose memory is rapid attention and accurate access to long-term memory. One method used to study this process has been to use a confrontational naming task in which participants are shown a picture depicting a single object and asked to name the object.

The Boston Naming Test (BNT) is a confrontational naming task often used in aging research (Moberg, Ferraro, & Petros, 2000). Prior studies had shown that a sharp decline in confrontational naming occurs after age 70, and age-related declines in memory are often attributed to retrieval difficulties (Nicholas et al., 1985). Previous studies have also demonstrated certain stimulus characteristics, such as frequency of occurrence and age of word acquisition can influence naming latency (Lachman, Shaffer, & Hennrikson, 1974). That is, words high in frequency and words acquired early in life are named faster than low frequency and recently acquired words. Moberg, Ferraro & Petros (2000) examined whether the lexical properties of words on the BNT could account for observed age differences. Older and younger adults were presented with words that represented the pictures in the Boston Naming Test. Participants were required to name each word as quickly as possible. Older adults named words slower than younger adults. The relationship between word frequency, number of letters in the word, rated familiarity of the word, the number of syllables in the word and naming latency was computed separately for each participant and represented as a beta weight. Multiple regression results indicated no significant age differences in the beta weights of the predictor variables: log of the word frequency, number of letters in the word, rated familiarity and number of syllables. This result suggests that the impact of these lexical properties of the word was similar in younger and older adults. A second experiment had younger and older adults complete a lexical decision task in which they were presented with the words from the BNT and pseudo-words and asked to decide as quickly as possible whether the stimulus was a word or not by using one of two computer keys. Older adults had longer reaction times than younger adults in this task. Again, there was no interaction between the lexical properties of the words and age. These experiments indicate lexical properties have a similar influence across age and cannot account for age differences found on BNT (Moberg, Ferraro, & Petros, 2000).

A number of theoretical accounts of age-related declines in memory performance have been put forth. For example, Hasher and Zacks (1988) proposed a theory of age-related changes in memory. They argue that inhibitory processes support working memory by limiting the access of irrelevant information into working memory, by deleting information that is no longer relevant from working memory, and by inhibiting prepotent responses (response inhibition). One hypothesis resulting from this theory is that the efficiency of inhibitory processes declines with age. A number of studies have documented the decline in working memory processes with age for access (Connelly, Hasher, & Zacks, 1991), deletion (Hamm & Hasher, 1992) and response inhibition (Kramer et al., 1994).

For example, Connelly, Hasher, and Zacks (1991) examined inhibitory mechanisms in aging and verbal ability level. Connelly, Hasher, & Zacks had younger and older adults read aloud short passages and answer questions of comprehension. In the experimental condition, the passages contained distracter material between words (e.g., "*The car ride* river *was getting bumpy* jeep *now that…"*), and the control condition had no distracters. Participants were instructed to ignore all distracting material. After the final story, the participants were given a free recall test of the distracter words. Reading times and distraction word recall were used as measures of how well the irrelevant stimuli were inhibited. Participants were also given the Vocabulary subtest of the Wechsler Adult Intelligence Scale- Revised (WAIS-R), a measure of verbal ability. Results showed older adults had slower reading times than younger adults for both conditions: distracting material and no distracting material. Younger and older adults had slower reading times during the distracter condition than the no distracter condition, but older adults had a larger discrepancy between the conditions than younger adults. The interaction between age and distractor condition on reading time indicates that distracter presence has a greater impact on older adults than younger adults. When verbal ability was co-varied with reading times, older adults with lower verbal ability were more vulnerable to the distraction effect than older adults with a higher verbal ability and younger adults. In a second experiment, Connelly, Hasher, and Zacks (1991) examined the impact of semantic content of the distraction material. Participants followed the same procedure as the first experiment, but with three experimental conditions: text-related, text-unrelated, and meaningless. In the text-related condition, the distracters were semantically related to the passage. The text-unrelated condition had distraction material unrelated to the passage. The meaningless condition had strings of *x*s that were matched for word length to the other experimental conditions. Younger and older adults had slower reading time when the distraction had meaning (text-related and text-unrelated) than when the distraction was meaningless (*x* strings). However, older adults' reading was more disrupted by text-related material than text-unrelated material, an effect not found in younger adults. Higher verbal ability in older adults attenuated the disruption of distracter material.

Another theory for age differences in memory is slowing in processing speed (Salthouse, 1996). That is, age-related declines are mediated by the slowing of cognitive processing which limits the amount of information that can be maintained or processed in working memory. Studies have revealed that slowed processing in older adults accounts for age differences in many cognitive tasks, and that slowed processing speed accounts for greater variability in age differences than other proposed variables, such as working memory capacity (Zacks, Hasher, & Li, 2000).

Limited cognitive resources is another explanation of age differences in memory. The limited cognitive resource account proposes that older adults have deficits in processing capacity that can include attention or working memory (Zacks, Hasher, Li, 2000). Age-related decline in memory have been found in tasks requiring high demands on working memory (Hamm & Hasher, 1992). Hamm & Hasher (1992) examined the impact of age on inference recall. In an inference task, participants are instructed to infer a correct interpretation of a short passage. Making inferences has a high demand on working memory by requiring maintenance of current material, retrieval of relevant information from the passage, and use of general knowledge. Hamm and Hasher had younger and older adults read passages, each implying an inference that was expected or unexpected. Expected inferences had semantic support throughout the passage. Unexpected inferences had initial support of a competing inference, but later information in the passage supported the correct, unexpected inference. Results indicated that older adults were more likely to support competing inferences than younger adults. Data revealed that older adults held more possible interpretations throughout the passage and failed to narrow down the possibilities. Maintaining multiple interpretations holds higher demands on working memory, resulting in age-related decline in memory.

The above research suggests that verbal ability will moderate age-related declines in cognitive performance such that high verbal individuals will show less cognitive decline than low verbal individuals. The time of day in which individuals are tested has also been proposed as a possible moderator of age-related declines in cognitive performance (May, Hasher, & Stoltzfus, 1993).

Research that involved younger adults has documented cognitive changes in individuals throughout the day (Petros, Beckwith, & Anderson, 1990). The effect of time of day on cognition is attributed to level of arousal. Arousal, typically indexed by body temperature, is relatively lower upon awakening, and increases throughout the day, reaching its peak in the early evening (Folkard, 1982). Morning-type people are more aroused in the morning and slowly decrease throughout the day, and evening-type people slowly increase in arousal throughout the day. The arousal explanation of the impact of TOD on cognition was further supported by the work of Horne and Ostberg (1976). Horne and Ostberg (1976) created a questionnaire to classify people along a morningness-eveningness dimension in circadian rhythms. The questionnaire’s scores range from 16 to 86; higher scores indicate a greater degree of morningness, and a lower score indicates a greater degree of eveningness. Horne and Ostberg (1976) found that

45% of adults were moderate to extreme evening types or moderate to extreme morning types (scores 41 and below, 59 and above, respectively). Evening types wake with a lower body temperature than morning types. The evening types' level of arousal gradually increases throughout the day. Morning types' level of arousal rises more quickly and reaches their peak 68 minutes before evening types.

Petros, Beckwith, and Anderson (1990) investigated the effect of time of day on prose recall in individuals who indicated that the morning was their optimal time of day (morning-type) and individuals who indicated that the afternoon or evening was their optimal time of day (evening-types). Previous research had shown a levels effect for prose memory; participants favor main ideas in their recall compared to the nonessential details. Memory for prose depends upon the effective operation of working memory, which had previously thought to decrease across time of day (Folkard & Monk, 1979). Petros, Beckwith, and Anderson (1990) predicted the time of day effects on prose memory would depend on whether the participant was a morning- or evening-type. Subjects completed the Horne & Ostberg Morningness-Eveningness Questionnaire and listened to four stories that were 270-315 words in length. Immediately after listening to each story, participants were asked to recall each story in as much detail as possible. Stories were either easy (5^{th}-6^{th} grade reading level) or difficult (9^{th}-10^{th} grade reading level) in readability and contained recall units of three levels of importance. Petros, Beckwith, and Anderson (1990) found the effect of time of day on prose memory was influenced by individual preference for time of day. Morning-type individuals recalled more at 9 a.m. than at both 2 p.m. and 8 p.m. Evening-type people did not show significant difference in recall across time of day. (However, average recall numerically increased across time of day.) Results also showed evening-type subjects recalled more than morning-type on all levels of unit importance except low importance in high difficult readability (Petros, Beckwith, & Anderson, 1990).

