FACTORS PREDICTING INTRAINDIVIDUAL COGNITIVE VARIABILITY IN OLDER ADULTS WITH DIFFERENT DEGREES OF COGNITIVE INTEGRITY

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ABSTRACT

Given the increasing number of older adults in the population, the fact that about 1 in 10 people over the age of 65 will develop mild cognitive impairment, and the substantial individual, familial, and financial burden associated with such disorders, the need for innovative research examining cognitive impairment in older adults is evident. The present study used a microlongitudinal design to assess cognition and contextual factors that may affect cognition for 14 consecutive days using a daily diary method in older adults with varying degrees of cognitive function. This study design enables investigation of concurrent associations between variables, as well as providing unique information not gleaned from the traditional focus on mean values of cognition. The present study had two broad aims: 1) to compare variability in cognition in older adults with varying degrees of cognitive impairment and 2) to investigate relationships between daily cognitive performance, variability in cognitive performance, and contextual factors that may influence daily cognitive performance and variability in older adults with varying degrees of cognitive impairment. Results suggest there was sufficient intraindividual variability in daily cognition to warrant investigation of within-person associations. Furthermore, the contextual factors of pain, stress, and sleep were predictive of cognitive performance, but with significance and directionality of these associations depending on level of measurement (baseline, daily, or mean values). Finally, associations between contextual factors and cognition were frequently conditional upon baseline cognitive status. The findings highlight the need for continued

examination of these associations to expand our understanding of cognition in older adults and to discover potential targets for interventions to attenuate cognitive decline.

DEDICATION

This dissertation is dedicated to my parents who taught me the value of hard work and the importance of using my intelligence to help others; for my brother—you are my hero and I am so proud of you; for the friends I have met in Alabama who offer unwavering support and lifesaving humor; for my husband and partner in all things, Jason, who reminds me of what life is all about; and for my little Eva, who has brought more love and joy into my life than I could have ever hoped.

LIST OF ABBREVIATIONS AND SYMBOLS

β□□	Standardized regression coefficient
B□	Unstandardized regression coefficient
df	Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data
ICC	Intraclass correlation coefficient: between-persons variance divided by total variance (sum of between- and within- persons variance)
IIV	Intraindividual variability
ISD	Intraindividual standard deviation: standard deviation around an individual's mean
M	Mean: sum of a set of measurements divided by the number of measurements in the set
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
r	Pearson product-moment correlation
R^2	Coefficient of determination
sr^2	Semi partial correlation coefficient
<	Less than
=	Equal to

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CHAPTER 1

INTRODUCTION

Overview and Specific Aims

Studies indicate that between 10-20% of Americans over the age of 65 suffer from mild cognitive impairment (MCI). Furthermore, older adults with MCI have increased risk of progressing to dementia, with 10-15% of people with MCI progressing to Alzheimer's disease (AD) within one year (Lopez, Jagust, DeKosky, Becker, Fitzpatrick, Dulberg, 2003; Manly et al., 2008). The consequences associated with AD are quite devastating, including caregiver burden (Bergvall et al., 2011; Yeager, Hyer, Hobbs, & Coyne, 2010), economic costs (Wimo, Winblad, & Jönsson, 2010), and eventual mortality (Moschetti, Cummings, Sorvillo, & Kuo, 2012), highlighting the need for innovative research into these disorders. The present study attempted to address this concern through an innovative approach – the investigation of intraindividual variability in cognitive functioning. Intraindividual variability, or within-person effects, refers to variability within an individual, and may be thought of as an indication of unpredictability (Buman, Hekler, Bliwise, & King, 2011). In contrast, interindividual differences, or between-person effects, refers to differences between individuals. Specifically, this study compared daily (within-person) variability in cognitive functioning in older adults with varying levels of cognitive impairment, and investigated factors (pain, stress, and sleep) that may influence cognitive performance and variability depending on an individual's cognitive status.

Investigation of differences in cognitive variability and what factors impact that variability can further our understanding in several ways. First, it may further understanding of the underlying cognitive processes in age-related cognitive decline. For example, people who are experiencing age-related cognitive decline might exhibit greater variability in the areas of cognition where they are showing declines. It may also provide a more complete picture of the nature of age-related cognitive impairments. Traditional analyses of cognition tend to measure outcomes based on a single testing session, or by averaging multiple testing sessions. Both approaches overlook a potentially large amount of within-person variation in cognition that may be worthy of independent investigation. In addition, investigation of whether cognitively impaired individuals are more vulnerable to the influence of contextual factors on cognitive functioning may help identify potential targets for future interventions that may attenuate cognitive decline.

Background and Significance

The study of variability has shown utility for capturing the true nature of psychological constructs that show natural fluctuation in their expression. In any behavior that fluctuates, assessing performance on a single occasion, or by averaging values, may be less accurate and representative than multiple assessments (MacDonald, Li, & Bäckman, 2009). Cognition is one construct that displays considerable fluctuation across various time scales, ranging from trial-to-trial variability to variability across testing occasions (Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000). Given the variability in cognition, the adequacy of the traditional method of using a one-time assessment or average value to estimate cognitive function comes into question. For example, poor performance on a cognitive task on a single day may be due to cognitive impairment, or may be due to extraneous factors, such as high levels of stress or pain

on a particular testing day. Another possibility is that two individuals may perform similarly on a single assessment day or may display similar mean values of cognitive performance despite different patterns of consistency in performance. Therefore, examining variability in cognition provides information about an individual's cognitive functioning that may complement what is captured in a one-time assessment or average value. The need for an accurate representation of a construct becomes even more relevant when there are increased levels of fluctuation due to the fact that mean values become less and less accurate as the amount of fluctuation increases (MacDonald et al., 2009). This may be the case with cognitive performance in older adults as compared to younger adults (Hultsch et al., 2000) or older adults with cognitive impairment as compared to healthy older adults (Strauss, MacDonald, Hunter, Moll, & Hultsch, 2002), where there are group differences in variability.

Research that has examined intraindividual variability in cognition has primarily focused on trial-to-trial variability in accuracy or latency (Hilborn, Strauss, Hultsch, & Hunter, 2009b). Although this approach provides insight into the stability of cognitive performance from moment to moment during a single testing session, this method shares similar limitations as assessing mean values of cognition in that it assesses performance at one period of time during the day (albeit examining consistency or inconsistency during the testing session).

Although there have been studies examining variability in cognition over time (Hilborn, Hultsch, & Hunter, 2009a; MacDonald, Hultsch, & Dixon, 2003), these studies usually do not assess cognition for multiple sequential days, but instead measure cognition several times over the course of a few weeks with multiple days in between each testing session. Such designs may be less precise in terms of capturing the patterns of cognitive functioning and influences on that functioning than consecutive daily measures. For example, if an individual performs poorly on

one day due to contextual influences such as stress or pain (factors that can fluctuate on a daily basis), they may display more deviation from their typical performance than they would on a day with less pain or stress, and researchers would be unable to control for these contextual factors that may have occurred that day or on previous days. An innovation of the present study is that by examining cognition across consecutive days, it may be possible to obtain a more accurate and thorough picture of the pattern of cognitive functioning an individual displays (e.g., amount of daily variability). In addition, this approach allows for the investigation of daily associations between cognition and factors that may play a role in cognitive variability. Factors such as sleep behavior, stress, and pain may influence cognition on a daily basis, a relationship that can only be investigated with a consecutive daily assessment design.

Cognitive Impairment and Intraindividual Variability

Although individuals were not formally classified as MCI for the purposes of this study, individuals with varying levels of cognitive impairment (excluding individuals whose score on a cognitive screening measure indicate impairment consistent with dementia) were enrolled in the study. Therefore, a discussion of the current consensus on MCI and its relationship with intraindividual variability is warranted. Mild cognitive impairment has been proposed as a transitional state between normal aging and dementia, with individuals displaying amnestic MCI thought to progress to Alzheimer's disease, while individuals with non amnestic MCI may progress to vascular, fronto-temporal, or Lewy body dementia (Mariani, Monastero, & Mecocci, 2007).

Studies examining neural correlates of cognitive impairment have found atrophy in entorhinal, hippocampal-amygdala, and medial temporal lobe regions of the brain in individuals with MCI (Mariani et al., 2007). Functional MRI studies have found non-linear activation

patterns in individuals with MCI and AD, such that a pattern of increased activation in the hippocampus, medial temporal lobe, and fusiform regions occurs in very mild MCI (Hämäläinen et al., 2007; Sperling, 2007), followed by decreased activation in more progressed MCI and AD (Sperling, 2007). Furthermore, this pattern of increased activation in MCI individuals occurs in the presence of more atrophy in the anterior hippocampus as compared to controls, suggesting a possible compensatory mechanism (Hämäläinen et al., 2007). These findings suggest there may be a period of increased activation in the brain regions critical for successful memory in the early stages of MCI that compensate for structural atrophy.

In a review of relevant literature, Mariani et al., (2007) found that individuals with MCI show impaired functioning in memory and complex reasoning tasks. Some studies suggest impairment not only in episodic memory, but also in executive function tasks requiring response inhibition, switching, and cognitive flexibility in individuals with MCI (Traykov, Raoux, Latour, Gallo, Hanon, Baudic, Bayle, Wenisch, Remy, & Rigaud, 2007). These results suggest that a focus on memory and executive functions was warranted in the current study.

The goal of this study was to examine individuals along a continuum of cognitive functioning to obtain a more accurate representation of relationships between contextual variables and cognition in individuals than might be obtained by placing individuals in one group or another. Such dichotomizing of individuals may necessarily exclude a number of participants who do not fully meet criteria for MCI but who are also not cognitively intact. Furthermore, MCI is quite heterogeneous in terms of underlying causes of the impairment, an individual's clinical presentation, and expected outcomes (Mariani et al., 2007). Given the diverse origin, presentation, and cognitive consequences of MCI, it was unlikely that we would obtain a homogeneous subset of MCI individuals that could be considered to have the same etiology and

presentation of their cognitive impairment. In other words, by examining cognitive impairment along a continuum, a more inclusive and ecologically valid sample of participants could be obtained.

There is evidence that intraindividual variability may be a useful indicator of cognitive integrity with more cognitive variability indicative of neurological disturbance or degeneration (Bielak, Hultsch, Strauss, MacDonald, & Hunter, 2010). For example, Hultsch et al. (2000) found that older adults with dementia displayed greater levels of intraindividual variability (IIV) in cognitive performance than older adults with arthritis or healthy older adults, who did not differ in variability. Variability uniquely differentiated between groups above and beyond average performance levels, attesting to the utility of variability as an indicator of possible neurological disturbance. In the Hultsch et al., 2000 study, individuals completed two reaction time tasks, and two episodic memory tasks on four separate weekly occasions. The current study extended these findings by addressing variability on a daily as opposed to weekly basis. However, at least one study did not find IIV to uniquely contribute to diagnostic status in people with MCI, although the MCI group did display significantly greater variability in reaction time than healthy older adults (Christensen et al., 2005). Studies in other domains, such as IIV in sleep processes, have found that changes in variability do not necessarily correlate with changes in mean values (Buman et al., 2011), suggesting variability within an individual may be independent of mean values for some constructs. Further research is needed to clarify whether measures of variability are useful in the diagnosis and prognosis of MCI.

Another important consideration is what factors may be influencing trial-to-trial variability as compared to day-to-day variability. Some researchers suggest that trial-to-trial variability is likely susceptible to brain-based influences, such as neural degeneration, while day-

to-day variability is more likely to be influenced by contextual or exogenous factors such as stress or pain (Bielak et al., 2010; MacDonald et al., 2009). A daily assessment of cognition was the most appropriate timescale for the present study given that an aim of the study was to determine what effect variables other than compromised neural integrity, such as pain, stress, and sleep, have on cognition. By determining what factors are associated with cognitive variability, and whether some individuals with differing levels of cognitive impairment are more vulnerable to those factors, important insight will be gained that can inform future treatment interventions.

Benefits and Limitations of Daily Process Study Designs

The use of daily assessment methods has several benefits. This design may help reduce recall bias, by allowing participants to report daily. Such a study design may be particularly useful in older adult populations who may be experiencing age-related declines in memory that make recall more difficult. Similar to other repeated measures study designs, in daily diary methods, each participant serves as his or her own control, eliminating some forms of confounding. In other words, the unobserved characteristics of participants that do not change over time, but are not being measured, are controlled in repeated measures, allowing each participant to serve as his or her own control.

Despite the many benefits of a microlongitudinal daily diary design, there are several limitations. First, daily diary studies are labor intensive, both for researchers and for the participants involved in the study. The amount of participant burden must be taken into consideration in order to design a study that will gather enough data but still be feasible for participants to complete on a daily basis. Daily cognitive assessments were completed over the telephone to help reduce participant burden by limiting the amount of paper and pencil materials participants were required to complete. This method also ensured that the assessments were

completed each day at a particular time, addressing one validity argument frequently raised against daily diary methods, namely that researchers are often unaware of exactly when participants complete their daily diaries. For example, when using paper diaries, a participant may forget to fill out their diary for three days, and then go back and complete the past three days at one time, increasing the likelihood that the data will not be reliable or valid. Second, the nature of daily diary studies raises questions about external validity. It is possible that people who are monitoring their behavior frequently give different responses than would be obtained from people not consciously monitoring their behavior (Affleck et al., 1999). To address this issue, time was included as a variable in the multilevel models for the second and third aims of the study, which allowed determination of whether individuals are responding differently the longer they are monitoring their behavior. Finally, daily diary studies collect data that may be influenced by the effects of time. For example, participants may show improved cognitive function simply from gaining familiarity with the daily cognitive measure over the course of two weeks (e.g., practice effects). This limitation was addressed by detrending the data for the effects of time (where indicated), thus removing the effects of time and leaving a pure measure of variability. This procedure is commonly used in daily diary studies to address learning and/or practice effects. Furthermore, alternate forms of the daily battery were used in an attempt to address the issue of practice effects and familiarity with the daily cognitive assessment.

The innovations of this study included: 1) the examination of daily variability in cognitive functioning in both cognitively impaired and healthy older adults; 2) the use of a microlongitudinal design which enables the study of concurrent relationships between contextual factors and cognition; and 3) by studying individuals in their own environments over time, while assessing multiple facets of their environment, a more ecologically valid understanding of

cognitive functioning can be obtained as compared to methods that only use laboratory assessments, at one time point, with a limited focus. The significance of this study is the ability to identify precursors to cognitive variability that could lead to future targets for treatment interventions.

Background for Specific Study Aims

Aim 1. The purpose of Aim 1 was to examine associations between baseline cognitive status and contextual factors as they relate to variability in daily cognitive performance. When investigating variability in cognition, a consistent finding in the literature is that older adults who display greater trial-to-trial variability also display lower cognitive functioning (Strauss et al., 2002). Given this finding, a similar relationship was expected when cognition is assessed daily, with older adults who performed worse on baseline cognitive measures showing more variable patterns of cognitive performance than older adults with better baseline cognitive performance. In other words, we expected to find an association between cognitive functioning and variability in cognition such that individuals who have poorer cognitive functioning at baseline would be more variable on a day-to-day basis.

As will be discussed in more detail below, there are associations in the literature between cognitive performance and pain (e.g., Weiner, Rudy, Morrow, Slaboda, & Lieber, 2006), stress (e.g., Stawski, Mogle, & Sliwinski, 2011), and sleep (e.g., Ohayon & Vecchierini, 2002). Specifically, greater pain, higher stress, and worse sleep are associated with worse cognitive performance. In addition, worse cognitive performance overall has been linked to more variable cognitive performance. Therefore, it was hypothesized that there would be significant associations between cognitive variability and the contextual factors of interest such that greater

baseline pain, higher baseline stress, and poorer baseline sleep predicted more variability in cognitive performance in the daily cognitive diaries.

Aim 2. Aim 2 sought to examine both between- and within-level associations between contextual factors and daily cognitive performance, and to determine if these associations were moderated by baseline cognitive status. Several hypotheses were made regarding the possible relationships between the contextual factors assessed and cognitive functioning. A detailed discussion of the contextual factors selected for inclusion in this study, how they relate to baseline and daily cognition, and how they relate to each other is included below.

Pain and Cognition. Previous research has found that older adults who experience chronic pain also display decreased cognitive performance (Weiner et al., 2006). Pain associated with rheumatoid arthritis, fibromyalgia, and musculoskeletal disorders has been associated with poorer performance on attention and working memory tasks as compared to healthy controls (Dick, Eccleston, & Crombez, 2002), and higher levels of pain have been associated with poorer performance on global cognitive measures (Kewman, Vaishampayan, Zald, & Han, 1991). Furthermore, people with low levels of pain have slower reaction times and displayed lower accuracy on visuospatial and decision making tasks than controls, suggesting that pain demands attention and may impair cognitive performance (Harman & Ruyak, 2005). While pain likely demands attention, some authors suggest that cortical plasticity plays a role in the effects of pain on cognition, such that chronic pain leads to decreased cortical plasticity, which in turn impairs cognitive function (Seminowicz & Davis, 2007).

Given the above findings, it was hypothesized that days with higher levels of pain would be associated with days of worse cognitive performance (Aim 2.1). Furthermore, it was hypothesized that people who had higher levels of pain in general would display lower baseline

cognitive function (Aim 2.1). This is the first study to my knowledge to investigate the relationship between pain and cognition on a daily basis in a sample of older adults with varying degrees of cognitive integrity, making Aim 2.2 exploratory. However, in terms of whether the hypothesized daily relationships between pain and cognition would differ depending on one's baseline cognitive functioning, the compromised brain structure and function of older adults with cognitive impairment might make them more susceptible to the effects of pain. For example, an individual with cortical degeneration in the frontal lobe may experience attention difficulties from this degeneration that are further exacerbated by any pain symptoms they experience. If pain indeed reduces cortical plasticity, people who experience pain in addition to cognitive impairment associated with aging may show additive negative effects of these two processes working in tandem. In other words, comparing two individuals with the same amount of daily pain, an individual with cognitive impairment may show a greater decrement in cognitive performance on days when they experience pain than an individual without cognitive impairment because the magnitude of the effects of daily pain on cognition is greater for the individual with cognitive impairment. A note of caution is warranted here, as several studies have found lower prevalence rates of reported pain associated with increased cognitive impairment, which was not a function of either lower prevalence of conditions that might cause pain or an increase in pain tolerance (e.g. Proctor & Hirdes, 2001), suggesting that older adults with cognitive impairment may not be able to accurately report their pain symptoms. Individuals with cognitive impairment may underreport pain due to decreased ability to understand verbal pain scales and communicate effectively about their pain (Snow & Shuster, Jr., 2006). Previous studies have found that individuals with an MMSE score below 15 are significantly impaired in terms of their ability to complete verbal pain rating scales, and suggest behavioral observations are essential to best

practices of pain assessment in impaired populations (Buffum, Hutt, Chang, Craine, & Snow, 2007). However, such behavioral observations were not feasible for the daily pain assessments in the present study. Instead, a 5-point pain rating scale was adopted based on literature suggesting older adults with cognitive impairment may have more success with a 5-point scale (Jones et al., 2005) than the classic 10-point pain scale used with cognitively intact individuals.