The effect of time of day (TOD) has also been observed in tests of sustained attention and simple working memory tasks (Lawrence & Stanford, 1999). Lawrence & Stanford examined the effect of time of day and impulsivity on sustained attention and working memory using the Connors Continuous Performance Task (CPT), time interval estimation, letter cancellation test, and digit span. The participants were undergraduate psychology students between the ages of 18 and 30. The Barrot Impulsiveness Scale (Patt et al., 1995) was used to identify high and low impulsive individuals. High and low impulsive individuals were tested between 8:00 and 10:00 a.m. or between 6:00 and 8:00 p.m. The results indicated that there was no interaction between time of day and impulsivity. However, there was a significant main effect for TOD. Participants had a lower number of response omissions on the CPT in the evening compared to the morning. Additionally, Digit Span forward had better recall in the evening than morning (Lawrence & Stanford, 1999).

In contrast to the results of Lawrence and Stanford, (1999), Bennett et al. (2008) found TOD differences in executive functions, but not working memory or sustained attention. Previous research supported that people tend to perform best when tested in their preferred time of day (morning or evening-type) (Petros, Beckwith, & Anderson, 1990). Bennett et al. had subjects complete the Morningness-Eveningness Questionnaire. Then morning-type and evening-type participants were tested in the morning (8-10 a.m.) or evening (3-5 p.m.) on a variety of executive functioning tasks.

Results showed no significant TOD effects on CPT or digit span. A synchrony effect, that is, better performance at preferred time of day, was present for the Wisconsin Card Sorting Task (WCST). Cognitive efficiency and flexibility in the WCST decreased across TOD for Morning-type subjects while Evening-type subjects showed increased performance across TOD (Bennett et al., 2008). One possible reason no effect was found on the CPT in Bennett et al. (2008), but an effect on CPT was found in Lawrence & Stanford (1999) is the difference in time of testing. Bennett et al. (2008) had afternoon testing between 3:00 and 5:00 p.m. while Lawrence & Stanford (1999) tested from 6:00 to 8:00 p.m. Perhaps ratings of fatigue along with nutritional intake and sleep quality may have also help to resolve these discrepancies or better explain these discrepancies.

Recently, research has begun examining the moderation of the age-related declines in memory performance by the time of testing. Using the Horne and Ostberg Morningness-Eveningness Questionnaire, older adults reported that the morning was their optimal time of day while younger adults prefer evening (May, Hasher, & Stoltzfus, 1993). May, Hasher, and Stoltzfus (1993) examined age differences in memory tested at optimal and non-optimal time of day. Prior research on age differences in memory tested younger and older adults in the afternoon, while the optimal time of day reported for older adults was the morning and for younger adults was the afternoon/evening. May, Hasher, and Stoltzfus predicted that testing participants during their optimal time of day moderates age differences in memory. Younger and older subjects performed verbatim recognition of sentences at 8 or 9 a.m. and 4 or 5 p.m. Younger adults improved in recognition from morning to afternoon while older adults declined in recognition performance across time of day. Also, older adults performed significantly worse on recognition than younger adults in the afternoon. There was no difference between young and older adults in recognition when tested in the morning (May, Hasher, & Stoltzfus, 1993).

Time of day effects have practical importance, especially if assessment results could vary in older adults depending on the time of testing. Martin et al. (2008) examined episodic memory of older adults across time of day on a variety of neuropsychological tests used for clinical detection of dementia. Cognitively normal older adults in an Alzheimer's prevention study were given several neuropsychological tests in 1-hr increments from 8 a.m. to 5 p.m. Delayed recall on the Brief Visuospatial Memory Test-Revised and delayed recall scores for the Narrative Passages of the Rivermead Behavioural Memory Test showed significant time of day effects; both were high in early morning, lowest at noon and high in the early afternoon. Attention, working memory, and verbal fluency tests did not show significant time of day effects (Martin et al., 2008).

Hasher et al. (2002) examined age differences and time of day effects on proactive interference. They argued that the inhibitory control process of deletion plays an important role in the build up and release from proactive interference. In a proactive interference task, participants are asked to recall three short lists of words, with the words in each list drawn from the same categories. Recall will typically decline over lists and the number of intrusions will increase. After recall of the third list is complete, a fourth list is presented that contains words drawn from different categories than those on the previous three lists. Recall will generally increase in the final list, demonstrating release of irrelevant information. Hasher et al. tested younger and older adults in the morning or afternoon. Subjects were presented four word lists. The first three lists were created from the same categories to create proactive interference. The final word list was created using a different category to test release from proactive interference. A TOD effect was observed for list recall. Results showed older adults and younger adults recalled a similar amount in the morning. However, the recall of younger adults significantly improved in the afternoon compared to the morning, while recall of older adults decreased in recall from the morning to the afternoon a nonsignificant amount. Younger adults recalled more than older adults in the afternoon. Compared to younger adults, older adults made more intrusion errors at both testing times. Analysis for proactive release revealed younger adults remembered more from lists 3 and 4 than older adults. Since lists 1-3 were composed of words from the same categories, words from the previous list interfere with recall of the most recent word list. When list four was presented, release was shown when words from the previous lists were not recalled. Younger adults showed reliable release by better recall in list four than list three, while older adults did not show reliable release (Hasher et al., 2002).

Borella, Ludwig, Dirk, and Ribaupierre (2011) investigated time of testing on age differences in interference, working memory, processing speed, and vocabulary. As previously discussed, interference occurs when irrelevant stimuli fails to be inhibited. Interference was measured using a Color Stroop test. In a Color Stroop test, participants are presented with color names written in different colors (e.g., the word “Green” written in blue ink). When participants are instructed to identify the ink color, the automatic reading response is inhibited. Longer response times reflect inhibition of the reading response. The researchers also measured negative priming effects in the Color Stroop task. During the priming test, participants were instructed to inhibit part of the stimulus.

Then, in the probe trial the previously inhibited stimulus becomes relevant. For example, in the negative priming trial the word "red" would be inhibited, but in the probe test the color red would be the response. A longer latency of response during the probe trial represents the inhibitory mechanism being more activated during the priming trial. A Reading Span test was used as a measurement of working memory. In the Reading Span test, participants were presented with a series of sentences and asked to answer semantic questions regarding sentence content while simultaneously remembering the last word of each sentence. Working memory was quantified as word recall, but 85% accuracy on the content questions was required to ensure sentence processing occurred. A Letter Comparison task, in which participants identified whether two letter series were identical or not, was used to measure processing speed. The Mill Hill Vocabulary score was used to measure vocabulary. The researchers had younger and older adults tested 8-11 a.m. and 2-5 p.m. at their presumed optimal (morning for older adults, afternoon for young adults) and non-optimal times (afternoon for older adults, morning for young adults). Results showed an interaction between age and time of day. There was no difference between young and older adults on measures of interference in the morning, but in the afternoon, older adults had significantly larger interference effects than younger adults. In the Reading Span test, older adults recalled fewer words than younger adults at both times of day. Older adults had slower processing speed in the Letter Comparison, but higher Mill Hill vocabulary scores than young adults. There was no effect of time of day or an interaction between age and time of day on the working memory, processing speed, and vocabulary tests. Time of day and age interactions were only found in interference tasks.

West et al. (2002) examined whether time of day moderates age-related declines in working memory performance. These authors adopted an inhibition-based framework of working memory proposed by Hasher and Zacks, (1988). Previous work has demonstrated age-related declines in the efficiency of inhibitory processes for access (Connelly et al., 1991), deletion (Ham & Hasher, 1992) and response inhibition (West, 1999). One limitation of the above work was that access, deletion and response inhibition were measured using different tasks. West et al, (2002) sought to examine the impact of age and time of day on each of these functions of working memory using the same task. West et al. found that younger adults reported more subjective alertness in the evening and older adults in the morning. Subjective arousal was compared to physiological arousal, as measured by body temperature. Temperature increased throughout the day equally in younger and older participants regardless of alertness rating. The temperature results were inconsistent with previous studies that used increased temperature to indicate arousal (Horne & Ostberg, 1976). Using a four-box task, intrusion and nonintrusion errors were measured in younger and older adults at 9 a.m. and 5 p.m. The results indicated that time-of-day influenced the efficiency of the access, deletion, and response inhibition function of working memory and this effect was greater for older adults than younger adults for the access and deletion functions (West et al., 2002).

Older adults are sensitive to TOD effects in explicit memory tasks (Martin et al., 2008). May, Hasher, and Foong (2005) examined whether age differences in implicit and explicit memory was moderated by testing younger and older adults at peak and off peak time of day. Previous examinations of the moderating effect of time of day on age differences in cognitive performance have focused mainly on explicit memory. May, Hasher, and Foong (2005) tested younger and older adults at 8-9 a.m. and 5-6 p.m. Participants were first presented with a list of word pairs with one of the words marked as a target. Participants were instructed to ignore the distracter word and rate the pleasantness of the target word on a 1 to 7 scale. After completing a 10-minute filler task, participants began the stem completion task, which involved viewing 48 word stems and completing each stem with the first word that came to mind. Twelve of the stems could be completed with words from the pleasantness rating task, 24 were control stems and 12 filler items. Following the stem completion, the explicit memory portion of the task was conducted. During this phase, participants were presented with word stems to be used as retrieval cues for words viewed in the first part of the study. Results showed both younger and older adults performed higher on implicit memory priming at off-peak time of day. There was also no interaction between age and time of testing for implicit memory. The results for explicit memory were consistent with previous research. Younger and older adults performed better at their optimal time of day. In a second study, May, Hasher, and Foong had young and older adults tested at optimal and nonoptimal time of day using a category generation task. In this task, participants were presented word lists consisting of 36 nouns (12 target words from 4 categories). The participants rated the words on a pleasantness-rating scale. Then, as a measure of implicit memory, they were asked to generate eight “exemplars” of the four target categories. Results showed both young and older adults had greater priming in implicit memory during off-peak time of testing.

Smith, Eklund, Ferraro, and Petros (2001) examined time of day effects on memory in younger and older adults. Participants completed prose and word memory tasks from the Wechsler Memory Scale-Third Edition. Participants were tested at optimal and nonoptimal time of day (9 a.m. and 3 p.m.). Results showed a significant two-way interaction between age and time of day on word memory. In word list tasks, younger adults recalled more than older adults with a larger age difference in the afternoon for immediate and short-delay recall. There was a significant effect of age on prose memory. Younger adults recalled more story units than older adults. Results for prose memory indicated age differences were not moderated by time of day.

The research reviewed above suggests that verbal ability and time of day of testing may moderate the magnitude of age-related declines observed in cognitive performance. The proposed research will also examine the impact of time of day and verbal ability as moderators of age-related declines in memory performance using a wider range of cognitive tasks than previous investigations. Second, we will examine the impact of nutrition and sleep as moderators of age-related changes in performance.

Nutrition

Poor nutrition has been associated with impaired cognitive performance, and older adults frequently have impaired nutritional status (Greenwood, 2003). The proposed study will examine whether nutritional status along with time of day has a moderating effect on age-related changes in memory performance.

Research that has examined the impact of nutrition on cognitive performance has focused on effects of macronutrients and micronutrients. Macronutrients (fat, protein, carbohydrates, etc.) are the substances consumed in the largest amount through diet.

Micronutrients (many vitamins and minerals) are required in only trace amounts for survival. The results of studies on the effect of macronutrients are often mixed (Dye, Lluch, & Blundell, 2000). Research has shown that as the cognitive demand of a task increases, the amount of glucose used in the brain increases (Dye, Lluch, & Blundell, 2000). Macronutrient manipulations in young adults have shown that memory tests, such as Serial Sevens, Free Word Recall and Cued Word recall, were the most sensitive to the manipulation's effect. When children, age 9-11, were given a glucose drink, they recalled more pictures in a memory task than a placebo group, but glucose had no effect on spatial memory (Benton & Stevens, 2008). Administering glucose may increase memory in older adults as well (Greenwood, 2003). An increased blood glucose level is one proposed mechanism for how ingestion of macronutrients can enhance cognitive performance. Kaplan et al, (2001) examined the effect of protein, carbohydrate, and fat on blood glucose levels and cognitive performance. After an overnight fast, participants received a pure form of carbohydrates, protein or fat, and then completed paragraph recall (immediate and delayed), word list recall, Trail Making Test, and an attention task consisting of watching television episodes and counting the times a specific word is spoken or doors are opened/closed. Kaplan et al. (2001) found that while only the carbohydrates increased blood glucose levels, improvement on delayed paragraph recall was found with all macronutrient groups. Energy, irrespective of source, can improve cognitive performance (Kaplan et al., 2001). Time of day may also influence the effects of dietary intake on cognitive performance. Natural circadian rhythms have supported a "postlunch dip", in which cognitive performance (e.g., sustained attention) is decreased in early afternoon. Studies examining nutrition have had difficulty separating the circadian rhythms from the effect of dietary intake (Dye, Lluch, & Blundell, 2000).

Micronutrients, such as Vitamin D, Iron and B12 may also impact cognitive function in adults (Miller, 2010). Annweiler et al. (2010) found that elderly women with a Vitamin D deficiency had a lower mean score on Pfeiffer's Short Portable Mental State Questionnaire and higher odds of being classified as cognitively impaired than elderly women without a Vitamin D deficiency. Vitamin D deficiency has been related to a higher risk of dementias and cerebrovascular diseases (Buell et al., 2008). Iron levels have been associated with global measures of cognitive performance, but research on its effect on specific cognitive tasks is often mixed (Ortega et al., 1997). Vitamin B12 deficiency in older adults has been correlated to decreased memory and cognitive performance (Goodwin, Goodwin, & Gary, 1983), and may be linked to Alzheimer's Disease rates (McCaddon et al., 1998).

The research reviewed above characterized the participants' nutritional status using different techniques. Research examining micronutrients used actual vitamin or nutrient concentrations in the participants' blood. Ortega et al. (1997) utilized a 7-day weighed-food record to estimate levels of iron. Research on macronutrients has been done primarily using experimental manipulation of consumption (e.g. participants are given a glucose drink or placebo and compared on a measure).

The proposed research will measure each participant's nutritional status (macronutrient and micronutrient levels) by a self-report measure of their typical nutritional intake. The measure we will utilize is the Block 2005 Brief Food Questionnaire. The questionnaire lists specific foods and requires participants to recall how frequently the item was consumed in the past 6 months. Using the frequency of consumption and portion size, multiple macronutrient and micronutrient amounts are yielded.

Self-administered food frequency questionnaires have comparable validity to interview-administered questionnaires. Jain, Howe, and Rohan (1996) had participants complete an interviewer-administered dietary history, a 7-day food record, and a self-administered food frequency questionnaire. Participants were divided into two groups. The first group completed the interview-administered history first, did a 7-day record of diet, and after a 1-month interval completed the self-administered questionnaire. The second group did the self-administered questionnaire first, completed a 7-day record, and then after a 1-month interval, completed the interview-administered dietary history. Results showed Pearson correlations between the food questionnaire and the seven-day record ranged from .38 to .67 for women and .28 to .72 for men. For macronutrients, the mean Pearson correlations were .55 (men) and .48 (women). Micronutrient mean correlations were .48 (men) and .54 (women). The interviewer-administered dietary history correlated with the 7-day record yielded similar results with Pearson's r ranging from .27 to .71. Results indicate that self-administered questionnaires are approximately as accurate as interviewer-administered dietary history in predicting nutrient intake.

Sleep

Sleep quality and length is another possible moderator of age-related memory performance. Healthy older adults report worse sleep quality than healthy younger adults (Buysse et al., 1991). A decline in sleep time has been correlated with increased napping during the day in older adults (Huang et al., 2002). Older adults tend to show decreases in total sleep, sleep efficiency and rapid eye movement (REM)/non-REM sleep cycles (Carrier et al., 1997; Huang et al., 2002). Compared to younger adults, older adults tend to sleep earlier at night and awaken earlier in the morning (Carrier et al., 1997). Differences in sleep quality may be accounted for by differences in sleep patterns. Sleep EEG studies of older adults have shown differences in sleep waves compared to younger adults (Carrier et al., 2001). Differences in sleep quality may impact age-related deficits in memory. Harrison & Horne (2000) had younger and older adults complete tasks of visual temporal memory, verb generation to noun generation, and response inhibition. Younger adults performed better than older adults, overall. However, after younger adults were deprived of sleep for 36 hours, their performance decreased to the same level as the older adults. The aging process of the brain, such as synaptic degeneration, reduced blood flow, and changes in neurochemistry, have been correlated to changes in both sleep and memory function (Cabeza et al., 2002). Decrements in sleep quality may account to some degree for age-related decline in memory performance. Nebes et al. (2009) found that self-reported sleep measures (Pittsburgh Sleep Quality Index) can account for some poorer cognitive performance on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) even after depression symptoms were controlled. In this study, older adults completed the Pittsburgh Sleep Quality Index, Geriatric Depression Scale, and the RBANS. Sleep latency (time to fall asleep) was negatively correlated with total RBANS score, and sleep efficiency was positively correlated with total RBANS score. However, time of testing was not presented, which may have confounding effects, since research suggests older and younger adults' cognitive function is sensitive time of testing.