Aim 3. Similar to the second aim but with a focus on variability in cognitive performance as opposed to overall cognitive performance, Aim 3 sought to examine both between- and within-level associations between contextual factors and variability in daily cognitive performance, and to determine if these associations were moderated by baseline cognitive status. Given the lack of research on contextual factors and their relationship to cognitive variability in general, Aim 3 is largely exploratory. However, several predictions can be made from the basis of what is known regarding cognitive variability, and how the contextual factors under consideration impact cognitive performance overall. Previous studies have established that cognitive variability is associated with poorer cognitive performance overall. Furthermore, the three contextual factors under consideration, namely pain, stress, and sleep, are known to impact cognitive performance negatively when sleep is disrupted, or when pain or stress increase. Therefore, an association was expected such that similar changes in contextual factors would lead to increased variability. In other words, poor sleep, for example, is associated with poor cognitive performance, and poor cognitive performance is associated with more variability in performance. Therefore, poor sleep (and greater stress and pain) may lead to more variable performance, which has previously been measured only at the average cognitive performance level (Aim 3a). In terms of the role of baseline cognitive status on the association between contextual factors and cognitive variability, an argument similar to Aim 2b can be

made, such that individuals with cognitive impairment have compromised cognitive abilities and likely damaged neural structures, and may therefore be less able to compensate for the deleterious effects of greater pain, higher stress, or poor sleep.

Stress and Cognition. A general finding in the literature is that people with more stress exhibit worse cognitive performance (Neupert, Almeida, Mroczek, & Spiro, 2006a). However, the relationship between stress and cognition on a daily basis has received less attention. Previous studies have found that subjective reports of everyday memory failures (Neupert, Almeida, Mroczek, & Spiro, 2006b) and subjective reports of cognitive interference (Stawski et al., 2011) are higher on days when individuals experience stressors. In addition, up to 20% of the variance in daily mood can be explained by daily stressors, suggesting there is justification for examining stress at the daily level (e.g. Bolger, Delongis, Kessler, & Schilling, 1989). Therefore, we hypothesized that on days when individuals reported higher levels of stress, they would also display poorer performance on cognitive tasks (Aim 2.1). Daily stressors may play an important role in cognition, as they likely divert attention towards the stressor, which may in turn make cognitive tasks more difficult (Neupert et al., 2006a). A daily diary study of 333 older adults found that individuals were more likely to report memory failures on days when they experienced stressors, and the experience of stressors was associated with memory failures on subsequent days as well (Neupert et al., 2006a). Importantly, memory failures recorded in the Neupert and colleagues study were all subjective in nature. The current study extended these findings by including objective measures of cognitive performance that may attenuate problems of recall and social desirability biases. Daily associations between stress and cognition have been found in both younger and older adults (Sliwinski, Smyth, Hofer, & Stawski, 2006),

suggesting that similar coupling between daily stress and daily cognitive performance would be found in the present study, with worse cognitive performance on days of higher stress (Aim 2.1).

The role of hormones in the link between stress and cognitive performance is well established (e.g., Mcewen & Sapolsky, 1995). It has long been known that stress leads to an increase in epinephrine, norepinephrine, and glucocorticoids, which in turn impacts cognitive performance (McEwen & Sapolsky, 1995). Prolonged exposure to stress is associated with impaired cognitive performance, but the short-term effects of stress on cognition may be more complex (McEwen & Sapolsky, 1995). Studies have shown that up to a certain point, stress may actually improve memory performance due to the release of glucocorticoids. However, too much stress impairs memory performance, with studies showing increased errors in immediate and delayed recall tasks as the amount of glucocorticoids increased (Mcewen & Sapolsky, 1995). These early findings suggest there may be an optimal level of stress at which memory is enhanced, but past this optimal level, memory performance decreases. More recently, it has been suggested that whether stress hormones have a positive or negative impact on cognition depends on the memory process under consideration. Lupien, Maheu, Tu, Fiocco, & Schramek (2007) reported that across studies, experimentally induced stress led to impaired cognitive performance, particularly in the domains of learning and memory. At the neuroendocrine level, elevated stress hormones in humans are associated with decreased memory performance (Lupien, Mcewen, Gunnar, & Heim, 2009). Furthermore, animal studies have shown atrophy in the hippocampus, amygdala, and frontal cortex, along with inhibited neurogenesis, and even Alzheimer's type pathology when older rats and monkeys are exposed to increased levels of stress hormones (Lupien et al., 2009).

In a review by Roozendaal (2002) the author suggests that in general, stress seems to improve memory consolidation but has deleterious effects on memory retrieval. Furthermore, studies examining the complex mechanisms underlying the relationship between stress and cognition have not been conducted in older adults with cognitive impairment, suggesting this is an area that deserves further attention. Given that these findings suggest stress exposure may impact both brain structure and function, an argument can be made that in individuals who may already be experiencing cognitive difficulties due to structural damage or degeneration, the effects of stress may be additive or may magnify the already diminished cognitive capabilities (Aim 2.2). Furthermore, it has been found that higher levels of fluid cognitive ability are associated both with greater exposure to daily stressors, but also with smaller changes in mood as a result of this exposure, suggesting that individuals with higher levels of fluid cognitive ability may be less impacted by the stress they encounter in daily life (Stawski, Almeida, Lachman, Tun, & Rosnick, 2010). Individuals experiencing cognitive impairment often show a decrease in fluid abilities while crystallized abilities remain intact for longer periods of time (Horn, & Cattell, 1967). Given the above findings, it is possible that individuals with cognitive impairment may not benefit from the buffering effect of higher fluid cognitive ability as they encounter daily stressors, which may lead to those stressors having a greater impact on cognitive performance in impaired individuals (Aim 2.2).

Sleep and Cognition. In terms of the association between sleep and cognition, studies have found that poor average sleep outcomes in older adults are associated with both subjectively reported and objectively measured impaired cognitive function (Ohayon & Vecchierini, 2002). Furthermore, cognitive decline has been associated with objective sleep disturbance as measured by actigraphy in non demented older women, with individuals experiencing cognitive decline

displaying decreased sleep efficiency, increased wake time after sleep onset, and increased time to fall asleep as averaged across three days (Yaffe, Blackwell, Barnes, Ancoli-Israel, & Stone, 2007). A 2004 survey found that older adults with memory problems were more likely to report disrupted sleep behavior, such as difficulty initiating and staying asleep, as compared to older adults without memory problems (Foley, Ancoli-Israel, Britz, & Walsh, 2004). In a recent review of the literature, it was found that 14-59% of patients with MCI reported disruptions in their sleep and that such complaints are among the most common neuropsychiatric symptoms in individuals with MCI (Beaulieu-Bonneau & Hudon, 2009). There is evidence that the reports of sleep disruption in people with MCI likely reflect actual changes in the structure of their sleep. For example, amnestic MCI patients displayed fewer components of sleep important for memory processing, such as time spent in slow wave sleep, than healthy controls (Westerberg et al., 2012).

Sleep is required for optimal cognitive functioning and is particularly important for memory consolidation. For example, a review of fMRI studies concluded that there was evidence that sleep deprivation disrupted sleep-dependent memory consolidation, resulting in decreased working memory, short term memory, and long term memory performance (Chee & Chuah, 2008). In addition, studies have found sleep disruptions in MCI patients may contribute to memory impairments by interfering with memory consolidation processes that occur during particular stages of sleep (Westerberg et al., 2012).

The relationship between sleep and cognition may vary between individuals as well as within each individual, and these relationships may represent distinct but equally important aspects of the association between sleep and cognition. Sleep loss has been associated with global deficits in working memory and executive functions, with the amount of deficit varying

significantly between individuals while remaining stable within individuals (Van Dongen, Baynard, Maislin, & Dinges, 2004). There is also evidence that individual differences in sleep behavior may influence cognitive performance, such that individuals who sleep less, or have difficulty falling or staying asleep on a regular basis, display poorer performance on tests of general cognition, verbal memory, category fluency, and attention (Tworoger, Lee, Schernhammer, & Grodstein, 2006). Furthermore, previous studies have found within-person coupling of sleep and cognition in healthy older African Americans, such that the greater an individual varied from his or her average amount of sleep, the worse global cognitive performance he or she displayed the following day (Gamaldo, Allaire, & Whitfield, 2010), and that individuals who had trouble falling asleep performed worse on short term memory and working memory tasks (Gamaldo, Allaire, & Whitfield, 2008).

These findings suggest examination of the relationship between sleep and cognition at both between- and within-level analyses is important. Taken together, the above-mentioned results suggest we may find similar relationships at both between- and within-person levels of analysis. Specifically, individuals with poorer sleep outcomes on average were expected to also display poorer cognitive functioning, representing a between-person association between sleep and cognition. Furthermore, poorer daily sleep outcomes were hypothesized to predict worse cognitive performance the next day, representing a within-person association between cognition and sleep on a daily basis.

Interestingly, the Gamaldo et al., (2010) study found that sleep duration, but not sleep quality, was related to cognitive performance on a daily basis (Gamaldo et al., 2010). However, several studies have found no relationship between total sleep time and cognitive functioning (Blackwell et al., 2006; Yaffe, Blackwell, Barnes, Ancoli-Israel, & Stone, 2007). Apart from the

Gamaldo et al., 2010 study mentioned previously, which examined associations at eight time points over several weeks, the majority of studies investigating the link between sleep and cognition used mean values of daily data in their analyses, and often measured cognition at only one point in time. It is possible that there is a daily relationship between sleep duration and cognition that is not found in one-time assessments or by averaging values. The current study sought to shed light on the reasons for such inconsistencies in the literature regarding sleep and cognition.

Importantly, research suggests cognitive impairment associated with poor sleep outcomes is specific to certain cognitive domains. For example, poor sleep has been associated with decreased working memory, set shifting, abstract problem solving, global cognition, verbal knowledge, long-term memory, visuospatial reasoning, and verbal short-term memory (Blackwell et al., 2006; Nebes, Buysse, Halligan, Houck, & Monk, 2009; Schmutte et al., 2007). Furthermore, sleep disorders, such as sleep-related breathing disorders, insomnia, and narcolepsy are associated with reduced performance on tasks of attention and memory (Fulda & Schulz, 2001; Haimov, Hanuka, & Horowitz, 2008), and excessive daytime sleepiness in individuals with mild to moderate dementia is associated with impaired cognitive performance in global cognition, executive function, attention, working memory, episodic memory, and reasoning (Bonanni et al., 2005). The baseline battery of the present study examined overall cognitive performance, executive function, attention, episodic memory, language, processing speed, and working memory. The daily cognitive diary assessed executive function, attention, episodic memory, working memory, reasoning, and processing speed. These specific domains were selected for their association with cognitive impairment, and inclusion in previous studies that used brief cognitive batteries similar to the one developed for the present study.

Although the literature examining daily relationships between sleep and cognition is limited, there are a few studies that have taken a daily diary approach to investigate this relationship. For example, Naismith et al., (2010) examined associations between cognition at baseline and averaged daily sleep outcomes in older adults with MCI. They found that greater time spent awake after falling asleep was associated with poorer performance on measures of attention and executive function. Furthermore, increased numbers of arousals during the night were associated with worse performance on measures of nonverbal learning and problem solving. These findings suggest that cognitive functions associated with the frontal lobe were affected by poor sleep outcomes (Naismith et al., 2010). While this study illuminates important associations between sleep and cognition in a population with cognitive impairment, and provides evidence for a link between a one-time measure of cognition and daily sleep outcomes, the results do not speak to the possible impact of daily sleep outcomes on daily cognitive performance. The present study extended these findings by measuring cognition daily to allow examination of associations between sleep and cognition at the daily level in older adults with varying levels of cognitive integrity. Furthermore, it is important to consider that the relationship between sleep and cognition may be bidirectional. In terms of possible temporal relationships between sleep and cognition, one study found that subjective sleep complaints predicted decreased cognitive performance at a three year follow up, suggesting that sleep can lead to poorer cognition (Jelicic, Bosma, Ponds, Boxtel, & Houx, 2002). The relationship between sleep and cognition may be straightforward, such that sleep impacts cognition directly or may be one in which sleep indirectly influences cognition, such as through a meditational relationship with another construct associated with sleep and cognition such as depression.

McCrae, Vatthauer, Dzierzewski, & Marsiske (2011) used daily diaries to examine sleep and cognition in healthy older adults with complaints of poor sleep. The authors found that variability in sleep outcomes was not significantly associated with cognition, but that average sleep outcomes were significantly associated with cognition, with increased average total wake time associated with higher scores on a measure of processing speed. These findings may at first seen counterintuitive, but the authors suggested they may represent a compensatory effect such as increased effort or hyperarousal due to the disruption in sleep the previous night (McCrae et al., 2011). In other words, individuals who slept poorly the night before may be hyperaware of their performance and monitor it more closely because they are expecting impairments due to poor sleep, thus leading to increased effort and arousal. The present study extended these findings by looking at the association between sleep outcomes and daily cognition in a sample of older adults with differing levels of cognitive ability and who may or may not have complaints of poor sleep. The inclusion of a more representative sample of older adults in terms of sleep behavior and cognitive ability may allow a more generalizable pattern of results. The McCrae et al. (2011) study also serves as a reminder that the relationship between sleep and cognition may not always be clear or follow the expected pattern and validates the examination of this relationship at multiple temporal levels (e.g., daily and at the individual level).

In summary, there is strong support for a link between sleep and cognition. Overall, the literature suggests that poor sleep is associated with worse cognition in various populations when looked at in terms of average values, but this relationship requires further exploration on the daily level. There is some evidence for a daily coupling effect, such that poor sleep on one day is associated with worse cognitive function the following day (Gamaldo et al., 2010), while other studies have found poor sleep outcomes to be associated with better performance the following

day (McCrae et al., 2011), suggesting further research is needed to determine what relationships exist between various sleep outcomes and different cognitive functions at the daily level. Furthermore, there is evidence that older adults with cognitive impairment show worse sleep than healthy older adults. This may lead to an additive effect, such that older adults with cognitive impairment also exhibit impairments in cognition due to disrupted sleep. There is a paucity of research on the relationship between sleep and cognition in older adults with cognitive impairment, and how this relationship may be different from healthy older adults when examined on a daily basis.

Based on the literature reviewed above, it was hypothesized that poor sleep would be associated with worse cognitive performance at both the between- and within-person level (Aim 2.1). Furthermore, older adults with cognitive impairment were expected to be more vulnerable to the effects of poor sleep than older adults without cognitive impairment (Aim 2.2). This hypothesis was based on the finding that older adults with cognitive impairment often display poorer sleep outcomes. In addition, poor sleep outcomes are associated with worse cognitive performance. Accordingly, older adults who display cognitive impairment may show cognitive deficits from an underlying neurological problem, which is exacerbated by a common symptom of cognitive impairment, namely poor sleep. Furthermore, older adults with cognitive impairment are known to display decreased activation in both frontal and medial temporal lobes of the brain, which are associated with deficits in performance of memory and executive function tasks. These cognitive domains are also affected by poor sleep, which could again prove to have an additive effect, such that neurological deficits are compounded by poor sleep, which impacts cognitive functions controlled by regions of the brain known to be affected in older adults with cognitive impairment.

Relationship Among Contextual Variables. There is undoubtedly a relationship among many of the contextual variables that were examined in this study. For example, there is a well-established link between pain and sleep (Dzierzewski et al., 2010). It was beyond the scope of this study to elaborate on all possible relationships among the various contextual factors under consideration. As such, the focus of this study was on the relationship between the chosen contextual factors and cognition.

Summary of Aims and Hypotheses of the Present Study

- **Aim 1.** To examine variability in cognition in older adults with varying degrees of cognitive impairment and varying presentations of baseline contextual factors.
- ***Aim 1.1.*** To examine the association between baseline cognitive status and variability in cognitive performance.
    - *Hypothesis 1.1.* Individuals who have poorer cognitive functioning at baseline will be more variable in their cognitive performance on a day-to-day basis.
- ***Aim 1.2.*** To examine the association between baseline pain, stress, and, sleep and variability in cognitive performance.
    - *Hypothesis 1.2.1.* Greater baseline pain will predict more variability in daily cognitive performance.
    - *Hypothesis 1.2.2*. Higher baseline stress will predict more variability in daily cognitive performance.
    - *Hypothesis 1.2.3*. Poorer baseline sleep will predict more variability in daily cognitive performance.
- **Aim 2.** To investigate relationships between contextual factors and cognitive performance.

- ***Aim 2.1.*** To investigate the relationship between contextual factors and daily cognitive performance at both between- and within-person levels of analyses.
    - *Hypothesis 2.1.1.* Higher levels of pain will be associated with worse cognitive performance at both the between- and within-person level.
    - *Hypothesis 2.1.2.* Higher levels of stress will be associated with worse cognitive performance at both the between- and within-person level.
    - *Hypothesis 2.1.3.* Poor sleep will be associated with worse cognitive performance at both the between- and within-person level.
- ***Aim 2.2.*** To determine if the relationships between contextual factors and cognitive performance differ between individuals depending on their level of cognitive functioning.
    - *Hypothesis 2.2.1.* This is the first study to my knowledge that investigated the relationship between pain and cognition on a daily basis in a sample of older adults with varying degrees of cognitive integrity, making this component of Aim 2.2 exploratory.
    - *Hypothesis 2.2.2.* In individuals who may already be experiencing cognitive difficulties due to structural damage or degeneration, the effects of stress may be additive or may magnify the already diminished cognitive capabilities such that older adults with lower baseline cognitive functioning show worse cognitive performance in association with stress compared to older adults with higher levels of baseline cognitive functioning.
    - *Hypothesis 2.2.3.* Older adults with lower baseline cognitive functioning will show a stronger association between poor sleep and worse cognitive performance than older adults with higher levels of baseline cognitive functioning.

- **Aim 3.** To investigate the relationship between contextual factors and cognitive variability.
- ***Aim 3.1.*** To investigate the relationship between contextual factors and variability in cognitive performance.
    - *Hypothesis 3.1.1.* Higher levels of pain will be associated with greater variability in cognitive performance.
    - *Hypothesis 3.1.2.* Higher levels of stress will be associated with greater variability in cognitive performance.
    - *Hypothesis 3.1.3.* Poor sleep will be associated with greater variability in cognitive performance.
- ***Aim 3.2.*** To evaluate whether contextual factors differentially predict variability in older adults with varying levels of cognitive functioning.
    - *Hypothesis 3.2.1.* This is the first study to my knowledge that investigated the relationship between pain and cognition on a daily basis in a sample of older adults with varying degrees of cognitive integrity, making this component of Aim 3.2 exploratory.
    - *Hypothesis 3.2.2.* In individuals who may already be experiencing cognitive difficulties due to structural damage or degeneration, the effects of stress may be additive or may magnify the already diminished cognitive capabilities such that older adults with lower baseline cognitive functioning show more cognitive variability in association with stress compared to older adults with higher levels of baseline cognitive functioning.