Previous research has shown age differences in memory are influenced by time of day effects. The present study will test participants at 9 A.M. and 3 P.M., which remains consistent with previous research that has found significant time of day effects at these times. Smith et al. (2001) did not find an interaction between time of day and age in younger and older adults in a prose memory task. One possible reason for a nonsignificant interaction between age and time of day in Smith et al.'s study is the length of prose passages used. The present study will utilize two levels of passages (narrative and expository), each 200-220 words at a 7-8th grade reading level. More difficult and longer passages should be more sensitive to time of day effects in younger and older adults. Another aim of the present study is to examine time of day effects on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). The RBANS is a recently developed neuropsychological measure often used in clinical settings to measure cognitive decline in older populations (Randolf, 1998). One study examined RBANS scores between cognitively normal older adults, and those diagnosed with Parkinson's disease (PD), Alzheimer's Disease (AD), and Mild Cognitive Impairment (MCI) (Morgan et al., 2010). Results showed that the normal group and AD group had significantly different scores than PD and MCI. The normal group had significantly higher RBANS scores than the remaining groups while the AD group had significantly lower scores than remaining groups. PD and MCI groups were not significantly different from one another (Morgan et al., 2010). These results suggest the RBANS is sensitive to cognitive impairments. Significant time of day effects in older adults could reveal important clinical implications. The final aim of the present study is to examine nutritional intake and sleep quality as moderators for time of day effects on cognitive performance differences in younger and older adults. Previous research has shown cognitive performance can be influenced by micronutrients and macronutrient intake. The present study will use a self-report measure of average nutritional intake over the past 6 months. Prior research has shown poor sleep quality is related to poorer cognitive performance, and that older adults tend to have decrements in sleep quality. Previous research has also shown the RBANS is sensitive to cognitive decrements in older adults with poorer self-reported sleep quality on the Pittsburgh Sleep Quality Index. The present study will utilize both the Pittsburgh Sleep Quality Index and RBANS to examine sleep's moderating effects on time of day differences on cognitive tasks in younger and older adults.

CHAPTER II

METHOD

Participants

Forty-eight young adults, ages 18-35 (*M* = 20.7) were recruited from undergraduate courses at the University of North Dakota. Twenty-five older adults, ages 60-84 (*M* = 71.4) were recruited from the community via newspaper advertisements, postings at local businesses, or letters to University of North Dakota alumni. Nineteen participants were male and 54 were female. Participants' race/ethnicities were as follows: 95.8% White; 2.8 % Hispanic, and 1.4% Native American. No other races or ethnicities were represented.

Community participants received monetary compensation of $20. Young adults received course credit for participation. Younger and older participants were randomly assigned for testing in the morning (8 or 9 A.M.) or the evening (3 or 4 P.M.). Participants with prior stroke, head injury, or history of dementia were excluded. Participants currently taking or have taken psychotropic medication in the past six months were be excluded.

Materials

The Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) contains 19 self-report questions aimed to measure multiple aspects of sleep quality over the past month. The PSQI produces seven component scores, each component weighted on a scale of 0-3. The global PSQI score (ranging from 0-21) is comprised of the seven component scores. Higher global PSQI scores represent worse overall sleep quality. The seven components measured are common sleep complaints assessed in clinical interviews. These components are sleep latency, sleep duration, habitual sleep efficiency, sleep quality, use of sleep medications, sleep disturbances, and daytime dysfunction. The PSQI has been found to discriminate between healthy middle-aged adults, depressed patients, and sleep-disorder patients (Buysse et al., 1991). The Vocabulary Subtest of the Wechsler Adult Intelligence Scale-IV (WAIS-IV) measures verbal ability by requiring individuals to define up to 30 words of increasing difficulty. Higher scores represent higher verbal ability. The Vocabulary subtest is widely accepted in research as a measurement of verbal ability. Additionally, the Vocabulary subtest correlates highly with the Verbal Comprehension Index and Full Scale IQ

The Horne & Ostberg Morningness/Eveningness questionnaire (Horne & Ostberg, 1976) contains 19 self-report items measuring habitual rising and bed times, time preference for physical and mental performance, and alertness before going to bed and after rising. The scale produces an overall morningness-eveningness score, ranging from 16-86. A higher score indicates a greater preference for the morning while lower scores indicate a greater preference for the evening.

Physiological measurements that will be taken by the experimenter include: systolic and diastolic blood pressure, heart rate, and temperature (ear).

Prose memory was measured using two narrative and two expository texts rated at a 7^{th}-8^{th} grade reading level. Each story consisted of 200-220 words and was auditorily recorded

Each passage has previously been divided into idea units and each idea unit was rated for its importance to the main theme of the passage (Petros et al., 1989). In previous research, participants were given a written copy of a prose passage and asked to cross out one-third of the story ideas that could be removed while losing the least amount of information relevant to the story's main idea (Low Importance level). Participants then crossed out the next third of story ideas that would lose the least amount of information relevant to the story's main idea (Medium Importance Level). The remaining third were considered the story's main ideas (High Importance Level). The number of story ideas ranged from 24 (Snails) to 34 (Dragon), with approximately one-third High Importance (main ideas), one-third Medium Importance, and one-third Low Importance (details) ideas in each story.

The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (Randolf, 1998) is a neuropsychological screening battery to identify cognitive decline. The RBANS consists of 12 subtests that comprise 5 indices: Immediate Memory, Visuospatial/Constructional, Language, Attention, and Delayed Memory. Index scores are combined to yield a Total Scale Score.

1) Immediate Memory consists of two subtests: List Learning and Story Memory. In List Learning, individuals are verbally presented with 10-item word lists over 4 trials. Immediately after hearing the list immediate recall is obtained. In Story Memory, a short story containing 12 predetermined segments or ideas are verbally presented. The participant must recall verbatim the story over two trials.

2) Visuospatial/Constructional consists of two subtests: Figure Copy and Line Orientation. In Figure Copy, participants copy a 10-part geometric figure with no time limit. In Line Orientation, participants match two target lines to its corresponding orientation on a 13-line array spanning 180 degrees.
3) Language contains two subtests: Picture Naming and Semantic Fluency. In Picture Naming, participants name 10 line drawings. Participants are given semantic cues if an image is perceived incorrectly. In Semantic Fluency, participants are given 60 seconds to name as many items within a semantic category.
4) The Attention Index consists of two subtests: Digit Span and Coding. In Digit Span, participants are verbally presented two strings of digits, increasing in length each item (starting at 2 digits, ranging to 9), and asked to recall the digits in order of presentation. The second string is presented if the first string is failed. Coding requires the participant to quickly match numbers to symbols in 90 seconds.
5) Delayed Memory contains four subtests: List Recall, List Recognition, Story Recall, and Figure Recall. List Recall requires the participant to free recall the word lists from the previous List Learning subtest. List Recognition is a yes/no recognition task containing items from the List Learning task. Story Recall requires the participant to free recall stories from the previous Story Memory task. Figure Recall requires the participant to free recall the figure drawn earlier in the Figure Copy task with no time limit.

The Geriatric Depression Scale-Short Form (GDS-SF) contains 15 yes/no items measuring depression in older populations. Items focus on psychological aspects of depression, excluding items confounded by age and diseases, such as many physiological symptoms of depression (change in sleep, psychomotor retardation). Research has supported the use of the GDS with younger adults (Ferraro & Chelminski, 1996).

The Block 2005 Brief Food Questionnaire was used to assess nutritional intake. The questionnaire requires participants to recall how frequently specific foods were consumed in the past 6 months and the average size of the portion. Each food item on the FFQ elicits two scores: frequency of consumption and portion size. From this information, nutritional intake estimates of multiple macronutrients (including carbohydrates, protein and fats) and micronutrients (including Vitamin D, iron, and Vitamin B12) are given. Food frequency questionnaires, in general, have good correlations with more extensive food histories and are useful for research purposes due to their accurate estimates, yet brief assessment (Block, 1982).