- *Hypothesis 3.2.3.* Older adults with lower baseline cognitive functioning will show a stronger association between poor sleep and worse cognitive performance than older adults with higher levels of baseline cognitive functioning.

CHAPTER 2

METHODS

Participants.

Older adults aged 65+ were recruited from the community including members of FOCUS on Senior Citizens, Osher Lifelong Learning Institute, and from the database of potential participants at the Center for Mental Health and Aging. A final sample of N = 38 individuals were included in analyses. Out of 40 participants originally recruited, one dropped out because of the amount of time required each day to complete the study, and one dropped out because of difficulty completing the daily cognitive diary. Inclusionary criteria for this study included being 65 years of age or older and having adequate hearing and vision to complete telephone and written assessments. Individuals were excluded if they have any of the following: hearing problems that prevent telephone screening or assessments, vision impairment that would prevent completion of questionnaires and baseline assessment, self-reported diagnoses of Parkinson's disease, Alzheimer's disease, any other form of dementia, Multiple Sclerosis, ALS/Lou Gherig's disease, Schizophrenia, Bipolar Disorder, history of stroke, or history of head trauma. The majority of the sample was White, female, married, had a Bachelor's degree or higher, and were unemployed or retired. See Table 1 for a summary of participant demographics.

Participants were given an incentive ($60 plus mileage reimbursement) to complete the study. All participants signed an informed consent at the first meeting with the researcher. Given the potential that participants may be cognitively impaired older adults, the Decision-

Making Capacity Assessment Tool provided by the University of Alabama IRB was administered to each potential participant to determine whether or not they are able to consent themselves to participate in the study. There were no potential participants who were deemed unable to consent to the study.

The presence of both between-person and within-person levels of analyses complicated the determination of power as both levels of analyses must be taken into account. Sample size has different effects at the different levels of analyses such that larger sample sizes increases reliability of measures of within-person variability at level 1 and reliability of measures of between-person differences at level 2. Importantly, greater sample size increases reliability of measures at both between- and within- person levels but, as they are measuring different outcomes, there is greater reliability for the level specific outcomes (i.e. within –person associations and between-person differences). Researchers have recommended a minimum sample size of $n = 6$ per Level 1 unit and a minimum of $N = 10$ for higher-level units (Snijders and Bosker, 1993). In this study, 14 level 1 units were nested within ≥10 level 2 units, whichexceeds the suggested minimum requirements for adequate power to detect an effect using multilevel modeling analyses. The final sample size for the current study was N = 38. Furthermore, a null model for the outcome variable of interest, namely daily cognition, was conducted to determine if there was a statistically significant level of variability in cognitive performance to justify proceeding with multilevel modeling analyses. Results of the null model are presented in Table 2 and indicated significant within-person variance ($p < .01$) to proceed with multilevel modeling analyses.

Table 1

Sample Characteristics (N = 38)

	Minimum	Maximum	Mean	St. Dev.
Age	65.00	89.00	73.40	7.19
Income	$10,000.00	$100,000.00	$57,354.85	$29,107.08
	Frequency		Percent of Sample	
Gender				
Male	8.00		24.20	
Female	25.00		75.80	
Race				
White	32.00		97.00	
Black	1.00		3.00	
Education				
High School	3.00		9.10	
Some College	7.00		21.20	
Bachelor's	5.00		15.20	
Master's	11.00		33.30	
Ph.D.	7.00		21.20	
Marital Status				
Single	2.00		6.10	
Married	18.00		54.50	
Divorced	5.00		15.20	
Widowed	8.00		24.20	
Employment Status				
Employed	5.00		15.60	
Unemployed/Retired	27.00		84.40	

Table 2

Estimates of Between- and Within-Person Variance in Daily Diary Variables for Entire Sample

	Within-person		Between-person		Covariance Significance Value	Ratio of Within/Between
	Variance Component	% Within	Variance Component	ICC (% Between)		
Cognition	0.08	24.19	0.26	75.81	<0.01	0.32
Pain	0.24	35.45	0.44	64.55	<0.01	0.55
Stress	1.06	72.20	0.41	27.80	<0.01	2.60
SOL	409.89	66.40	207.39	33.60	<0.01	1.98
NWAK	0.76	39.08	1.19	60.92	<0.01	0.64
WASO	598.98	59.52	407.43	40.48	<0.01	1.47
SQR	0.05	45.69	0.55	54.31	<0.01	0.84
TWAK	772.22	44.31	970.73	55.69	<0.01	0.80
TST	7345.85	52.74	6582.48	47.26	<0.01	1.12
TWT	2428.10	49.92	2435.53	50.08	<0.01	1.00
SEI	77.10	38.72	122.03	61.28	<0.01	0.63

Note. ICC = intraclass correlation coefficient; SOL= sleep onset latency; NWAK= number of nighttime awakenings; WASO= wake-time after sleep onset; SQR = sleep quality ratings; TWAK = total wake time after morning awakening before exiting bed; TST = total sleep time; TWT = total wake time; SEI = sleep efficiency index.

Variance components estimated from null multilevel models.

Procedure

During an initial over-the-phone interview, all potential participants were screened for the inclusionary/exclusionary criteria. Participants then completed baseline self-report measures and an in-person baseline cognitive assessment in the lab at the University of Alabama. Following the baseline assessment, participants were asked to complete 14 consecutive telephone and self-administered daily diaries (assessing cognition, sleep behavior, stress, and pain) and to wear an Actiwatch 2 on their non-dominant arm (Phillips Respironics [Actiwatch 2]. Andover, MA: Phillips Healthcare, 2009) (assessing sleep behavior and physical activity) for 14 consecutive days. Actigraphic results will not be presented in the current document but will be used in future analyses. All daily cognitive diaries were completed over the telephone. Daily sleep, stress, and pain were assessed via paper packets given to participants during the baseline assessment. Each participant was provided face-to-face feedback after completion of the 14 days of daily data collection to answer any questions that may have come up during the course of the study and to also provide an opportunity to suggest further evaluation to those individuals who displayed impairment in cognitive function.

Measures

Screening and Demographics. The following measures were used to screen potential participants and to gather demographic, health, and psychological information to be used in analyses of the data.

Telephone Interview for Cognitive Status-Modified (TICS-M). All potential participants first completed a telephone screening to assess for inclusion and exclusion criteria and gather general demographic information (see Appendix I). Individuals eligible for study participation after screening were given the Telephone Interview for Cognitive Status-Modified

(TICS-M) (Brietner et al., 1990) (see Appendix II). The TICS-M comprises four domains assessed with 13 items (maximum total score = 39): 1) orientation, 2) memory (registration, recent memory, and delayed recall 3) attention/calculation, and 4) language (semantic memory, comprehension, and repetition) (De Jager et al., 2003). Each individual's score on the TICS-M was adjusted for education (Breitner et al., 1995). A cutoff score of 20 was used to exclude potential participants who likely had cognitive impairment severe enough to hinder study completion. The TICS has shown excellent test-retest reliability (r = 0.90) and good convergent validity (0.86) with other measures of general cognitive status (e.g. MMSE; Folstein, Folstein, & McHugh, 1975). It also demonstrates good sensitivity (1.00) and specificity (0.83) when a cutoff score of <25 is used to discriminate between individuals who likely have dementia versus individuals who do not (Desmond, Tatemichi, & Hanzaw, 1994).

Demographics and Health Questionnaire. Prior to the baseline assessment, participants completed a demographics and health form asking for basic information such as age, gender, race and ethnicity, occupational status, marital status, level of education, and questions regarding their health status and history (see Appendix III).

Pittsburg Sleep Quality Index (PSQI). The PSQI is a self-report measure of sleep quality and disturbance (see Appendix VII). Participants rate their sleep quality over the past month. The scale consists of 19 items covering seven components of sleep: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The component scores on the measure can be used to calculate a global score of sleep quality. This measure has acceptable internal consistency (Chronbach's $\alpha = 0.83$) and test-retest reliability (Chronbach's $\alpha = 0.85$). It has concurrent validity with polysomnography recordings and

displays discriminant validity in its ability to differentiate between good and poor sleepers with a sensitivity and specificity of 89.6% and 86.5%, respectively (Buysse et al., 1989). The global sleep quality score (PSQI Total) was used in all analyses.

NIH Toolbox Perceived Stress Scale (PSS). Perceived stress refers to how individuals view different events in his or her lives in terms of how stressful they are, how they relate to their values, and their ability to cope with stressors. The NIH Toolbox version of the PSS is a modified, computer adapted version of the Perceived Stress Scale originally developed by Cohen, Kamarck, & Mermelstein (1983). Examples of items on the PSS include: "In the past month please describe how often have you…a) been upset because of something that happened unexpectedly, b) felt nervous and stressed, c) felt that you could not cope with all of the things that you had to do." Participants were asked to rate each item on a scale from 1 to 5 with 1 = never, 2 = almost never, 3 = sometimes, 4 = fairly often, and 5 = very often. The adjusted PSS score (adjusted for age, gender, and education) was used in all analyses.

Philadelphia Geriatric Center Pain Scale. Pain was assessed at baseline using the Philadelphia Geriatric Center Pain Scale (see Appendix VIII; Parmelee, 1994). This measure first asks participants to answer pain intensity items, such as, how much they are bothered by pain at that moment, when their pain is at its worst, when their pain is at its least, and how much their pain interferes with their daily functioning. These pain intensity items are scored on a scale from 1-5 (1 = *not at all* to 5 = *extremely)*. There is also a question concerning the number of days a week when the participant's pain is very bad. This number is converted to the same 1-5 scale as the intensity items by multiplying by 5/7, yielding a possible range of 0 (no days) to 5 (7 days). This converted score is then averaged with the pain intensity items to yield a total pain intensity score.

Baseline Measures of Cognitive Functioning. Baseline cognitive functioning was used to determine the level of cognitive ability in each individual, and to determine each individual's level of cognitive impairment, if any. Given that declines in some areas of cognition are associated with normal aging, it is important to select measures that are sensitive enough to distinguish between normal age-related changes in cognition, and changes associated with cognitive impairment. De Jager, Hogervorst, Combrinck & Budge (2003) found several measures to optimize sensitivity and specificity in differentiating between controls and individuals with MCI (e.g., Hopkins Verbal Learning Test (HVLT) total recall, Category Fluency, Letter Comparison speed, Tactual Performance Test (TPT), and CLOX 1 and 2). Letter Cancellation and the Boston Naming Test (BNT) were also useful, but to a lesser degree. In addition, measures of verbal episodic memory and recall, such as Logical Memory, Verbal Paired Associates, California Verbal Learning Test (CVLT), and Rey Auditory Verbal Learning Test (Rey, 1941) are useful in distinguishing individuals with MCI from controls (Collie & Maruff, 2000).

In order to most accurately determine whether baseline cognitive functioning is representative of cognitive impairment, the measures chosen for inclusion in the baseline battery represent a broad range of cognitive functions, and include measures that are most sensitive to cognitive impairment. For this study, the NIH Toolbox was chosen as the primary baseline cognitive assessment battery. The purpose of the NIH Toolbox is to provide brief, comprehensive assessment measures and to encourage the use of these measures to facilitate cross-study comparisons of results. Using these measures across studies can enable cohesiveness and deeper understanding in the scientific community, and address the major obstacle that the use of different measures across studies presents when aggregating data into a meaningful whole

(e.g., meta-analyses). The measures included in the toolbox were developed simultaneously and normed together. The norms are provided to NIH Toolbox users for ages 3-85. For the purposes of this study, any older adults over the age of 85 were compared to the norms for 85-year-olds. The cognitive measures included in the NIH toolbox battery are the following: Picture Vocabulary, Flanker Inhibitory Control and Attention, List Sort Working Memory, Dimensional Change Card Sort, Pattern Comparison Processing Speed, Picture Sequence Memory, Oral Reading Recognition, Auditory Verbal Learning Test, and Oral Symbol Digit. The entire NIH Toolbox cognitive battery is administered via computer, which enhances standardization of administration. In addition, the following measures have been added to the battery for their sensitivity in the detection of cognitive impairment: Trail Making Test A & B (TMT; Reitan, 1958) and Stroop Color and Word test (Stroop; Trenerry, Crosson, DeBoe, Leber, 1989). The baseline cognitive battery and the self-report baseline measures took approximately 1.5 to 2 hours to complete. See Appendix IX for a brief summary of the cognitive measures included in the baseline assessment. The NIH Toolbox provides the following fully adjusted (adjusted for age, gender, race, ethnicity, and educational attainment) variables that were used in analyses: Total Cognition Composite, Fluid Cognition Composite, and Crystallized Cognition Composite.

Daily Measures of Cognitive Functioning. The daily cognitive assessment was designed to be short, easily administered over the telephone, and still comprehensive in its coverage of cognitive function.

The MIDUS II Cognitive Project used the Brief Test of Adult Cognition by Telephone (BTACT) to collect cognitive data by telephone (Tun, & Lackman, 2006). This assessment, which takes approximately 15-20 minutes to complete includes the following measures: Word List Recall, Digit Backward, Category Fluency, Stop and Go task, Number Series, Counting

task, and Word list Delayed Recall. The six original measures of the BTACT can be converted to z-scores and averaged into a composite. This composite has demonstrated good internal consistency (Cronbach's $\alpha = 0.082$). Concurrent validity was also demonstrated by its significant correlation with standard in-person assessments of episodic memory, processing speed, and vocabulary (Tun, & Lackman, 2006).

The daily cognitive assessment for this study was modeled after the BTACT with the addition of several measures (as described by Kalbe et al., 2004) in order to obtain a daily measure of cognition that assesses several cognitive domains and is sensitive to cognitive impairment. The cognitive domains assessed in the daily cognitive battery were selected due to their association with the contextual variables of interest, previous inclusion in studies of daily variability in older adults, or due to deficits in that domain in older adults with MCI.

Daily Cognition. The daily cognitive battery consisted of the following measures administered in random order, with the exception of immediate recall, which was always administered first, and delayed recall, which was always administered last: Immediate Word List Recall, Digit Forward, Digit Backward, Digit Sequence, Letter Fluency, Category Fluency, Stop-Go Normal, Stop-Go Reverse, Stop-Go Mixed, Number Series, Backward Counting, and Short Delay Word Recall. The daily cognitive assessments took 20-30 minutes to complete each day. The full daily battery is included in Appendix XIII. For analyses, a cognitive composite variable was created by first obtaining a standardized, or z-score, for each of the measure level variables and then averaging all of the standardized scores to create a cognitive composite variable for each participant for each day.

Daily Measures of Contextual Factors. Participants were given a 14-day daily diary that included measures assessing sleep, stress, and pain. Participants were asked to complete

these diaries each morning upon awakening. The daily diary participants completed each morning is included in Appendix XII.

Daily Sleep. Daily sleep behavior was assessed with a sleep diary. Due to their ease of use, ecological validity, and reliability assessing sleep behaviors, sleep diaries have become a primary method of sleep assessment (Lichstein et al., 1999). In addition, sleep diaries have shown acceptable criterion validity in older adult samples when compared with other commonly used measures of sleep, such as the Pittsburg Sleep Quality Inventory (r = .55-.76; Grander, Kripke, Yoon, & Younstedt, 2006). For this study, the Consensus Sleep Diary for Morning (Carney et al., 2012) was used (see Appendix XII). The sleep diary contains questions about the following: time in bed, sleep onset latency, number and duration of awakenings, final wake time, early morning awakenings, time out of bed, and total sleep time. Respondents also rate the perceived quality of his or her sleep the previous night a scale from 1 to 5 (1 = *very poor* to 5 = *excellent*). The following sleep variables used in analyses were either taken directly from the sleep diary or calculated from values provided in the sleep diary: sleep onset latency (SOL), wake time after sleep onset (WASO), number of awakenings (NWAK), time between participant's final awakening and when they exit the bed (TWAK), sleep quality rating (SQR), total wake time (TWT; calculated by [SOL + WASO + TWAK]), total sleep time (TST; calculated by [TIB - TWT]), and sleep efficiency index (SEI; calculated by [TST/TIB * 100]). Note that TIB, used in calculation of TST and SEI, represents time in bed, calculated by subtracting the time participants got out of bed in the morning from the time participants entered bed the night before.

Daily Stress. Daily stress was assessed with a modified version of the 4-item Perceived Stress Scale (PSS-4) as found in Cohen, Kamarck, & Mermelstein (1983). This scale contains

general, non-content specific questions, making this scale useful for a wider range of potential participants. This stress scale has overall reliability estimates ranging from 0.84 to 0.86, and test-retest reliability estimates of 0.85. Furthermore, it has shown good concurrent and predictive validity in a sample of college students (Cohen et al., 1983). Scores for the PSS-4 were obtained by reverse scoring the positive items (items 2 and 3) (e.g., 0 = 4, 1 = 3, 2 = 2, etc.) and then summing across all four items for a daily total stress score. The four items of the daily stress scale are included in Appendix XII.

Daily Pain. Daily pain was measured with a single question that asks "How much pain have you had since yesterday on a scale from 1 to 5". Participants are asked to choose a number 1 through 5: 1 = none, 2 = a little, 3 = a moderate amount, 4 = a great deal, and 5 = extreme pain.

Calculation of mean and daily variables. Analyses for the current study involved examination of both mean and daily associations. To this end, the daily variables described above were modified in two ways. First, the day-level data was aggregated to create a mean variable for use in analyses of between-person associations. Second, subtracting the newly created mean variable from the original day-level variable created a person-centered variable. Centered variables were used in analyses of within-person associations.

CHAPTER 3

RESULTS

The present study had two broad aims: 1) to compare variability in cognition in older adults with varying degrees of cognitive impairment and 2) to investigate relationships between daily cognitive performance, variability in cognitive performance, and contextual factors that may influence daily cognitive performance and variability in older adults with varying degrees of cognitive impairment. To address these aims, analyses at multiple levels were performed. For Aim 1, several hierarchical regression analyses were conducted with baseline cognitive performance, pain, stress, and sleep predicting variability in cognitive performance. Aim 2 involved multilevel modeling analyses to examine the within-person and between-person associations between contextual factors (pain, stress, and sleep) and cognitive performance measured across 14 days. Additionally, baseline cognition was examined as a moderator of these associations. Aim 3 also involved multilevel modeling analyses but instead of predicting cognitive performance, variability in cognitive performance was used as an outcome. Baseline cognition was also examined as a moderator of these associations.

Multilevel modeling (MLM) analyses were selected for the majority of the aims. Traditional statistical methods for examining associations between variables often involve averaging data. In other words, while previous research has focused on between-person differences, the use of multilevel modeling analyses allows examination of variations within individuals in addition to between-person differences. As opposed to the common practice of labeling within-person variability as “noise” or “error”, the present study focused on those

intraindividual variations. For behaviors that have known variability (e.g., cognition, sleep, pain) the fluctuations taken into account in within-person analyses are often meaningful and may be indicative of outcomes (e.g., greater cognitive variability is associated with poor outcomes, such as greater cognitive impairment). Furthermore, examining within-person variability in cognition and the association between that variability and contextual variables may allow more precise differentiation between older adults with and without cognitive impairment. Additionally, there are several advantages of MLM that make it particularly suited to daily assessment designs. First, it does not require observations to be independent. This is particularly important for multi-level data such as days nested within persons. Second, missing data can be handled flexibly in MLM, which serves to improve the power of the analyses, as entire subjects are not excluded for missing data. Third, time can be treated as a continuous variable rather than a categorical variable as with ANOVA. This allows for unequal spacing between measurements, whereas ANOVA requires that the data be balanced in terms of spacing. Finally, MLM does not assume that the variance-covariance matrix meets the requirements of sphericity required in ANOVA (Kwok et al., 2009).

Calculation of Intraclass Correlation Coefficients. An important initial step in MLM analyses involves parsing of variability into between-person variability and within-person variability to determine whether or not investigation of within-person variability is warranted. To accomplish this task, intra-class correlation coefficients (ICC) were calculated for both predictor and outcome variables. ICC values estimate the amount of between-subject variance relative to total variance. Using ICC values, by subtracting the amount of variance due to between-person effects from the total amount of variance, an estimation of within-person variance can be obtained. The percentage of within-person variability represents the amount of

variability in the construct not accounted for when examining mean values. When this value is substantial (e.g., greater than five percent; Heck, Thomas, & Tabata, 2010) it suggests that mean values may not be capturing a complete picture of the construct of interest. The amount of total variance in the variables in the present study that could be attributed to within-person variability ranged from 24% to 72%, suggesting that at least almost a quarter of variance in all variables could be attributed to fluctuation occurring within individuals, across days, rather than attributed to between-person differences. Additionally, a significant amount of within-person variability (e.g., $p < .05$) was found for all variables of interest, providing justification for investigation of associations between constructs at this level of analyses. Specific ICC values for each variable were reported previously in Table 2.

Detrending Daily Microlongitudinal Data. When analyzing daily data, it is also important to consider the possible effects of time, such as learning or practice effects. When present, these effects can distort data and undermine the validity of results. To determine if de-trending is necessary, multilevel models for the daily variables with linear, quadratic, and cubic time as the independent variable were created. If any of the three time variables were significant predictors of the outcome variables, this would signify a time-dependent trend in the data, and detrending would be necessary in order to create a pure measure of intraindividual variability. Time was not a significant predictor in any of the models, so no data used in the present analyses were detrended for time. However, in the analyses presented, the day of the study was entered as a covariate to control for possible effects of time not detected in detrending MLM's.

Aim 1 Analysis. In order to examine the association of baseline cognitive performance, baseline pain, baseline stress, and baseline sleep with variability in cognitive performance, a separate regression for each of the four predictors was conducted predicting cognitive

intraindividual standard deviation (ISD) values (representing mean variability in daily cognitive performance). ISD values were created by calculating the standard deviation for each individual. The following covariates were entered into each regression: age, gender, and education. Contrary to the hypothesis for Aim 1, there was no significant association found between baseline cognition, baseline stress, or baseline global sleep, and cognitive variability. However, as hypothesized, a positive association was found between baseline pain and cognitive variability ($\beta = 0.07$, SE = 0.03, $p = 0.03$) such that greater pain was associated with greater cognitive variability (See Table 3).

Aim 2 Analyses. Associations between contextual factors that may influence cognition within an individual (e.g. sleep, stress, and pain) and cognitive performance were examined using MLM. Analyses were used to examine associations on two levels; daily observations (level one) nested within each participant (level two). Level one, or within-person, analyses were used to answer questions such as "On days where people have more pain, do they also show poorer cognitive performance"? This is an example of a within-person coupling effect. Level two, or between-person analyses, were used to answer questions such as "Do people who experience more pain overall also exhibit poorer overall cognitive performance?" and "Is there a group interaction effect where the relationship between pain and cognition is stronger if you are more cognitively impaired"?

Table 3

Multiple Regression Analyses Predicting Cognitive Performance (Aim 1)

Predictor	B	*SE* B	*β*	*t*	*p*	sr^2
Baseline cognitive status	-0.00	0.00	-0.17	-0.78	0.44	0.02
Baseline Pain	0.08	0.03	0.47	2.37	0.03	0.17
Baseline Stress	0.01	0.00	0.31	1.38	0.18	0.08
Baseline Sleep	0.01	0.01	0.20	0.96	0.35	0.04

Note. B = Unstandardized residual; SE B = Standard error of B; β = Standardized residual; *t* = computed value of t-test; *p* = Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value; $sr^2 = R^2_{change}$ = amount of additional variance accounted for in model with addition of predictor.

For all results reported below in Aims 2 and 3, the following covariates were entered into the models: day, age, gender, and education. In the models presented in these analyses, MLM was used to examine fixed and random effects. Fixed effects, which are average effects that apply to all individuals, were examined at two levels. Level 2 effects were estimated by using mean values, while Level 1 effects were estimated using centered daily scores (i.e., daily score - person's mean). Level 1 effects represent daily deviations from the average value, for each person, for each predictor examined.

Random effects reflect the level of individual variability in fixed effects. In other words, a significant random effect for the daily pain and cognitive performance association would indicate that the magnitude of the relationship between overall pain and cognitive performance varied substantially across individuals. There were no significant random effects in the present study.

To determine the model of best fit for each construct of interest, a series of four hierarchical model steps were used, with each successive model building on the previous model(s). The four steps were as follows: step 1: null model (no predictors); step 2: fixed and random effects of day; step 3: fixed effects of age, gender, and education; step 4: fixed and random effects of the contextual variables (sleep, stress, pain). Model fit was determined by comparison of -2 Log Likelihood (-2LL) values for each successive model, with lower -2LL values indicating better model fit.

Aim 2.1. The purpose of Aim 2.1 was to examine the association between daily contextual factors and daily cognitive performance at both within-person and between-person levels of analyses. Analyses revealed the best fitting model for all predictors was the fourth model, with all covariates entered. See Table 4 for a summary of results for Aim 2.

Association Between Pain and Cognitive Performance. Daily, but not mean pain predicted daily cognitive performance ($\beta = 0.10$, SE = 0.03, $p < 0.01$; see Table 5). At the within-person level across the entire sample, daily pain was found to predict daily cognitive performance, such that on days when an individual reported higher pain, they were likely to also exhibit higher cognitive performance than on a day with less pain.

Association Between Stress and Cognitive Performance. Both daily and mean stress were not found to be significant predictors of cognitive performance on the daily diaries.

Association Between Sleep and Cognitive Performance. Regarding the sleep variables of interest, mean, but not daily TST, was a significant predictor of cognitive performance on the daily diaries ($\beta = -0.00$, SE = 0.00, $p = 0.01$: See Table 6). Individuals who reported greater mean total time spent sleeping exhibited lower mean performance on the daily cognitive diaries.

No other sleep variables were significant predictors of cognitive performance at either the daily or overall level of analyses.

Table 4

Contextual Variables Associated with Daily Cognitive Diary Performance

Predictors	Main Effects (Aim 2.1) Daily Cognitive Performance					
Daily Pain	+					
Mean Pain						
Daily Stress						
Mean Stress						
Daily SQR						
Mean SQR						
Daily TST						
Mean TST	-					
Daily SEI						
Mean SEI						
	Interaction Effects (Aim 2.2)					
	Baseline Cognitive Performance			Crystallized Baseline Cognitive Performance		
	Above Average	Average	Below Average	Above Average	Average	Below Average
Daily Pain						
Mean Pain	-		-			-
Daily Stress						-
Mean Stress				-	+	-
Daily SQR						
Mean SQR	+	+	-	-	+	-
Daily TST						
Mean TST	-	-	-			-
Daily SEI						
Mean SEI	-	+	-	-		-
Daily TWT				+	-	+
Mean TWT						

Table 5

Main Effects of Daily and Mean Pain Predicting Cognitive Performance

	β	*SE*	*df*	*t*	*p*-value
			Fixed Effects		
Within-person					
Intercept	2.46	1.32	31.06	1.86	0.07
Day	0.01	0.00	278.97	1.50	0.14
Daily Pain	0.10	0.03	278.43	3.07	0.01**
Between-Person					
Age	-0.04	0.02	31.18	-2.47	0.02*
Gender	0.04	0.24	31.09	0.16	0.87
Education	0.08	0.08	31.26	1.07	0.29
Mean Pain	-0.24	0.16	31.00	-1.50	0.14

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

Table 6

Main Effects of Daily and Mean TST Predicting Cognitive Performance

	β	*SE*	*df*	*t*	*p*-value
			Fixed Effects		
Within-person					
Intercept	2.83	1.20	30.39	2.35	0.03*
Day	0.01	0.00	279.85	1.22	0.22
Daily TST	-0.00	0.00	277.41	-0.01	0.99
Between-Person					
Age	-0.04	0.01	30.23	-2.52	0.02*
Gender	-0.08	0.22	29.82	-0.34	0.74
Education	0.10	0.07	31.10	1.38	0.18
Mean TST	-0.00	0.00	32.06	-2.71	0.01*

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

Aim 2.2. The purpose of Aim 2.2 was to determine if the relationships between contextual factors and daily assessments of cognition that were examined in Aim 2.1 are conditional on an individual's baseline cognitive functioning. In order to examine the influence of baseline cognition on these associations, interaction terms were entered into the multilevel

models using the same model building process mentioned in Aim 2.1. Interaction terms included baseline cognitive functioning by sleep variables, baseline cognitive functioning by stress, and baseline cognitive functioning by pain. As previously stated, the NIH toolbox that was used to assess baseline cognitive functioning provided an overall baseline composite of cognitive functioning, as well as separate measures of crystallized and fluid cognitive abilities. All three fully-adjusted measures of baseline cognition (overall baseline cognition, crystallized baseline cognition, and fluid baseline cognition) were entered into interactions to test for moderation of the contextual variables relationship with cognition performance as measured by the daily cognitive diaries. Decomposition of interactions was accomplished by graphing the simple slopes of baseline cognitive scores of three different groups of participants created using NIH normative data: individuals scoring one standard deviation or more below the mean (referred to as below average), individuals scoring within one standard deviation of the mean (referred to as average), and individuals scoring one standard deviation or more above the mean (referred to as above average). That is to say, given that the scores provided by NIH were based on their normative data, and individual in the current study labeled as "below average" would fall one standard deviation below the average of the population as represented with the NIH normative data, not below the average of the sample in the current study. For all subsequent interaction graphs, the below average, average, and above average cognitive groups are represented by blue, green, and gold fit lines, respectively.

Moderation of Pain-Cognitive Performance by Overall Cognitive Status. There was a significant overall baseline cognition by mean pain interaction ($\beta = 0.01$, SE = 0.00, $p = 0.01$; see Table 7). Decomposition of this interaction revealed for both below average and above average

individuals, there was a negative association, such that greater pain was associated with worse cognitive performance (See Figure 1).

Moderation of Pain-Cognitive Performance by Crystallized Cognitive Status. There was also a significant crystallized baseline cognition by mean pain interaction ($\beta = 0.01$, SE = 0.00, $p < 0.001$; see Table 8). For individuals with below average baseline crystallized cognition, greater mean pain was associated with lower cognitive performance (See Figure 2).

Moderation of Stress-Cognitive Performance by Crystallized Cognitive Status. There was a significant crystallized baseline cognition by mean stress interaction ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 8). For individuals with average baseline crystallized cognition, greater stress was associated with higher cognitive performance. Alternately, for individuals with below average and above average baseline crystallized cognition, greater stress was associated with poorer cognitive performance. This effect was stronger in individuals with above average baseline crystallized cognition (See Figure 3). There was also a significant crystallized baseline cognition by daily stress interaction ($\beta = 0.00$, SE = 0.00, $p = 0.05$; see Table 9). For individuals with below average baseline crystallized performance, there was a negative association such that on days when an individual experienced greater stress, they exhibited poorer cognitive performance (See Figure 4).

Table 7

Moderation of Pain-Cognitive Performance by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	1.72	1.25	28.39	1.38	0.18
Day	0.01	0.00	247.67	1.06	0.29
Daily Pain	-0.21	0.26	246.61	-0.82	0.41
Daily Pain * Overall cognition	0.00	0.00	246.62	1.24	0.22
Between-Person					
Age	-0.02	0.014	28.60	-1.25	0.22
Gender	-0.10	0.22	28.21	-0.42	0.68
Education	0.03	0.06	28.45	0.44	0.66
Mean Pain	-0.91	0.25	28.17	-3.70	0.01**
Mean Pain * Overall cognition	0.01	0.00	28.22	3.02	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

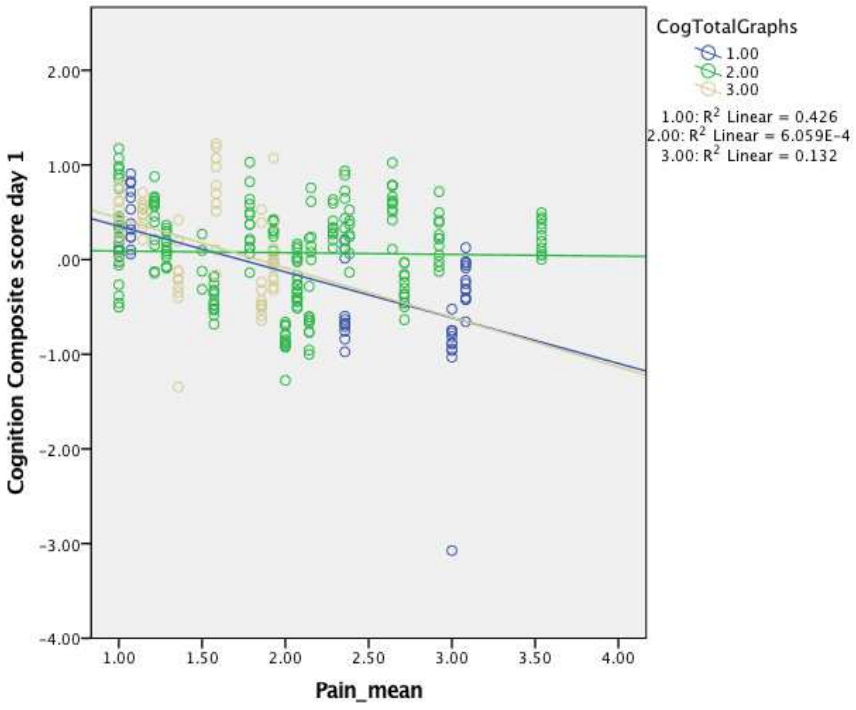

Figure 1. Moderation of mean pain-cognitive performance by overall baseline cognition.

Table 8

Moderation of Pain-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.29	1.07	28.85	2.13	0.04*
Day	0.01	0.00	259.61	1.23	0.22
Daily Pain	-0.36	0.34	258.35	-1.06	
Daily Pain * Crystallized cognition	0.00	0.00	258.32	1.37	0.17
Between-Person					
Age	-0.02	0.01	29.17	-1.80	0.08
Gender	-0.14	0.17	28.62	-0.80	0.43
Education	-0.02	0.06	29.10	-0.30	0.76
Mean Pain	-1.24	0.25	28.96	-4.89	0.01**
Mean Pain * Crystallized cognition	0.01	0.00	29.02	4.43	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

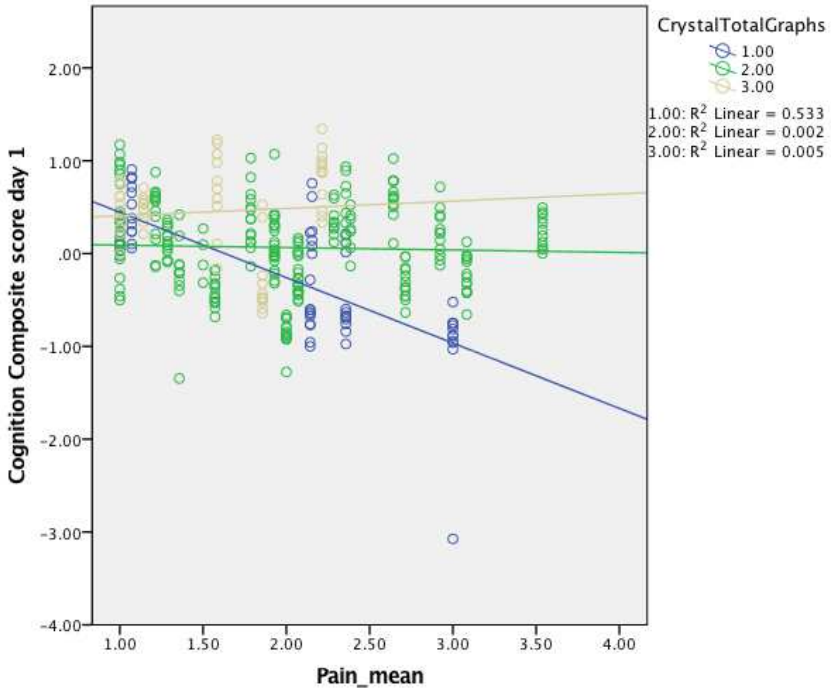

Figure 2. Moderation of mean pain-cognitive performance by crystallized baseline cognition.