Procedure

Older adult participants were mailed the questionnaires (Food Frequency Questionnaire, PSQI, Morningness-Eveningness Questionnaire) and the informed consent prior to their testing date. Complete instructions for each questionnaire were included. Younger adults completed all questionnaires after informed consent was obtained. All participants were tested independently. After completing informed consent, the participants' demographic information was obtained. Participants were given the WAIS-IV Vocabulary subtest, during which the examiner presented words verbally and visually for the participant to define. After completing the WAIS-IV Vocabulary subtest, physiological measures (blood pressure, pulse and temperature) were taken.

Participants were administered the RBANS. After a short break, participants were administered a test of prose memory. Audio recordings of prose stories were presented (1 practice, 4 experimental), and the participants were asked to immediately recall each story after its presentation.

CHAPTER III

RESULTS

Demographics

A series of 2 (Age) x 2 (Time of Day) Analyses of Variance (ANOVA) were used to analyze participant demographic variables. Group means and standard deviations are presented in Table 1.

A significant main effect for Age was found, F (1, 67) = 1515.2, $p < .001$. The main effect for Age indicated that participants in the young adult group (M = 20.68) were significantly younger than the older adult group. (M = 71.38).

Significant main effects for Age F (1, 67) = 52.52, $p < .001$, and Time of Day F (1,67) = 7.07, $p = .01$,were found for the Horne and Ostberg. The main effect of Age indicates that the Horne and Ostberg scores of older adults (M = 61.94) were significantly higher than young adults (M = 48.385), indicating that older adults prefer morning activities more than young adults. The main effect of Time of Day indicates that the Horne and Ostberg score of participants tested in the morning (M = 57.68) was significantly higher than participants' who were tested in the afternoon (M = 52.68), indicating that participants tested in the morning preferred morning activities more than participants tested in the afternoon. A significant interaction F (1, 67) = 6.43, $p < .05$ between Age and Time of Day for the Horne and Ostberg was found. The interaction indicates that older adults tested in the morning scored significantly higher than older

Table 1. Means and Standard Deviations of Participant Characteristics.

	AM		PM	
	Young	Old	Young	Old
Age	21.850 (1.170)	71.857 (1.398)	19.500 (0.989)	70.909 (1.577)
Horne & Ostberg	48.500 (1.679)	66.857 (2.007)	48.269 (1.472)	57.091 (2.264)
GDS	1.250 (0.451)	0.308 (0.560)	1.964 (0.382)	0.818 (0.609)
Education	13.950 (0.361)	15.643 (0.431)	12.964 (0.305)	15.300 (0.511)
Vocabulary	36.550 (1.656)	40.714 (1.979)	33.286 (1.400)	45.364 (2.233)
Health Rating	4.000 (0.148)	3.929 (0.176)	4.107 (0.125)	4.000 (0.209)

adults tested in the afternoon while young adults did not significantly differ in their Horne and Ostberg scores from the morning and afternoon.

A significant main effect of Age for participants' Mood was found F (1, 66) = 4.221, $p < .05$, indicating that young adults (M = 1.61) scored significantly higher than older adults (M = 0.56) on the Geriatric Depression Scale- Short Form.

A significant main effect of Age was found for Vocabulary, F (1, 69) = 19.39, $p < .001$, indicating that older adults (M = 43.04) had higher vocabulary scores than young adults (M = 34.92). A significant interaction between Age and Time of Day was found for Vocabulary score F (1,69) = 4.60, $p < .05$). The interaction for Vocabulary indicates that vocabulary scores for young adults tested in the morning were significantly higher (*M* = 36.55) compared to young adults tested in the afternoon (*M* = 33.29) while older adults tested in the morning had significantly lower ' vocabulary scores (M = 40.71) compared to those tested in the afternoon (*M* = 45.36).

A significant main effect of Age for participants' Education level was found *F* (1, 69) = 24.22, p < .001, indicating that the educational level of young adults (M = 13.46) was significantly lower than older adults (M = 15.47).

No significant main effects or interactions were found in the analysis of the participants' Health Rating.

Pittsburgh Sleep Quality Index

A series of 2 (Age) x 2 (Time of Day) Analyses of Variance (ANOVA) were used to analyze the Pittsburgh Sleep Quality Index scores. Group means and standard deviations are presented in Table 2.

No significant main effects or interactions were found for participant's Global Pittsburgh Sleep Quality Index scores.

A significant main effect of Age for Component 1: Subjective Sleep Quality was found, *F* (1, 72) = 7.58, p < .05, indicating that young adults (M = 1.01) reported worse sleep quality than older adults (M = 0.63). No other significant main effects or interaction were found for Subjective Sleep Quality.

No significant main effects or interactions were found for Sleep Latency, Sleep Duration, Habitual Sleep Efficiency, Sleep Disturbance, Use of Sleep Medications, and Daytime Dysfunction.

Table 2. Means and Standard Deviations of Participant Pittsburgh Sleep Quality Index.

	AM		PM	
	Young	Old	Young	Old
PSQI Global	4.90 (0.61)	4.92 (0.75)	5.93 (0.51)	4.73 (0.82)
Subjective Sleep Quality	0.95 (0.122)	0.54 (0.15)	1.07 (0.10)	1.15 (0.16)
Sleep Latency	1.15 (0.20)	0.62 (0.24)	1.32 (0.17)	1.00 (0.26)
Sleep Duration	0.40 (0.18	0.69 (0.23)	0.68 (0.16)	0.25 (0.25)
Habitual Sleep Efficiency	0.25 (0.12)	0.39 (0.15)	0.32 (0.10)	0.09 (0.16)
Sleep Disturbances	1.05 (0.11)	1.46 (0.14)	1.11 (0.09)	1.18 (0.15)
Use of Sleep Medicaton	0.20 (0.20)	0.31 (0.25)	0.46 (0.17)	0.64 (0.23)
Daytime Dysfunction	0.90 (0.17)	0.92 (0.21)	0.96 (0.14)	0.82 (0.23)

Physiological Measures

A series of 2 (Age) x 2 (Time of Day) ANOVAs were used to analyze the physiological variables. Group means and standard deviations are presented in Table 3.

A significant main effect of Age was found for Right Systolic Blood Pressure, F (1, 67) = 14.50, $p < .001$, indicating that participants in the young adult group (M = 122.26) had significantly lower Right Systolic Blood Pressure than the older adult

Table 3. Means and Standard Deviations of Participant Physiological Measures.

	AM		PM	
	Young	Old	Young	Old
BP Systolic Right	120.050 (4.519)	147.286 (5.401)	124.464 (3.819)	135.545 (6.093)
BP Diastolic Right	70.750 (2.141)	76.857 (2.559)	72.000 (1.809)	75.182 (2.887)
BP Systolic Right	120.200 (3.520)	144.786 (4.207)	119.571 (2.975)	135.909 (4.746)
BP Diastolic Left	72.750 (2.054)	75.143 (2.456)	72.750 (1.736)	76.727 (2.770)
BP Systolic	120.125 (3.536)	146.036 (4.226)	122.018 (2.988)	135.727 (4.768)
Bp Diastolic	71.750 (1.965)	76.000 (2.348)	72.375 (1.661)	75.955 (2.649)
Temperature	97.925 (0.161)	97.571 (0.192)	98.050 (0.136)	98.155 (0.217)
Heart Rate	70.400 (2.273)	65.462 (2.820)	72.815 (1.957)	74.300 (3.215)

group (*M* = 141.42). A significant main effect of Age for Left Systolic Blood Pressure was found, F (1, 67) = 27.25, $p < .001$. The main effect for Left Systolic Blood Pressure indicates that participants in the young adult group (*M* =119.87) had significantly lower Left Systolic Blood Pressure than the older adult group. (*M* = 140.35). A significant main effect of Age for Mean of Right and Left Systolic Blood Pressure was found, F (1, 67) = 25.31, $p < .001$. The main effect of age for Mean Systolic Blood Pressure indicates that participants in the young adult group (*M* =121.07) had significantly lower Systolic Blood Pressure than the older adult group. (*M* = 140.88).