Table 9

Moderation of Stress-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	0.40	1.44	28.85	0.28	0.78
Day	0.01	0.00	259.00	1.27	0.20
Daily Stress	-0.29	0.14	262.09	-2.05	0.04*
Daily Stress * Crystallized cognition	0.00	0.00	261.85	2.01	0.05*
Between-Person					
Age	-0.01	0.01	29.14	-1.07	0.30
Gender	-0.29	0.19	28.57	-1.54	0.13
Education	-0.00	0.06	29.03	-0.03	0.98
Mean Stress	-0.06	0.12	29.01	-0.48	0.63
Mean Stress * Crystallized cognition	0.00	0.00	29.16	3.14	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

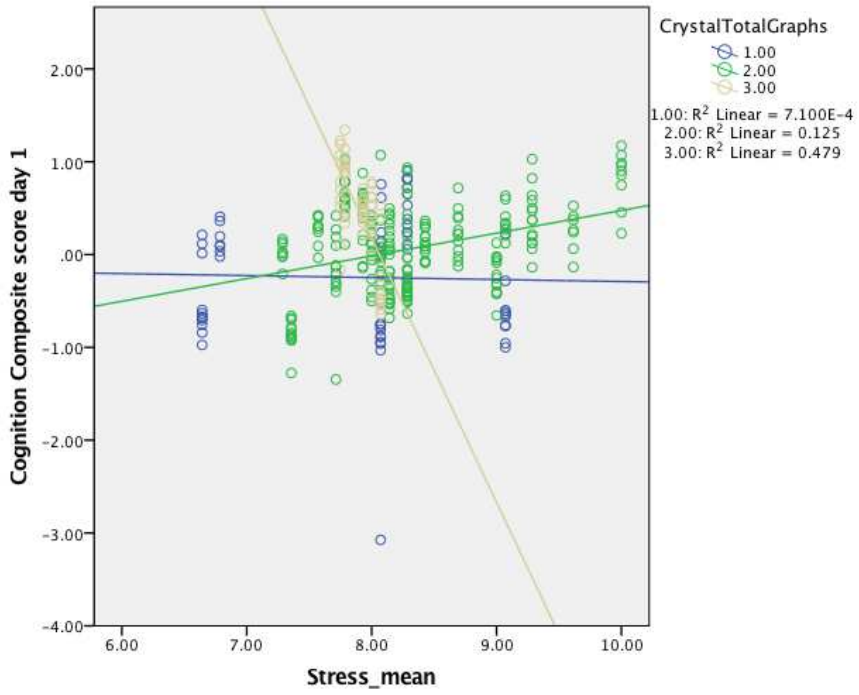

Figure 3. Moderation of mean stress-cognitive performance by crystallized baseline cognition.

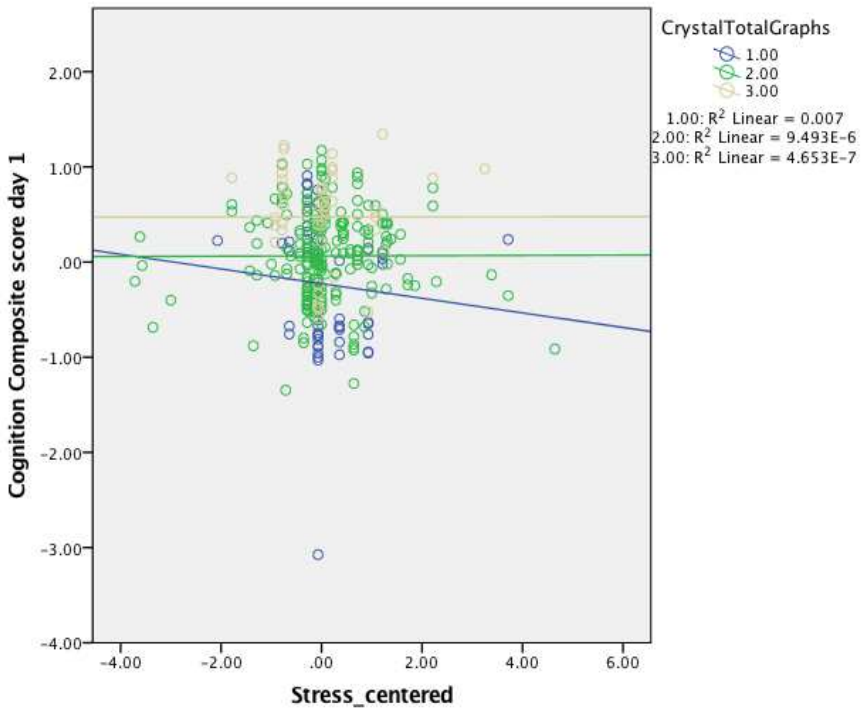

Figure 4. Moderation of daily stress-cognitive performance by crystallized baseline cognition.

Moderation of Sleep-Cognitive Performance by Overall Cognitive Status. There was a significant overall baseline cognition by mean SQR interaction (β = 0.00, SE = 0.00, p = 0.02; see Table 10). For individuals with average or above average overall baseline cognition, higher mean sleep quality ratings were associated with higher mean cognitive performance. For individuals with below average overall baseline cognitive performance, greater mean sleep quality ratings were associated with lower mean cognitive performance (See Figure 5). There was a significant overall baseline cognition by mean TST interaction (β = 0.00, SE = 0.00, p = 0.03; see Table 11). For all three cognitive groups, greater total sleep time was associated with lower mean cognitive performance, with the effect weakest for individuals with average baseline cognitive performance and strongest for individuals with below average baseline cognitive performance (See Figure 6). There was a significant overall baseline cognition by mean SEI interaction (β = 0.00, SE = 0.00, p = 0.02; see Table 12). For individuals with average baseline

cognitive performance, greater sleep efficiency was associated with higher mean cognitive performance. For individuals with above average or below average baseline cognition, there was a negative association such that higher sleep efficiency was associated with lower mean cognitive performance (See Figure 7).

Table 10

Moderation of SQR-Cognitive Performance by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	1.73	1.39	28.85	1.25	0.22
Day	0.00	0.00	260.59	1.04	0.30
Daily SQR	0.05	0.15	260.75	0.31	0.76
Daily SQR * Overall cognition	-0.00	0.00	260.46	-0.42	0.68
Between-Person					
Age	-0.01	0.01	28.73	-1.00	0.33
Gender	-0.26	0.24	28.11	-1.11	0.28
Education	0.04	0.07	28.77	0.55	0.59
Mean SQR	-0.38	0.18	28.13	-2.07	0.05*
Mean SQR * Overall cognition	0.00	0.00	27.95	2.48	0.02*

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

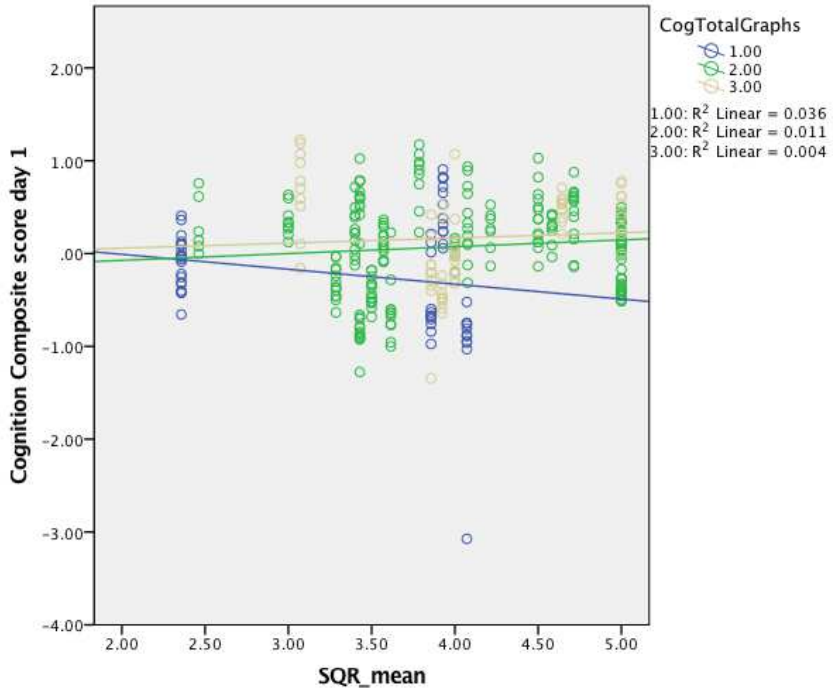

Figure 5. Moderation of mean SQR-cognitive performance by overall baseline cognition.

Table 11

Moderation of TST-Cognitive Performance by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.74	1.38	28.11	1.98	0.06
Day	0.00	0.00	246.98	0.75	0.45
Daily TST	0.00	0.00	243.75	1.146	0.25
Daily TST * Overall cognition	-0.00	0.00	243.76	-1.15	0.25
Between-Person					
Age	-0.02	0.01	27.76	-1.35	0.19
Gender	-0.28	0.22	26.71	-1.24	0.22
Education	0.04	0.06	28.53	0.73	0.47
Mean TST	-0.00	0.00	27.59	-3.67	0.01**
Mean TST * Overall cognition	0.00	0.00	26.85	2.37	0.03*

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

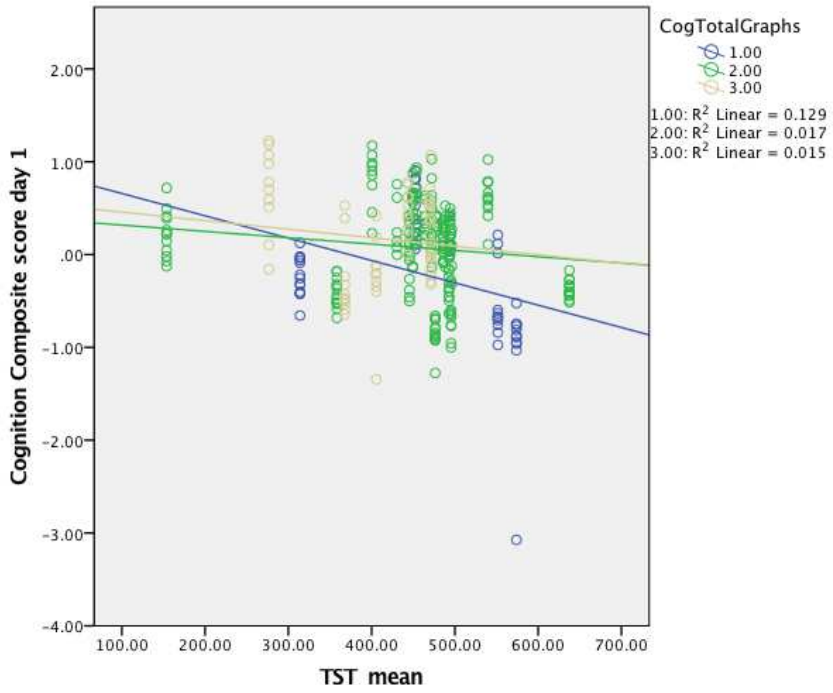

Figure 6. Moderation of mean TST-cognitive performance by overall baseline cognition.

Table 12

Moderation of SEI-Cognitive Performance by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.51	1.52	27.98	1.65	0.11
Day	0.00	0.00	246.22	0.77	0.44
Daily SEI	0.01	0.01	243.56	0.99	0.32
Daily SEI * Overall cognition	-0.00	0.00	243.60	-0.94	0.35
Between-Person					
Age	-0.02	0.02	27.34	-1.12	0.27
Gender	-0.33	0.24	26.63	-1.36	0.19
Education	0.03	0.07	28.41	0.41	0.68
Mean SEI	-0.02	0.01	28.24	-2.63	0.01*
Mean SEI * Overall cognition	0.00	0.00	26.63	2.57	0.01*

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

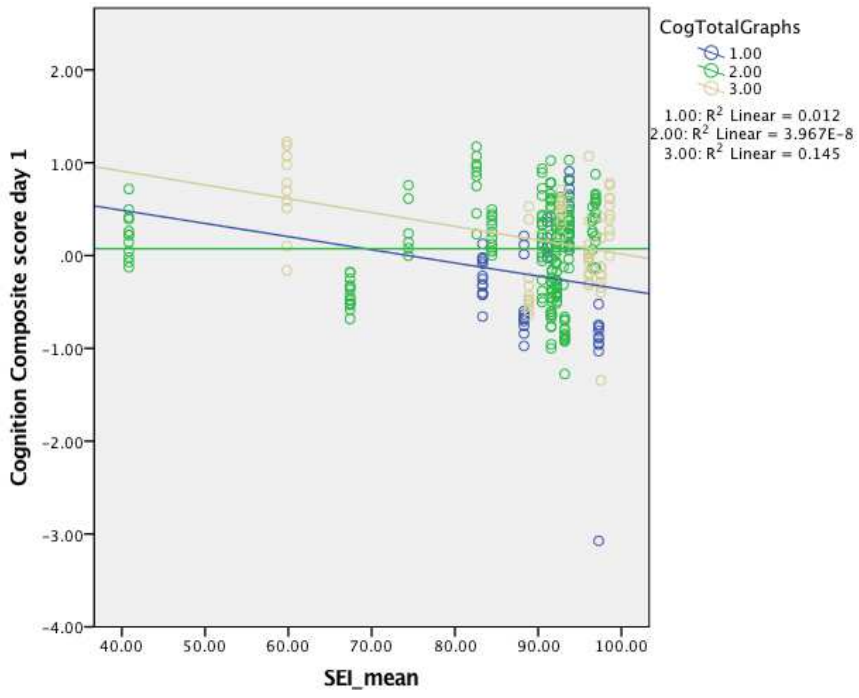

Figure 7. Moderation of mean SEI-cognitive performance by overall baseline cognition.

Moderation of Sleep-Cognitive Performance by Crystallized Cognitive Status. There was also a significant crystallized baseline cognition by mean SQR interaction ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 13). For individuals with average baseline crystallized cognition, greater mean sleep quality ratings were associated with higher mean cognitive performance. The opposite pattern was found for individuals with above and below average baseline crystallized cognition such that greater mean sleep quality ratings were associated with lower mean cognitive performance. This effect was stronger for individuals with below average baseline crystallized cognitive performance (See Figure 8). There was also a significant crystallized baseline cognition by mean TST interaction ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 14). For individuals with below average crystallized cognitive performance, there was a negative association such that greater total sleep time was associated with lower mean cognitive performance (See Figure 9). There was also a significant crystallized baseline cognition by mean SEI interaction ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 15). For individuals with above average or below average baseline crystallized cognitive performance, there was a negative association found such that greater sleep efficiency was associated with lower mean cognitive performance, with a stronger effect for individuals with below average cognition (See Figure 10). There was a significant crystallized baseline cognition by mean TWT interaction ($\beta = 0.00$, SE = 0.00, $p = 0.03$; see Table 16). For individuals with average baseline crystallized cognitive performance, higher total wake time was associated with lower mean cognitive performance. For individuals with above average and below average baseline crystallized cognitive performance, there was a positive association such that higher total wake time was associated with greater mean cognitive performance. This effect was stronger for individuals with above average baseline crystallized cognitive performance (See Figure 11).

Table 13

Moderation of SQR-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.48	0.98	30.53	2.52	0.02*
Day	0.00	0.00	286.03	0.87	0.39
Daily SQR	0.05	0.16	287.80	0.32	0.75
Daily SQR * Crystallized cognition	-0.00	0.00	287.35	-0.38	0.70
Between-Person					
Age	-0.02	0.01	30.52	-1.76	0.09
Gender	-0.30	0.17	29.81	-1.72	0.10
Mean SQR	-0.64	0.18	29.69	-3.60	0.01**
Mean SQR * Crystallized cognition	0.00	0.00	29.94	4.10	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

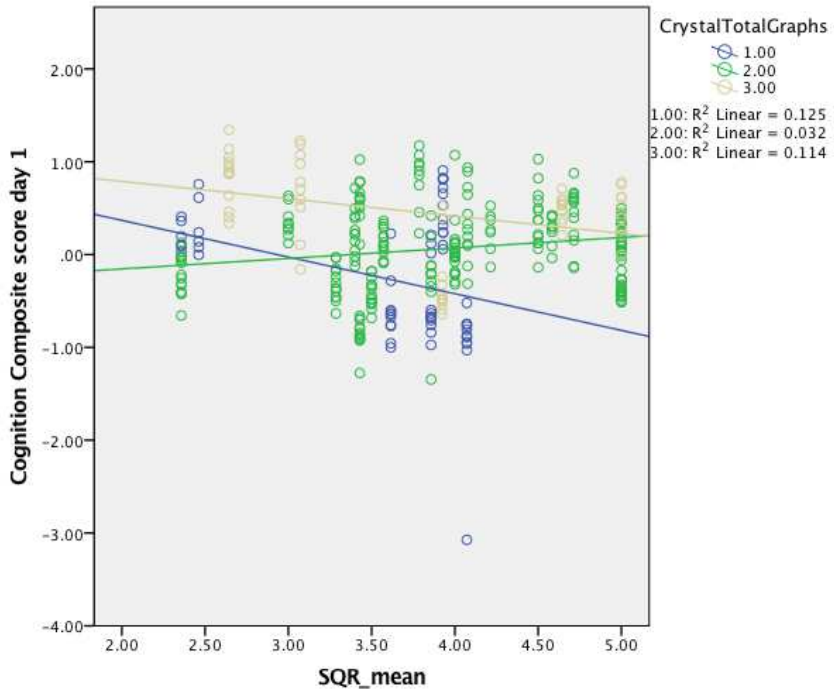

Figure 8. Moderation of mean SQR-cognitive performance by crystallized baseline cognition.

Table 14

Moderation of TST-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.85	1.04	29.83	2.74	0.01*
Day	0.00	0.00	272.60	0.63	0.53
Daily TST	0.00	0.00	268.40	1.50	0.14
Daily TST * Crystallized cognition	-0.00	0.00	268.41	-1.50	0.14
Between-Person					
Age	-0.02	0.01	28.94	-1.77	0.09
Gender	-0.29	0.17	28.05	-1.77	0.09
Mean TST	-0.00	0.00	29.19	-4.55	0.01**
Mean TST * Crystallized cognition	0.00	0.00	29.14	3.35	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

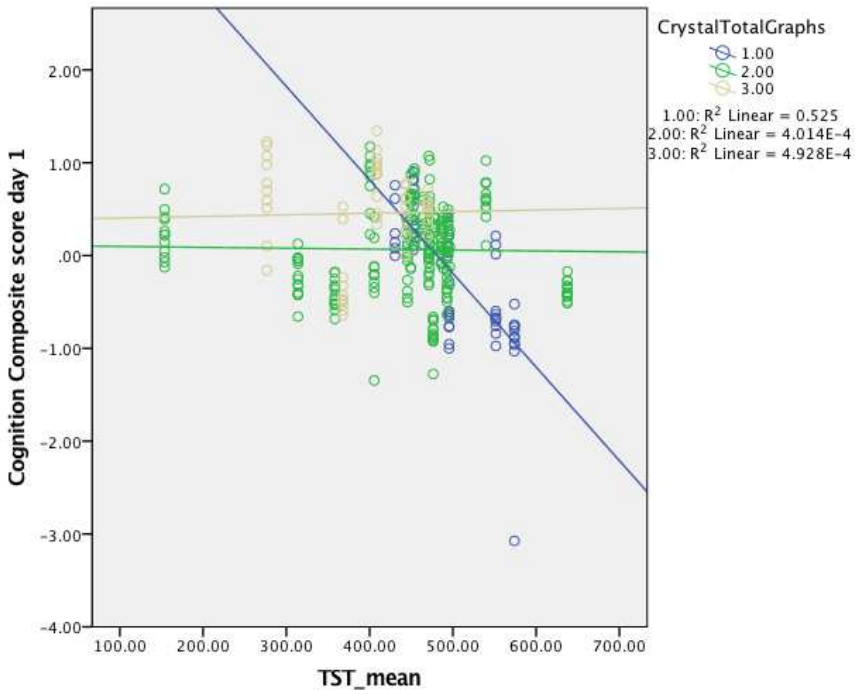

Figure 9. Moderation of mean TST-cognitive performance by crystallized baseline cognition.

Table 15

Moderation of SEI-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	2.69	1.10	29.51	2.45	0.02*
Day	0.00	0.00	272.12	0.63	0.53
Daily SEI	0.01	0.01	268.32	0.95	0.35
Daily SEI * Crystallized cognition	0.00	0.00	268.38	-0.89	0.36
Between-Person					
Age	-0.02	0.01	28.63	-1.50	0.14
Gender	-0.32	0.17	28.00	-1.84	0.08
Mean SEI	-0.03	0.01	29.86	-3.57	0.01**
Mean SEI * Crystallized cognition	0.00	0.00	28.58	3.63	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

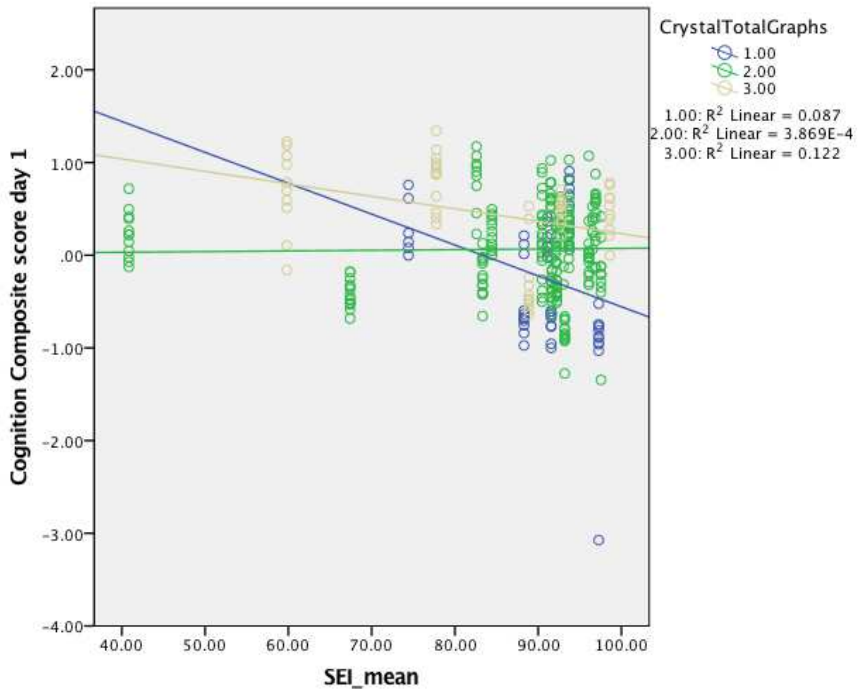

Figure 10. Moderation of mean SEI-cognitive performance by crystallized baseline cognition.

Table 16

Moderation of TWT-Cognitive Performance by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Within-person					
Intercept	1.51	1.15	28.61	1.31	0.20
Day	0.00	0.00	271.52	0.69	0.50
Daily TWT	-0.00	0.00	268.29	-0.79	0.43
Daily TWT * Crystallized cognition	0.00	0.00	268.34	0.71	0.48
Between-Person					
Age	-0.02	0.01	28.81	-1.14	0.26
Gender	-0.23	0.19	28.32	-1.17	0.25
Mean TWT	-0.01	0.01	29.70	-1.96	0.06
Mean TWT * Crystallized cognition	0.00	0.00	29.22	2.29	0.03*

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

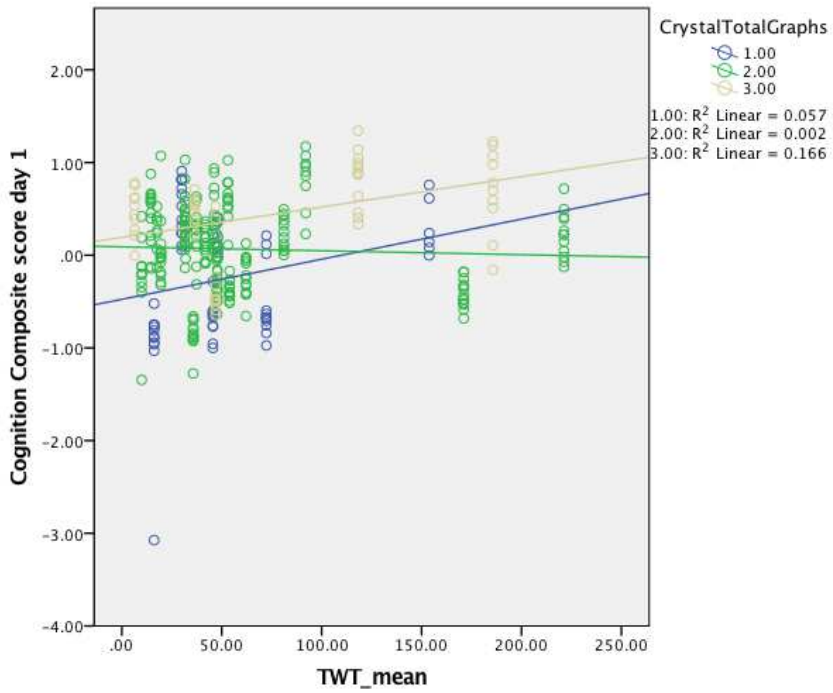

Figure 11. Moderation of mean TWT-cognitive performance by crystallized baseline cognition.

Aim 3 Analyses

Aim 3.1. The purpose of Aim 3.1 was to investigate the association between contextual factors and cognitive variability. To accomplish this, pain, stress, and sleep values from the daily diaries were entered as predictors into separate multilevel models with average variability in cognitive performance, as represented by ISD values, as the outcome variable. See Table 17 for a summary of results for Aim 3.

Associations Between Pain, Stress, Sleep, and Cognitive Variability. Separate MLM analyses indicated that only mean SOL ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 18) significantly predicted variability in cognitive performance. Taking longer to fall asleep was associated with greater variability in daily cognitive performance.

Aim 3.2. The purpose of Aim 3.2 was to determine whether the association between contextual factors and cognitive variability is conditional on baseline levels of cognitive function. Similar to Aim 2.2, MLM analyses entering interaction terms for overall baseline cognition, crystallized baseline cognition, and fluid baseline cognition were conducted to determine if cognitive status at baseline moderated the association between daily contextual variables and variability in daily cognition. The same model building procedure described for Aim 2 was used, with four successive models.

Table 17

Contextual Variables Associated with Daily Cognitive Diary Variability

Predictors	Main Effects (Aim 3.1) Daily Cognitive Performance
Daily Pain	
Mean Pain	
Daily Stress	
Mean Stress	
Daily SOL	
Mean SOL	+
Daily SQR	
Mean SQR	
Daily TWAK	
Mean TWAK	
Daily TST	
Mean TST	
Daily SEI	
Mean SEI	

	Interaction Effects (Aim 3.2)								
	Baseline Cognitive Performance			Crystallized Baseline Cognitive Performance			Fluid Baseline Cognitive Performance		
	Above Average	Average	Below Average	Above Average	Average	Below Average	Above Average	Average	Below Average
Daily Pain									
Mean Pain	+	-	+	+	-	+			
Daily Stress									
Mean Stress	-	+	+	-	+	+			
Daily SOL									
Mean SOL	+	+	-	+	+	-	+	+	-

Interaction Effects (Aim 3.2)									
	Baseline Cognitive Performance			Crystallized Baseline Cognitive Performance			Fluid Baseline Cognitive Performance		
	Above Average	Average	Below Average	Above Average	Average	Below Average	Above Average	Average	Below Average
Daily SQR									
Mean SQR	-	-	+	-	+	+			
Daily TWAK									
Mean TWAK	+	-	-	+	-	-	-	+	-
Daily TST									
Mean TST	-	-	+	-	-	+	-	+	+
Daily SEI									
Mean SEI	-	-	+	-	+	+	-	-	+
Daily TWT									
Mean TWT	-	+	-	+	-	-	+		-

Table 18

Main Effects of Daily and Mean SOL Predicting Cognitive Variability

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.34	0.08	420.00	4.37	0.01**
Day	0.00	0.00	420.00	0.00	1.00
Age	-0.00	0.00	420.00	-1.39	0.17
Gender	0.03	0.01	420.00	1.96	0.05
Race	0.01	0.04	420.00	0.18	0.86
Education	-0.01	0.01	420.00	-2.77	0.01**
Mean SOL	0.00	0.00	420.00	3.71	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

Moderation of Pain-Cognitive Variability by Overall Cognitive Status. There was a significant interaction between mean pain and overall baseline cognition ($\beta = 0.01$, SE = 0.00, $p < 0.01$; see Table 19). For both below average and above average individuals, greater overall pain was associated with more variability in cognitive performance, with a stronger effect in those with above average cognition. For individuals with average cognitive performance at baseline greater pain was associated with less variability in cognitive performance (See Figure 12).

Moderation of Pain-Cognitive Variability by Crystallized Cognitive Status. There was a significant interaction for mean pain with crystallized baseline cognition ($\beta = 0.01$, SE = 0.00, $p <0.01$; see Table 20). Greater daily pain was associated with more variability in cognitive performance for both above average and below average individuals, with a stronger effect in individuals with above average cognition at baseline. The opposite relationship was found for individuals with average cognitive performance at baseline, such that greater pain was associated with less variability in cognitive performance (See Figure 13).

Table 19

Moderation of Pain-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.40	0.10	392.00	3.86	0.01**
Day	-0.00	0.00	392.00	0.00	1.00
Age	-0.00	0.00	392.00	-2.69	0.01**
Gender	0.05	0.02	392.00	2.94	0.01**
Education	0.00	0.00	392.00	0.56	0.56
Mean Pain	0.12	0.02	392.00	5.69	0.01**
Mean Pain * Overall cognition	-0.00	0.00	392.00	-6.36	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

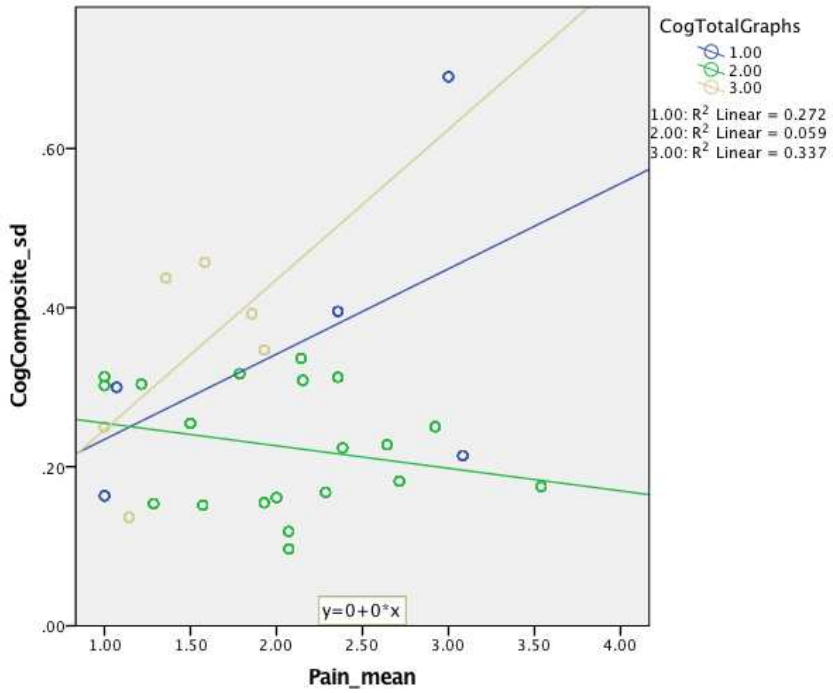

Figure 12. Moderation of mean pain-cognitive variability by overall baseline cognition.

Table 20

Moderation of Pain-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.45	0.10	406.00	4.62	0.01**
Day	0.00	0.00	406.00	0.00	1.00
Age	-0.00	0.00	406.00	-3.18	0.01**
Gender	0.02	0.02	406.00	1.60	0.11
Education	0.01	0.01	406.00	1.24	0.21
Mean Pain	0.12	0.02	406.00	5.50	0.01**
Mean Pain * Crystallized cognition	-0.00	0.00	406.00	-5.89	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

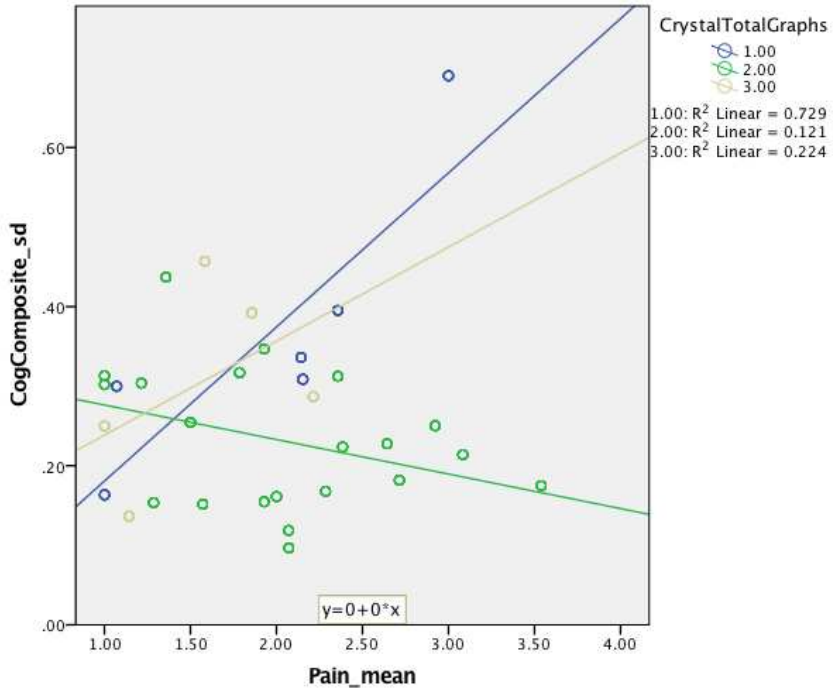

Figure 13. Moderation of mean pain-cognitive variability by crystallized baseline cognition.

Moderation of Stress-Cognitive Variability by Overall Cognitive Status. There was a significant mean stress by overall baseline cognition interaction ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 21). For average and below average individuals, greater stress was associated with greater cognitive variability, with a stronger effect in individuals with average cognitive performance at baseline. For individuals with above average performance, the opposite pattern was found, such that greater stress was associated with less variability in cognition (See Figure 14).

Moderation of Stress-Cognitive Variability by Crystallized Cognitive Status. There was a significant interaction between mean stress and crystallized baseline cognition ($\beta = 0.00$, SE = 0.00, $p < 0.01$; see Table 22). Greater stress was associated with more variability in daily cognitive performance for both average and below average individuals, with a stronger effect in individuals with below average cognitive performance at baseline. For individuals with above average cognition at baseline, the opposite pattern was found, with greater stress associated with less variability in cognitive performance across days (See Figure 15).

Table 21

Moderation of Stress-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.35	0.13	392.00	2.58	0.01*
Day	0.00	0.00	392.00	0.00	1.00
Age	-0.00	0.00	392.00	-2.30	0.02*
Gender	0.05	0.02	392.00	2.49	0.01*
Education	-0.00	0.01	392.00	-0.11	0.91
Mean Stress	0.02	0.01	392.00	1.89	0.06
Mean Stress * Overall cognition	-0.00	0.00	392.00	-3.29	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

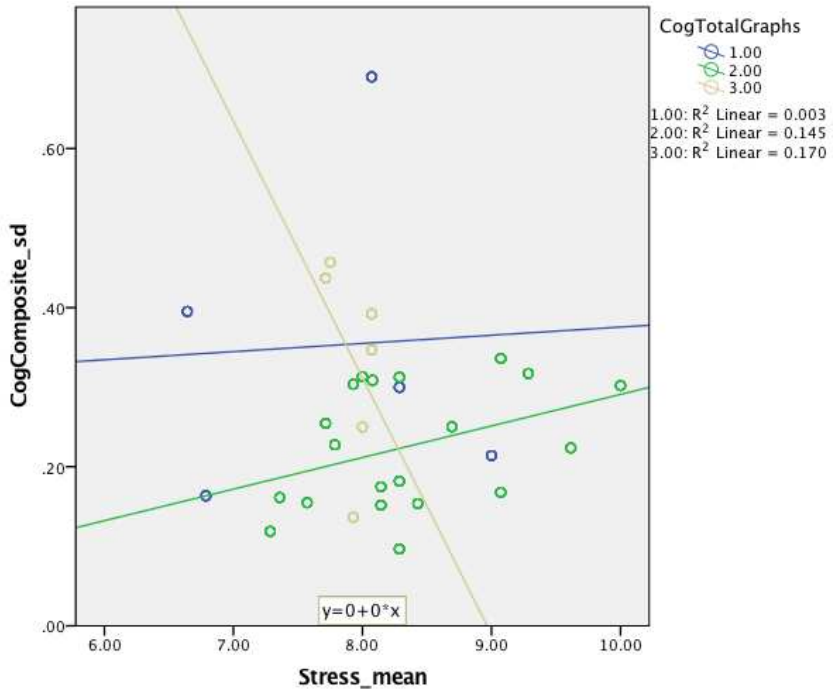

Figure 14. Moderation of mean stress-cognitive variability by overall baseline cognition.

Table 22

Moderation of Stress-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.46	0.12	406.00	3.91	0.01**
Day	0.00	0.00	406.00	0.00	1.00
Age	-0.00	0.00	406.00	-3.17	0.01**
Gender	0.03	0.02	406.00	1.72	0.09
Education	0.00	0.01	406.00	0.15	0.88
Mean Stress	0.01	0.01	406.00	1.39	0.17
Mean Stress * Crystallized cognition	-0.00	0.00	406.00	-2.69	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

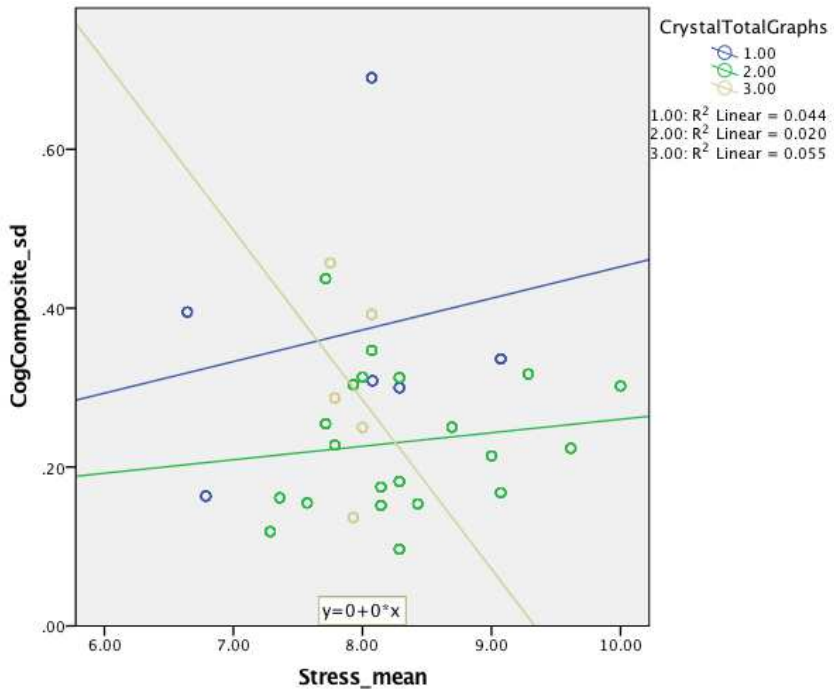

Figure 15. Moderation of mean stress-cognitive variability by crystallized baseline cognition.