No significant main effects or interaction were found for participants' Left Diastolic Blood Pressure, Right Diastolic Blood Pressure, or Average Diastolic Blood Pressure.

No significant main effects or an interaction were found for Temperature. A marginal main effect for Time of Day on Temperature, F (1,69) = 3.90, p = .052 was found, indicating that participants tested in the morning (*M* = 97.75) had lower temperatures than participants tested in the afternoon (*M* = 98.13).

A significant main effect of Time of Day for heart rate was found, F (1, 66) = 4.64, $p < .05$. The main effect for heart rate indicates that participants in the morning (*M* = 67.93) had a significantly slower heart rate than participants in the afternoon (*M* = 73.56).

Nutritional Intake

A series of 2 (Age) x 2 (Time of Day) ANOVAs were used to analyze participant daily macronutrient intake. Group means and standard deviations for macronutrient intake are presented in Table 4. No significant main effects or interactions were found for participants' self-reported Protein, Carbohydrate, and Total Fat intake.

A series of 2 (Age) x 2 (Time of Day) ANOVAs were used to analyze participant daily micronutrient intake. Group means and standard deviations for micronutrient intake are presented in Table 5. A significant interaction between Age and Time of Day was revealed for Vitamin D consumption, F (1,69) = 4.32, $p < .05$. The interaction for Vitamin D indicates that young adults tested in the morning consumed less Vitamin D

Table 4. Means and Standard Deviations for Participants' Daily Macronutrient Nutritional Intake.

	AM		PM	
	Young	Old	Young	Old
Protein (g)	60.649 (6.637)	57.707 (7.933)	66.904 (5.610)	57.161 (8.950)
Fat (g)	57.955 (6.882)	47.881 (8.226)	60.934 (5.817)	67.722 (9.280)
Carbohydrates (g)	156.398 (16.521)	159.310 (19.747)	173.088 (13.963)	156.295 (22.277)

(*M* = 148.7) than young adults tested in the afternoon (*M* = 188.1) while older adults tested in the morning consumed more Vitamin D (*M* = 200.7) than older adults tested in the afternoon (*M* = 95.69).

No significant main effects or interactions were found for Calcium, Iron, Zinc, Vitamin B6, Vitamin B12, and Magnesium.

A series of 2 (Age) x 2 (Time of Day) ANOVAs were used to analyze additional data of participant nutritional intake. Group means and standard deviations for additional nutritional intake data are presented in Table 6.

A significant main effect for Time of Day for percent of calories from alcohol, F (1, 69) = 10.40, $p < .05$), indicates that participants tested in the morning (*M* =5.94) had a significantly higher percentage of calories from alcohol than participants tested in the afternoon (*M* = 2.17).

Table 5. Means and Standard Deviations for Participants' Daily Micronutrient Nutritional Intake.

	AM		PM	
	Young	Old	Young	Old
Calcium (mg)	822.389 (99.628)	855.822 (119.078)	909.127 (84.201)	613.235 (134.338)
Iron (mg)	10.264 (1.133)	10.412 (1.354)	12.576 (0.957)	8.970 (1.527)
Cholesterol	189.994 (26.998)	148.296 (32.268)	214.882 (22.817)	173.548 (36.404)
Zinc (mg)	8.096 (0.883)	8.263 (1.055)	8.688 (0.746)	7.867 (1.191)
Vitamin B6 (mg)	1.387 (0.154)	1.566 (0.185)	1.668 (0.130)	1.566 (0.208)
Magnesium (mg)	233.059 (23.056)	238.174 (27.557)	235.846 (19.486)	206.685 (31.089)
Vitamin D (IU)	148.709 (31.191)	200.652 (37.281)	188.081 (26.362)	95.686 (42.059)
Vitamin B12 (ug)	3.605 (0.470)	3.909 (0.562)	4.132 (0.397)	2.982 (0.634)

No significant main effects or interactions were found for Caloric intake, Cholesterol, and Caffeine.

Table 6. Means and Standard Deviations for Additional Nutritional Data.

	AM		PM	
	Young	Old	Young	Old
Calories	1437.986 (146.300)	1308.754 (174.861)	1503.811 (123.646)	1447.945 (197.270)
Caffeine (mg)	6.988 (4.811)	2.571 (5.751)	9.577 (4.066)	19.522 (6.487)
Percent Calories From Alcohol	7.012 (1.052)	4.873 (1.257)	2.272 (0.889)	2.057 (1.418)
Percent Calories From Sweets	6.696 (1.393)	9.049 (1.665)	6.751 (1.178)	13.315 (1.879)

Repeatable Battery for the Assessment of Neuropsychological Status

A series of 2 (Age) x 2 (Time of Day) ANOVAs were used to analyze participant RBANS subtest scores. Group means and standard deviations are presented in Table 7.

A two between (Age, Time of Day) and 1 within (List) mixed ANOVA was used to analyze RBANS Immediate List Recall. A significant main effect of Age was found for RBANS Immediate List Recall F (1, 69) = 37.57, p < .001. The main effect of Age indicates that young adults (M = 7.66) recalled on average more words for each of the four trials than older adults (M = 6.26). A significant main effect for List was found, F (3, 207) = 142.61, p < .001, indicating that significantly more words were recalled in Trial 4 (M = 8.18) than Trial 3 (M = 7.94), Trial 3 than Trial 2 (M = 6.78), and Trial 2 than Trial 1 (M = 4.94). No other significant main effects or interactions were found for RBANS Immediate List Recall.

Table 7. Means and Standard Deviations of Repeatable Battery for Assessment Neuropsychological Status.

	AM		PM	
	Young	Old	Young	Old
List Recall Immediate Trial 1	5.95 (0.24)	4.29 (0.29)	5.18 (0.20)	4.36 (0.32)
List Recall Immediate Trial 2	7.70 (0.30)	6.36 (0.36)	7.36 (0.26)	5.73 (0.41)
List Recall Immediate Trial 3	8.65 (0.31)	7.57 (0.37)	8.36 (0.26)	7.18 (0.42)
List Recall Immediate Trial 4	9.05 (0.27)	7.50 (0.32)	9.07 (0.23)	7.09 (0.37)
List Recall Immediate Total	31.45 (0.84)	25.71 (1.00)	30.11 (0.71)	24.36 (1.13)
List Recall Delay	10.20 (0.49)	8.64 (0.58)	9.89 (0.41)	8.73 (0.66)
List Recognition	19.45 (0.26)	19.37 (0.31)	19.82 (0.22)	18.46 (0.35)
Story Immediate Trial 1	8.35 (0.56)	7.64 (0.67)	7.00 (0.47)	6.64 (0.76)
Story Immediate Trial 2	11.00 (0.34)	10.57 (0.41)	10.64 (0.29)	9.82 (0.46)
Story Immediate	19.35 (0.84)	18.21 (1.00)	17.64 (0.71)	16.46 (1.13)
Story Delay	10.20 (0.49)	8.64 (0.58)	9.89 (0.41)	8.73 (0.66)
Figure Copy	16.75 (0.43)	18.71 (0.52)	18.75 (0.37)	17.82 (0.58)

Table 7 (cont.)

	AM		PM	
	Young	Old	Young	Old
Figure Recall Delay	12.80 (0.71)	12.64 (0.84)	17.07 (0.60)	12.46 (0.95)
Line Orientation	17.10 (0.53)	17.36 (0.63)	17.11 (0.45)	17.55 (0.71)
Semantic Fluency	19.85 (1.15)	20.57 (0.98)	21.64 (1.38)	23.91 (1.56)
Picture Naming	9.65 (0.14)	9.86 (0.16)	9.54 (0.12)	9.55 (0.19)
Digit Span	11.70 (0.57)	10.93 (0.68)	11.46 (0.48)	10.93 (0.77)
Coding	58.20 (1.92	42.21 (2.30)	59.75 (1.62)	47.73 (2.59)

A significant main effect of Age was found for RBANS Delayed List Recall, F (1, 69) = 22.67, $p < .001$, indicating that young adults (M = 7.84) recalled more words after an approximately 5-10 minute delay than older adults (M = 5.38). Difference scores for RBANS List Recall (Immediate (Trial 4) - Delayed) were analyzed using a 2 (Age) x 2 (Time of Day) ANOVA. No significant main effects or interactions were found. When the proportion of recall ([Immediate (Trial 4) - Delayed]/ Immediate) were analyzed, a significant main effect for Age was found, F (1,69) = 5.135, p = 0.027, indicating that older adults (M = 0.27) recalled a significantly smaller proportion of words from their immediate recall than young adults (M = 0.14). No other significant main effects or interactions were found.

A significant main effect of Age was found for RBANS List Recognition, *F* (1, 69) = 6.514, p < .05. The main effect of Age indicates that young adults (*M* = 19.64) correctly identified more words than older adults (*M* = 18.91). A significant interaction between Age and Time of Day was observed for RBANS List Recognition, *F* (1, 69) = 4.96, *p* < .05. The interaction between Age and Time of Day indicates that young adults' recognition was approximately the same in the morning (*M* = 19.45) as older adults in the morning (*M* = 19.36), and younger adults recognized significantly more words in the afternoon (*M* = 19.82) than older adults in the afternoon (*M* = 18.46).

A two between (Age, Time of Day) and 1 within (Story Trial) mixed ANOVA was used to analyze RBANS Immediate Story Recall. A significant main effect for Story Trial was found, *F* (1,69) = 193.16, *p* < .001, indicating that more story elements were recalled in the Trial 2 (*M* = 10.51) than Trial 1 (*M* = 7.41). No other significant main effects or interactions were found for RBANS Immediate Story Recall.

A significant main effect of Age was found for RBANS Delayed Story Recall, *F* (1, 69) = 6.263, *p* < .05, indicating that young adults (*M* = 10.05) recalled more of the short story than older adults (*M* = 8.69) after 5-10 minute delay. A 2 (Age) x 2 (Time of Day) ANOVA was used to analyze difference scores of Story Recall (Immediate Story Recall (Trial 2) - Delayed Story Recall). No significant main effects or interaction were found. The proportion of the story lost during the delay ([Immediate Story Recall (Trial 2) - Delayed] / Immediate) was also analyzed. No significant main effects or interactions were found for proportion of story not recalled after the delay.

A significant interaction between Age and Time of Day was revealed for RBANS Figure Copy, *F* (1, 69) = 9.06, *p* < .05. This interaction indicates that young adults' figure copy scores were significantly lower in the morning (*M* = 16.750) compared to the afternoon (*M* = 18.75) and older adults scored higher the morning (*M* = 18.714) compared to the afternoon (*M* = 17.82). Older adults' figure copy scores were significantly higher than younger adults in the morning, and younger and older adults did not significantly differ in the afternoon.

Significant main effects for Age, F (1, 69) = 9.255, $p < .05$, and Time of Day, F (1, 69) = 6.770, $p < .05$, were found for RBANS Figure Recall. The main effect of Age suggests that young adults (*M* = 14.94) recalled more figure details in the correct location than older adults (*M* = 12.55). The main effect of Time of Day indicates that participants in the morning (*M* = 12.72) recalled less than participants in the afternoon (*M* = 14.76). A significant interaction between Age and Time of Day was found for RBANS Figure Recall. The interaction for Figure Recall indicates that recall of young adults recall in the morning (*M* = 12.800) was not significantly different from older adults in the morning (*M* = 12.643), but younger adults in the afternoon (*M* = 17.071) recalled significantly more than older adults in the afternoon (*M* = 12.455). Analysis of difference scores (Figure Copy - Figure Recall) revealed a significant main effects of Age, F (1, 69) = 17.95, $p < .001$, and Time of Day, F (1, 69) = 4.725, $p < .05$. The main effect of Age indicates that young adults had a significantly smaller difference between Figure Copy and Figure Recall (*M* = 2.81) than older adults (*M* = 5.72). The main effect of Time of Day indicates that participants in the morning had a significantly larger difference between Figure Copy and Figure Recall (*M* = 5.01) than participants in the afternoon (*M* = 3.52). No other significant main effects or interactions were found.

A significant main effect of Time of Day for RBANS Semantic fluency was found, F (1, 69) = 3.985, $p = .05$. The main effect of Time of Day indicates that participants in the morning (M = 20.21) produced fewer words than participants in the afternoon (M = 22.78).

A significant main effect of Age was found for RBANS Coding, F (1, 69) = 42.84, $p < .001$. The main effect of Age indicates that young adults (M = 58.98) completed more coded numbers than older adults (M = 44.97). No other main effects or interactions were revealed for RBANS Coding.

No significant main effects or interactions were found for RBANS Line Orientation, Picture Naming, and Digit Span.

Prose Recall

Prose passage recall was audio recorded for each participant and transcribed after testing was complete. Researchers scored story ideas present in each participant's recall blinded to story idea importance level. Eleven percent of the stories were independently scored and inter-rater reliability was calculated. Inter-rater reliability was 0.85, indicating that the stories were adequately scored in a consistent manner. After all participants recall of each story was scored for each story, number of High, Medium, and Low Importance Level story ideas were identified. Recall proportions were calculated for each story at each importance level by dividing story ideas recalled by the total number of story ideas in the relevant importance level (e.g., If a participant recalled six High Importance Level ideas from the Carver passage, the participant's proportion of High Importance Level recall for Carver would be 6/11 = 0.545). Recall proportions for Narrative Passages (Carver and Dragon) were averaged for each participant at each story importance level yielding three new scores: Proportion of Narrative High Importance Recall, Proportion of Narrative Medium Importance Recall, and Proportion of Narrative Low Importance Recall. Recall proportions for Expository Passages (Parakeets and Snails) were averaged for each participant at each story importance level yielding three new scores: Expository High Importance Recall, Expository Medium Importance Recall, and Expository Low Importance Recall.

A mixed design ANOVA with Story Type (Narrative, Expository) and Importance Level (High, Medium, Low) as within-subjects factors and Age (Young, Older) and Time of Day (Morning, Afternoon) as between-subjects factors was used to analyze prose recall. Group means and standard deviations are presented in Table 8.

A significant main effect of Story Type was found, F (1, 64) = 105.0, $p < .001$, indicating that participants recalled a higher proportion of story elements from narrative passages (M = 0.52) than expository (M = 0.45). A significant main effect of Importance Level was found, F (2, 128) = 192.1, $p < .001$, indicating that the highest proportion recalled were the high importance level (M = 0.58), which was significantly higher than the medium importance level recall (M = 0.48), and both were significantly higher than the recall of the lowest importance level (M = 0.30). An interaction between Story Type and Importance Level, F (2, 128) = 84.65, $p < .001$ was found. Tukey post hoc analysis of the interaction between Story Type and Importance Level indicates that in the expository passages proportion of recall medium importance level recall (M = 0.47) was significantly higher than high importance level recall (M = 0.42), and both were significantly higher than low importance recall (M = 0.26). For the narrative passages, the high importance level recall (M = 0.74) was significantly higher than the medium

Table 8. Means and Standard Deviations of Participants' Proportion of Story Recall.

	Narrative High	Narrative Medium	Narrative Low	Expository High	Expository Medium	Expository Low
			AM			
Young	0.75 (0.033)	0.53 (0.037)	0.41 (0.034)	0.41 (0.029)	0.52 (0.043)	0.29 (0.031)
Old	0.71 (0.038)	0.45 (0.043)	0.32 (0.040)	0.44 (0.034)	0.49 (0.050)	.25 (0.037)
			PM			
Young	0.77 (0.029)	0.48 (0.033)	0.37 (0.031)	0.44 (0.026)	0.48 (0.038)	0.28 (0.028)
Old	0.74 (0.043)	0.47 (0.049)	0.29 (0.045)	0.37 (0.038)	0.39 (0.056)	0.22 (0.041)

importance level recall (M = 0.48), and both were significantly higher than the low importance level recall (M = 0.35). No other significant main effects or interactions were observed.

The prose recall data were examined for outliers using Box Plots calculated separately for young and older adults for recall scores at the Narrative High Importance, Medium Importance, and Low Importance and Expository High Importance, Medium Importance, and Low Importance level. Participants whose recall performance was beyond the third quartile or below the first quartile for each group (Young, Old) were considered outliers and removed from further analyses. Two older and two younger participants were identified as outliers.

A mixed design ANOVA with Story Type (Narrative, Expository) and Importance Level (High, Medium, Low) as within-subjects factors and Age (Young, Older) and Time of Day (Morning, Afternoon) as between-subjects factors was used to analyze prose recall after removal of outliers.

No changes in significance were found for main effects of the between-subjects variables (Age, Time of Day). No changes in significance were found for main effects of within-subjects variables (Story Type, Importance Level).