Moderation of Sleep-Cognitive Variability by Overall Cognitive Status. There was a significant interaction between the following mean sleep variables and overall baseline cognition: SOL (β = 0.00, SE = 0.00, p = 0.01), SQR (β = -0.00, SE = 0.00, p < 0.01), TWAK (β = 0.00, SE = 0.00, p < 0.01), TST (β = -0.00, SE = 0.00, p < 0.01), TWT (β = 0.00, SE = 0.00, p < 0.01), and SEI (β = -0.00, SE = 0.00, p < 0.01). See Tables 23-28 for a summary of the models of sleep variables listed above. Decomposition of these interactions revealed, in below average individuals, SOL, TWAK, and TWT were negatively associated with cognitive variability, while SQR, TST, and SEI were positively associated with cognitive variability. For average individuals, SOL and TWT were positively associated with cognitive variability, while SQR, TWAK, TST, and SEI were negatively associated with cognitive variability. Finally, for above average individuals, SOL, TWAK, and TWT were positively associated with cognitive variability, while SQR, TST, and SEI were negatively associated with cognitive variability (See Figures 16-21).

Moderation of Sleep-Cognitive Variability by Crystallized Cognitive Status. The following mean sleep variables had a significant interaction with crystallized baseline cognition: SOL (β = 0.00, SE = 0.00, p < 0.01), SQR (β = -0.00, SE = 0.00, p < 0.01), TWAK (β = 0.00, SE = 0.00, p < 0.01), TST (β = -0.00, SE = 0.00, p < 0.01), TWT (β = 0.00, SE = 0.00, p <0.01), and SEI (β = -0.00, SE = 0.00, p < 0.01). See Tables 29-34 for a summary of the models of sleep variables listed above. Decomposition of these interactions revealed for below average individuals, SOL, TWAK, and TWT were negatively associated with cognitive variability, while SQR, TST, and SEI were positively associated with cognitive variability. For average individuals, SOL, SQR, and SEI were positively associated with cognitive variability, while TWAK, TST, and TWT were negatively associated with cognitive variability. For above

average individuals, SOL, TWAK, and TWT were positively associated with cognitive variability, while SQR, TST, and SEI were negative associated with cognitive variability (See Figures 22-27).

Table 23

Moderation of SOL-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.38	0.11	378.00	3.61	0.01**
Day	0.00	0.00	378.00	0.00	1.00
Age	-0.00	0.00	378.00	-1.29	0.20
Gender	0.02	0.02	378.00	1.15	0.25
Education	-0.02	0.01	378.00	-2.93	0.01**
Mean SOL	-0.00	0.00	378.00	-2.04	0.04*
Mean SOL * Overall cognition	0.00	0.00	378.00	3.22	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

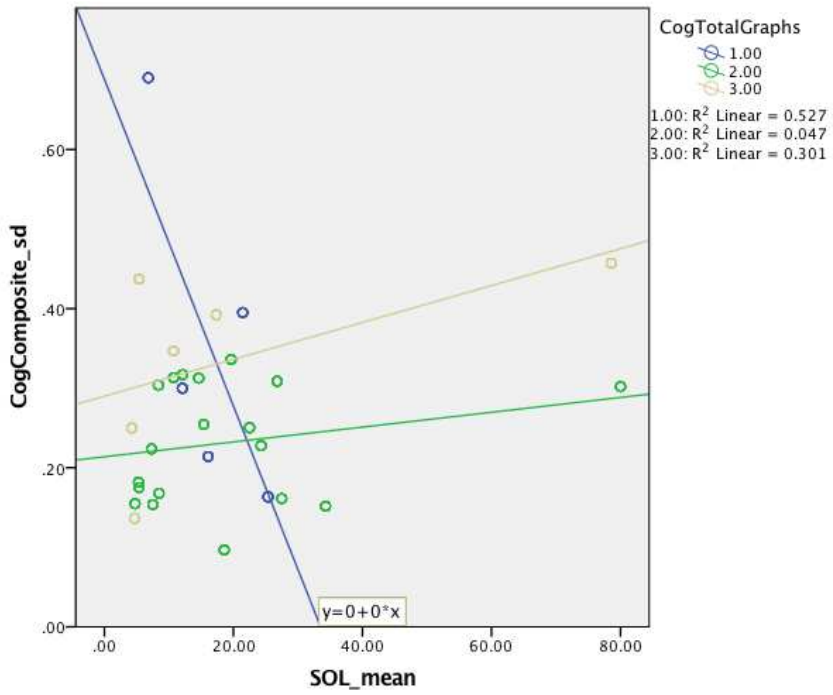

Figure 16. Moderation of mean SOL-cognitive variability by overall baseline cognition.

Table 24

Moderation of SQR-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.35	0.11	392.00	3.30	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	-0.00	0.00	392.00	-2.06	0.04*
Gender	0.06	0.02	392.00	3.06	0.01**
Education	0.00	0.01	392.00	0.23	0.82
Mean SQR	0.04	0.01	392.00	2.70	0.01**
Mean SQR * Overall cognition	-0.00	0.00	392.00	-4.48	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

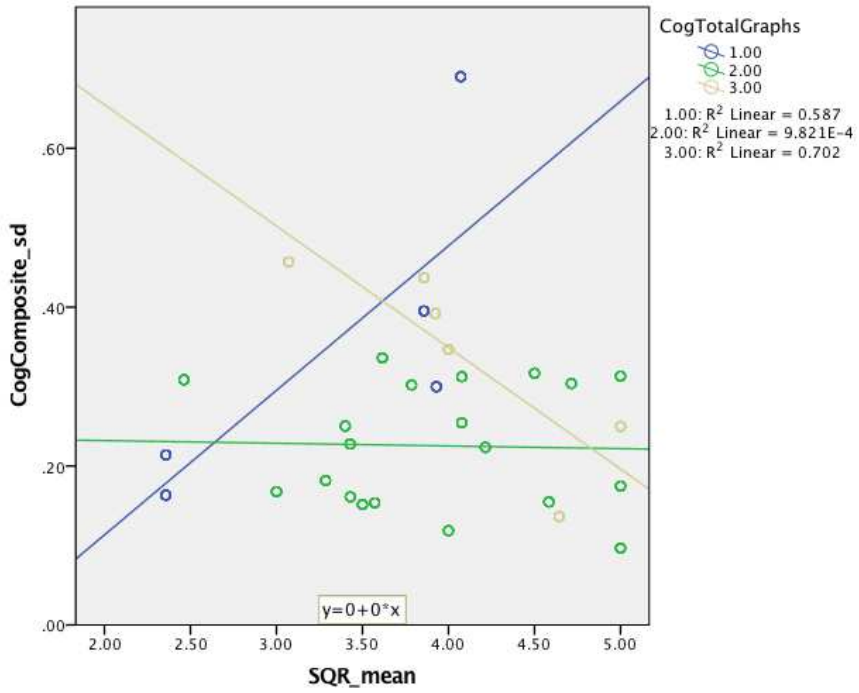

Figure 17. Moderation of mean SQR-cognitive variability by overall baseline cognition.

Table 25

Moderation of TWAK-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.61	0.10	392.00	6.01	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	-0.00	0.00	392.00	-3.67	0.01**
Gender	-0.00	0.02	392.00	-0.15	0.88
Education	-0.01	0.01	392.00	-2.71	0.01**
Mean TWAK	-0.01	0.00	392.00	-5.25	0.01**
Mean TWAK * Overall cognition	0.00	0.00	392.00	5.16	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

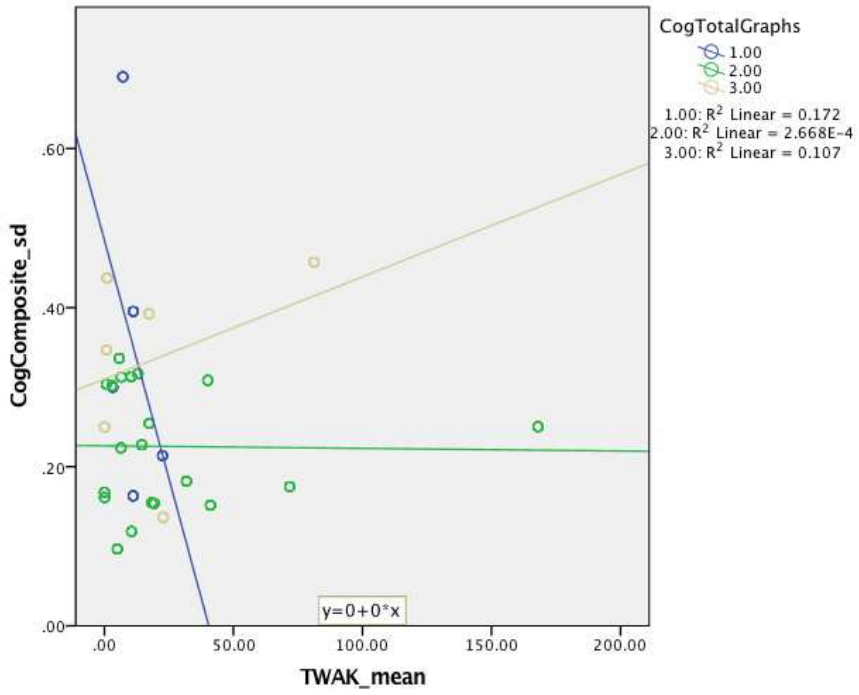

Figure 18. Moderation of mean TWAK-cognitive variability by overall baseline cognition.

Table 26

Moderation of TST-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.20	0.11	378.00	1.80	0.07
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	0.00	1.00
Gender	0.09	0.02	378.00	5.28	0.01**
Education	0.00	0.00	378.00	-0.14	0.89
Mean TST	0.00	0.00	378.00	4.36	0.01**
Mean TST * Overall cognition	0.00	0.00	378.00	-7.58	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

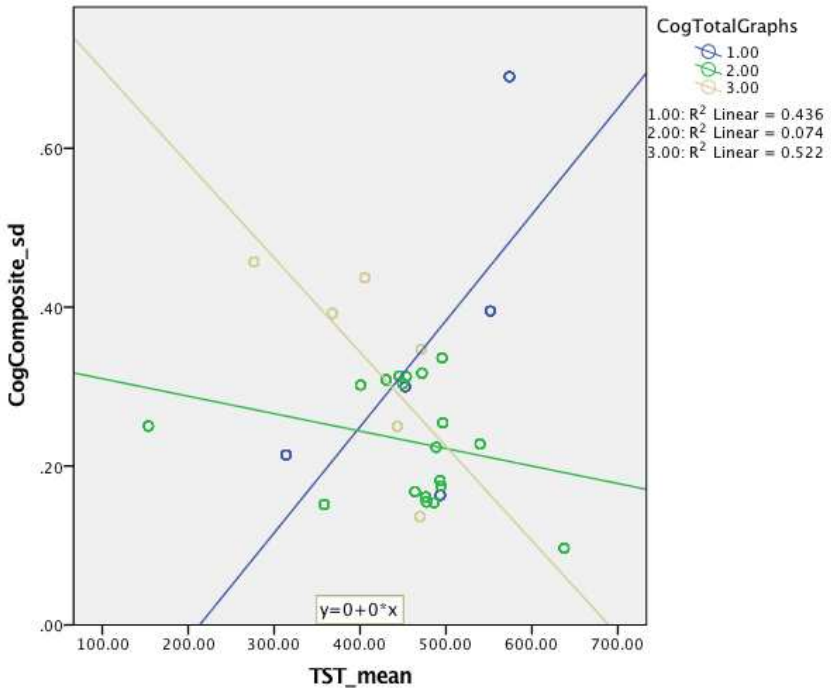

Figure 19. Moderation of mean TST-cognitive variability by overall baseline cognition.

Table 27

Moderation of TWT-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.38	0.11	378.00	3.53	0.01**
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	-1.18	0.24
Gender	0.02	0.02	378.00	1.28	0.20
Education	0.00	0.01	378.00	-2.28	0.02*
Mean TWT	0.00	0.00	378.00	-3.37	0.01**
Mean TWT * Overall cognition	0.00	0.00	378.00	3.38	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

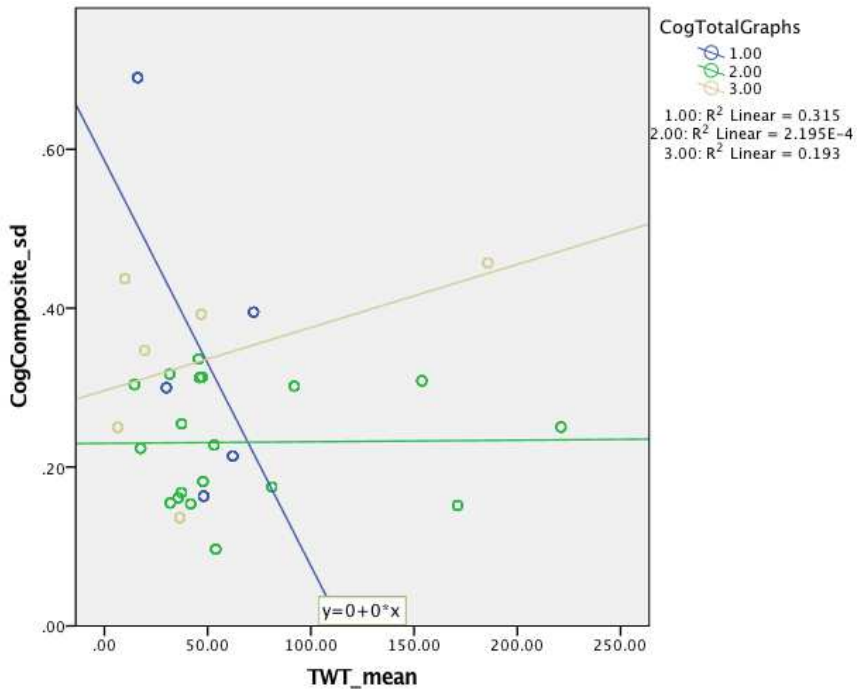

Figure 20. Moderation of mean TWT-cognitive variability by overall baseline cognition.

Table 28

Moderation of SEI-Cognitive Variability by Overall Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.12	0.12	378.00	1.04	0.30
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	0.14	0.89
Gender	0.08	0.02	378.00	4.48	0.01**
Education	0.00	0.00	378.00	-0.86	0.39
Mean SEI	0.00	0.00	378.00	3.84	0.01**
Mean SEI * Overall cognition	0.00	0.00	378.00	-5.48	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

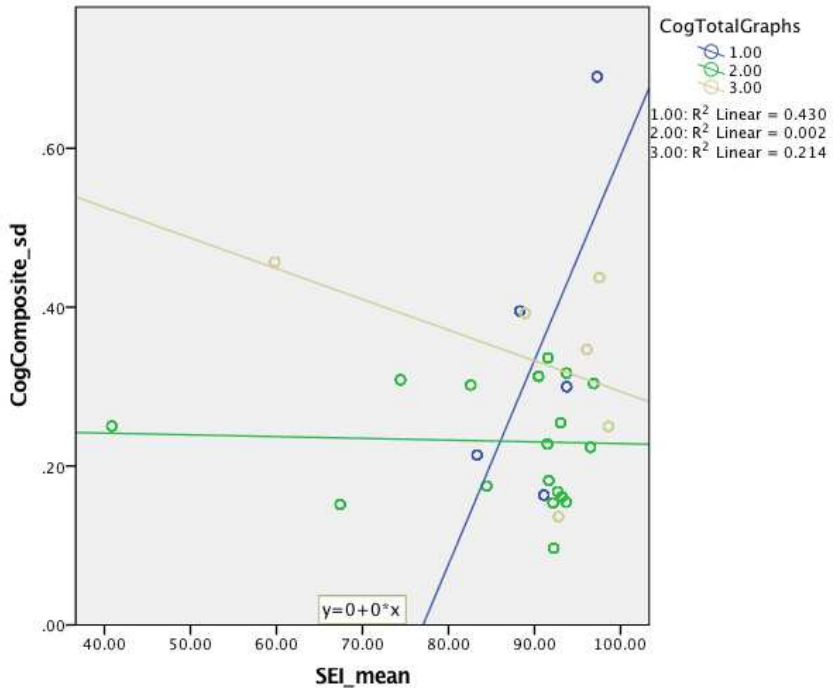

Figure 21. Moderation of mean SEI-cognitive variability by overall baseline cognition.

Table 29

Moderation of SOL-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.36	0.09	392.00	3.92	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	0.00	0.00	392.00	-1.11	0.27
Gender	0.02	0.01	392.00	1.51	0.13
Education	-0.02	0.01	392.00	-3.40	0.01**
Mean SOL	0.00	0.00	392.00	-3.10	0.01**
Mean SOL * Crystallized cognition	0.00	0.00	392.00	4.08	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

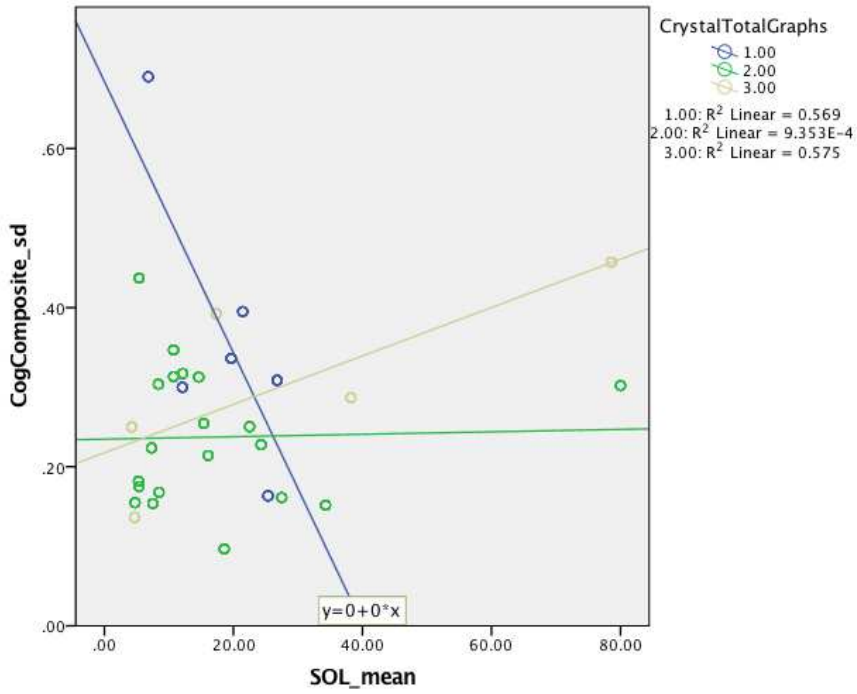

Figure 22. Moderation of mean SOL-cognitive variability by crystallized baseline cognition.