After removal of outliers a significant interaction between Age, Story Type, and Time of Day $F(1, 60) = 4.97$, $p < .05$ was found. Tukey post hoc analysis, presented in Table 9, of the interaction reveals that young adults recalled a significant amount more of the expository passages in the afternoon ($M = 0.398$) than older adults in the afternoon ($M = 0.339$). Young adults did not recall significantly more of the expository passages in the morning ($M = 0.404$) than older adults in the morning ($M = 0.382$). Young adults recalled significantly more of the narrative passages in the morning ($M = 0.573$) than older adults in the morning ($M = 0.484$). Young adults did not recall significantly more of the narrative passages in the afternoon ($M = 0.537$) than older adults in the afternoon ($M = 0.531$). No other changes in interactions were found after outliers were removed.

Table 9. Post Hoc Age x Time of Day x Story Type Interaction Analysis.

	Expository		Narrative	
	AM	PM	AM	PM
Young	.404	.398	.573	.537
Older	.382	.339	.484	.531
Difference	.022	.059*	.089*	.006

* represents statistically significant difference, $p < .05$

CHAPTER IV

DISCUSSION

Previous work has suggested that cognitive performance of older and younger adults was best when they were tested at their optimal time of day (May et al., 1993; Hasher et al., 2002; Borella, Ludwig, Dirk, & Ribaupierre, 2011). This synchrony effect has been found for some cognitive tasks (sentence recognition, prose recall, Wisconsin Card Sorting Task, list recall, interference tasks) but has not been found using other tasks (Continuous Performance Test, digit span, working memory tasks, processing speed). The present study examined synchrony effects across a variety of cognitive tasks. Overall, a synchrony effect was not observed for prose recall tests but was observed for RBANS subtests.

Synchrony effects were evident by the observations of interactions between Age and Time of Day for RBANS List Recognition, Figure Copy, and Figure Recall. On Figure Recall, young adults performed better in the afternoon than the morning, while older adults remained consistent in their performance across time of day. A similar pattern of performance was found for List Recognition; older adults recognized more words in the morning than in the afternoon while young adults performance remained stable across time of day. The Age and Time of Day interaction for Figure Copy supports a synchrony effect; young adults performed better in the afternoon than the morning in Figure Copy, while older adults performed better in the morning than the afternoon.

Copying a complex figure, as found in RBANS, requires multiple cognitive domains, including visuospatial processing and executive function. A time of day effect has been supported for executive function tasks in previous research (Bennett et al., 2008). However, the present study's synchrony pattern of performance for Figure Copy also could have been produced by motivational/effort differences in young adults across time of day causing a significant interaction. Although a significant interaction on prose recall between Story Type, Age and Time of Day was observed, the interaction did not support a synchrony effect because peak performance for young and older adults did not occur consistently with their coinciding optimal time of day.

Previous research suggests that time of day moderates differences between young and older adults in some areas working memory (Borella et al., 2011; West et al., 2002; Hasher et al., 2002). Tasks in the present study did not include measures of areas of working memory such as inhibition and deletion, in which previous studies have found moderating effects for time of day. However, many of the tasks were heavily dependent upon the efficiency of working memory operations. The present study did find a possible synchrony effect for RBANS List Recognition, but not for prose recall, which is consistent with previous research that demonstrated moderating effects for time of day on word list memory, but not prose recall (Smith, Eklund, Ferraro, & Petros, 2001).

The present study also aimed to identify any moderating effects of sleep on age differences in cognitive performance. Self-reported global sleep quality was not significantly different between young and older adults. However, young adults reported significantly worse subjective sleep quality (Component 1) within the Pittsburgh Sleep Quality Index. Previous research has indicated that older adults have lower sleep quality than young adults. However, poorer sleep quality in older adults compared to young adults was not supported in the present study using a self-report measure. In previous research, longer sleep latency and poorer sleep efficiency were related to lower RBANS scores in older adults (Nebes et al., 2009). However, previous studies have not examined differences in young and older adults in sleep quality and RBANS. A lack of age differences in self-reported sleep quality fails to support sleep as significant moderating effect of age-related cognitive difference.

Another purpose of the present study was to examine possible moderating effects of nutritional intake on age-related cognitive differences. The results indicated that self-reported daily macronutrient intake (protein, fat, and carbohydrates) did not significantly differ between young and older adults. No age group differences were found for daily micronutrient (Vitamin D, Calcium, Iron, Zinc, Vitamin B6, and Magnesium) intake. However, an interaction between age and time of day was found for daily Vitamin D intake. Young adults consumed more Vitamin D per day in the afternoon than the morning, and older adults consumed more Vitamin D in the morning than the afternoon. Additionally, no age differences were found for overall caloric, cholesterol, percent of calories from alcohol, and caffeine intake.

Based on the self-report nutritional intake measure used in the present study young and older adults do not significantly differ in their daily macronutrient and micronutrient intake. Previous research examining cognitive effects of macronutrient intake primarily used experimental manipulation of macronutrient intake during or prior to cognitive testing (Benton & Stevens, 2008; Greenwood, 2003). Research has offered mixed results for macronutrient effects on cognitive performance. The present study used a self-report measure of macronutrient intake instead of experimental manipulation. A lack of age differences on the self-report measure indicates that daily macronutrient intake likely does not account for age-related cognitive differences. However, macronutrient level at time of testing, which previous research has suggested could affect cognitive performance, was not addressed in the present study.

The lack of age differences in most daily micronutrient intake also suggests that micronutrients do not significantly account for age-related cognitive differences. Previous research suggests that deficiencies in Vitamin D (Buell et al., 2008) and Vitamin B12 (Goodwin, Goodwin, & Gary, 1983) have been correlated with poorer cognitive performance. The present study was aimed to identify differences in young and older adults and, therefore, did not categorize individuals into deficient and non-deficient groups for further analysis. Since previous studies have examined deficient from non-deficient groups for effects of micronutrients, it is possible that negative effects on cognitive performance only occur after a prolonged deficiency.

A limitation of the present study is small group sizes for the older adults. Many volunteers were declined participation due to currently taking antidepressants or anti-anxiety medication. The low *n* in the older groups resulted in low power. Age differences in prose recall are strongly supported in previous studies (Dixon et al.,1984; Petros et al., 1989; Smith, Eklund, Ferraro, & Petros, 2001) and the present study did not find this effect.

Another limitation in the present study is the use of self-report measures. Self-report measures are inherently biased and may not have accurately reflected actual nutritional intake or sleep quality. Precise, objective measures or experimental manipulation may be necessary to detect effects of sleep quality and nutritional intake on cognitive performance if a small effect is present.

Motivation may have been another limitation in the present study. No effort or measures of motivation were included. Young adults were recruited from undergraduate classes for course credit, which is often required for course completion. Older adults were recruited from the community by answering advertisements or letters to alumni and were paid for participation. Overall interest in the study's topic, motivation to participate and do well likely differed across age groups. Older adults likely have had more personal experience with age-related changes in cognitive performance, which may increase interest in the study's topic. Older adults may have been aware that memory performance decreases as we age, and the older participants may have put forth greater effort to show their best performance. In contrast, the young adults likely have less personal experience with age-related cognitive changes and may have less interest in the study's topic.

A limitation in the present study is task difficulty. The RBANS is a clinical tool designed to screen older adults for cognitive decline. The RBANS subtests may not have challenged younger adults and cognitively intact older adults. While age differences were found in the present study, few time of day effects were found. The RBANS may not have been sensitive enough to produce time of day differences.

Future research could include more objective measures of nutritional intake and sleep quality. Since the present study used self-report measures and found few differences between younger and older adults for sleep quality and nutritional intake, more objective and precise measure may be necessary to find age differences. If age differences are found, then any moderating effects of sleep and nutritional intake on age-related cognitive differences could be analyzed. In addition to objective measures of overall nutritional intake, future studies could also examine current macronutrients levels through an analysis of most recent meals.

Past studies finding effects of micronutrients on cognitive performance have included older adults with normal micronutrient level compared to older adults with micronutrient deficiencies. Studying micronutrient deficiencies in young adults or micronutrient levels as predictors of cognitive performance could help further our understanding of micronutrient effects on cognitive performance.

Additionally, a battery of more cognitively challenging tasks may show more differences may be more sensitive to time of day effects. Longer word lists, increased story difficulty and length, increased complexity of the figure, and longer delay intervals could increase cognitive challenge on tasks similar the RBANS subtests.

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