Table 30

Moderation of SQR-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.42	0.09	406.00	4.54	0.01**
Day	0.00	0.00	406.00	0.00	1.00
Age	0.00	0.00	406.00	-2.70	0.01*
Gender	0.04	0.02	406.00	2.22	0.03*
Education	0.00	0.01	406.00	0.58	0.56
Mean SQR	0.04	0.02	406.00	2.36	0.02*
Mean SQR * Crystallized cognition	0.00	0.00	406.00	-3.72	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

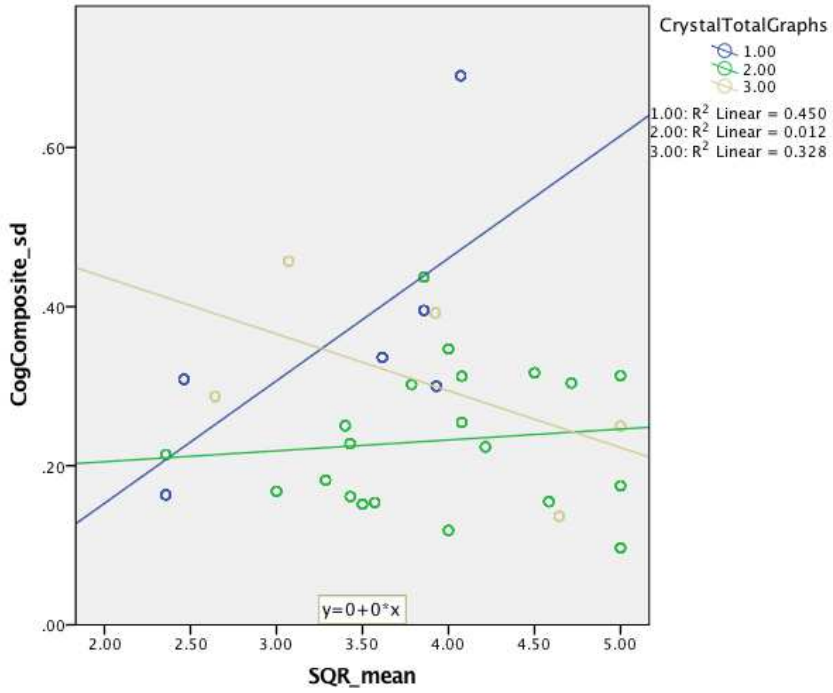

Figure 23. Moderation of mean SQR-cognitive variability by crystallized baseline cognition.

Table 31

Moderation of TWAK-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.56	0.09	406.00	6.00	0.01**
Day	0.00	0.00	406.00	0.00	1.00
Age	0.00	0.00	406.00	-3.53	0.01**
Gender	0.01	0.02	406.00	0.58	0.56
Education	-0.01	0.01	406.00	-2.17	0.03*
Mean TWAK	0.00	0.00	406.00	-3.23	0.01**
Mean TWAK * Crystallized cognition	0.00	0.00	406.00	3.15	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

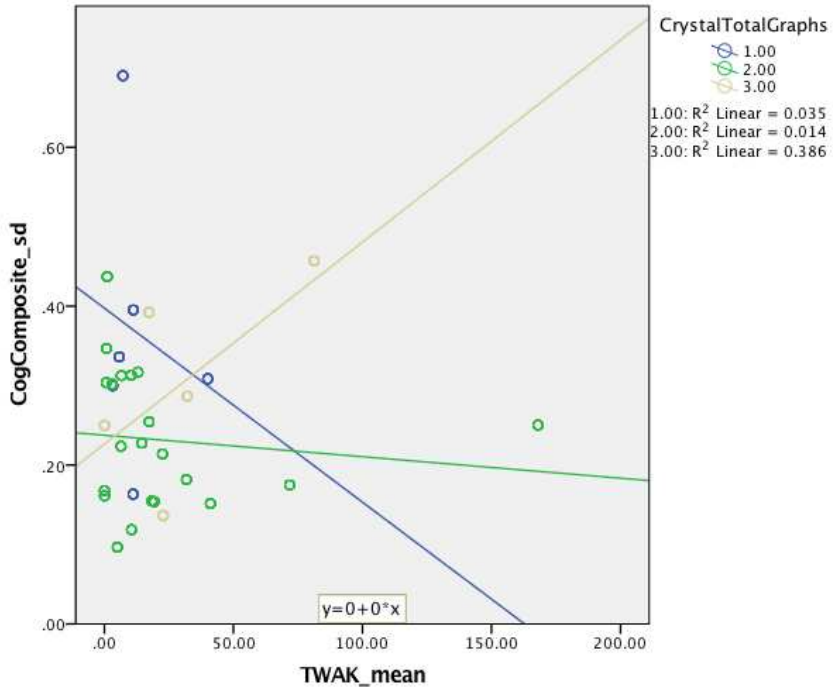

Figure 24. Moderation of mean TWAK-cognitive variability by crystallized baseline cognition.

Table 32

Moderation of TST-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.39	0.10	392.00	3.96	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	0.00	0.00	392.00	-1.54	0.13
Gender	0.05	0.02	392.00	3.32	0.01**
Education	0.00	0.01	392.00	0.40	0.69
Mean TST	0.00	0.00	392.00	2.50	0.01*
Mean TST * Crystallized cognition	0.00	0.00	392.00	-5.05	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

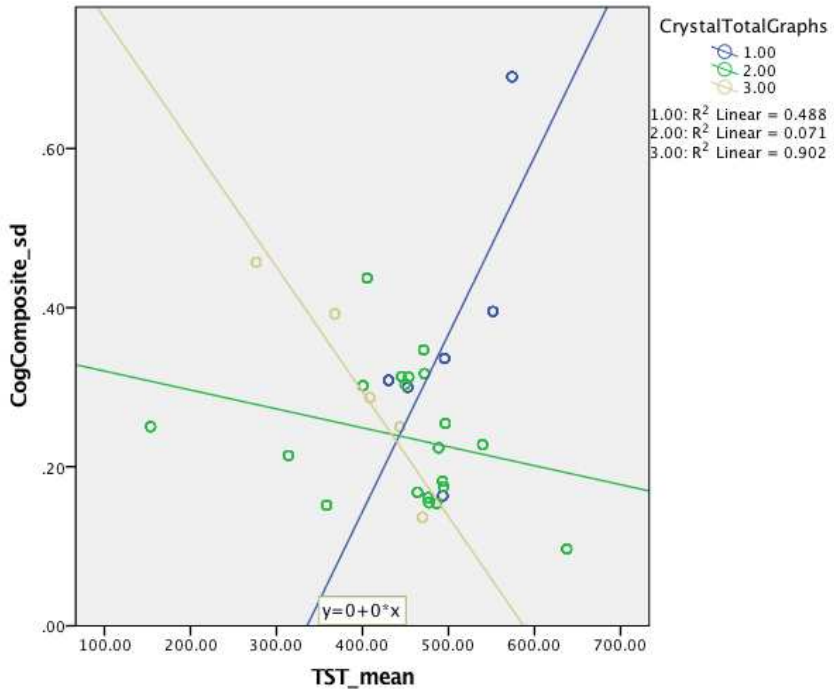

Figure 25. Moderation of mean TST-cognitive variability by crystallized baseline cognition.

Table 33

Moderation of TWT-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.38	0.10	392.00	3.95	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	0.00	0.00	392.00	-1.29	0.20
Gender	0.03	0.02	392.00	1.72	0.09
Education	-0.01	0.01	392.00	-2.49	0.01*
Mean TWT	0.00	0.00	392.00	-3.37	0.01**
Mean TWT * Crystallized cognition	0.00	0.00	392.00	3.40	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

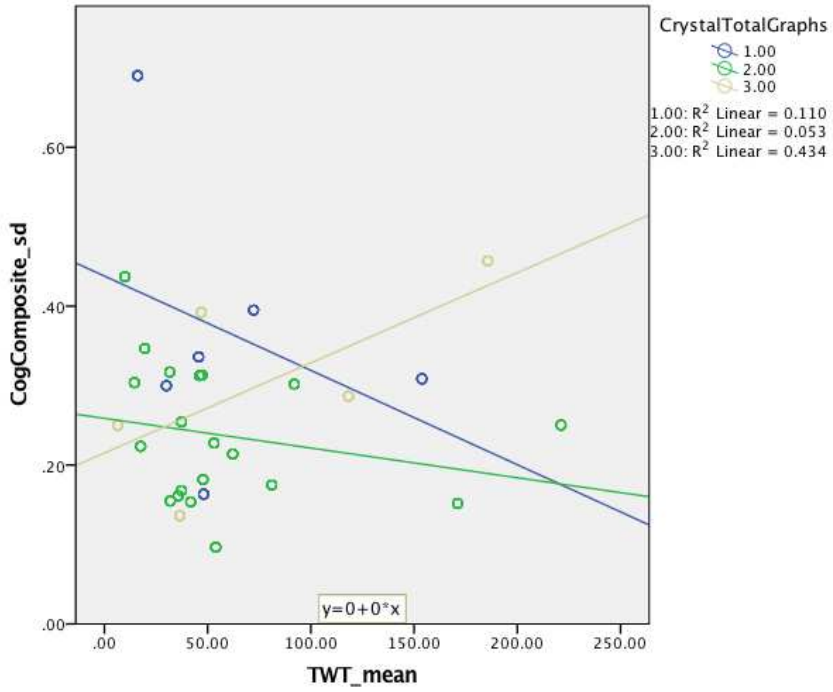

Figure 26. Moderation of mean TWT-cognitive variability by crystallized baseline cognition.

Table 34

Moderation of SEI-Cognitive Variability by Crystallized Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.31	0.10	392.00	3.03	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	0.00	0.00	392.00	-1.32	0.19
Gender	0.04	0.02	392.00	2.86	0.01**
Education	0.00	0.01	392.00	-0.42	0.68
Mean SEI	0.00	0.00	392.00	2.57	0.01*
Mean SEI * Crystallized cognition	0.00	0.00	392.00	-3.64	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at $p<0.01$

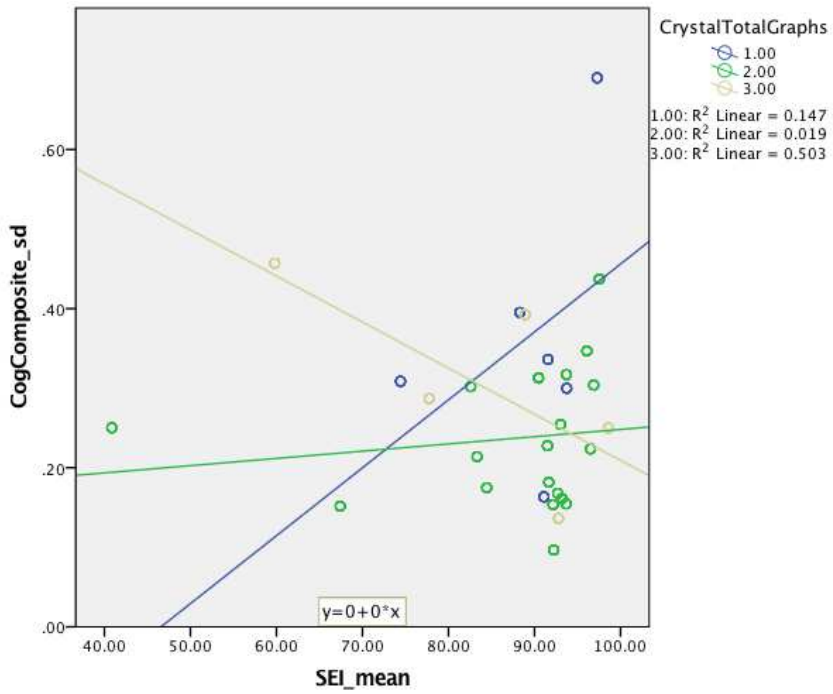

Figure 27. Moderation of mean SEI-cognitive variability with crystallized baseline cognition.

Moderation of Sleep-Cognitive Variability by Fluid Cognitive Status. With respect to fluid baseline cognition, there was not a significant interaction for mean pain or mean stress with fluid baseline cognition. For sleep, the following variables had a significant interaction with fluid baseline cognition: SOL (β = 0.00, SE = 0.00, p = 0.02), TWAK, (β = 0.00, SE = 0.00, $p < 0.01$), TST (β = -0.00, SE = 0.00, p = 0.01), TWT (β = 0.00, SE = 0.00, $p < 0.01$) and SEI (β = -0.00, SE = 0.00, p = 0.01). See Tables 35-39 for a summary of the models of sleep variables listed above. Decomposition of these interactions revealed for below average individuals, SOL, TWAK, and TWT were negative associated with cognitive variability, while TST and SEI were positively associated with cognitive variability. For average individuals, SOL was positively associated with cognitive variability, while TWAK, TST, and SEI were negatively associated with cognitive variability. Finally, for above average individuals, SOL, TWAK, and TWT were positively associated with cognitive variability, while TST and SEI were negatively associated with cognitive variability (See Figures 28-32).

Table 35

Moderation of SOL-Cognitive Variability by Fluid Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.39	0.11	378.00	3.57	0.01**
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	-1.48	0.14
Gender	0.02	0.02	378.00	1.31	0.19
Education	-0.01	0.01	378.00	-2.51	0.01*
Mean SOL	0.00	0.00	378.00	-1.61	0.11
Mean SOL * Fluid cognition	0.00	0.00	378.00	2.33	0.02*

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

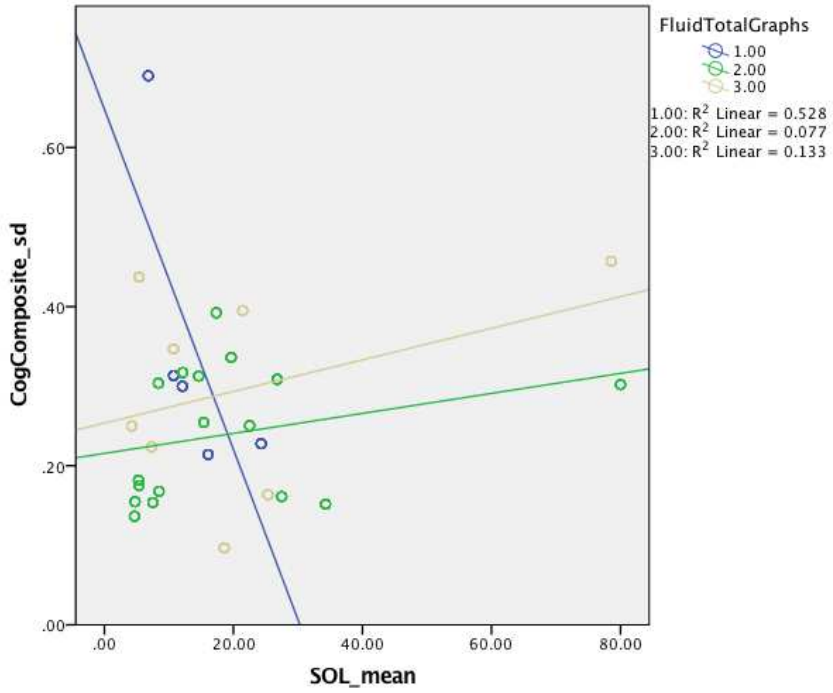

Figure 28. Moderation of mean SOL-cognitive variability by fluid baseline cognition.

Table 36

Moderation of TWAK-Cognitive Variability by Fluid Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.66	0.10	392.00	6.70	0.01**
Day	0.00	0.00	392.00	0.00	1.00
Age	0.00	0.00	392.00	-4.49	0.01**
Gender	-0.01	0.02	392.00	-0.32	0.75
Education	-0.01	0.00	392.00	-1.86	0.06
Mean TWAK	-0.01	0.00	392.00	-7.75	0.01**
Mean TWAK * Fluid cognition	0.00	0.00	392.00	7.68	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

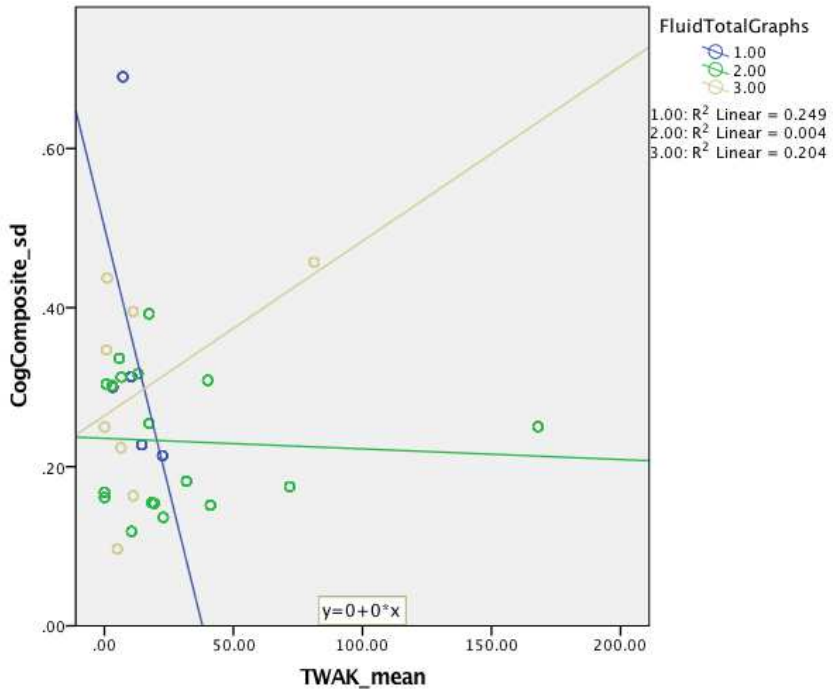

Figure 29. Moderation of mean TWAK-cognitive variability by fluid baseline cognition.

Table 37

Moderation of TST-Cognitive Variability by Fluid Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.21	0.12	378.00	1.78	0.08
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	0.02	0.98
Gender	0.07	0.02	378.00	3.52	0.01**
Education	-0.01	0.001	378.00	-1.87	0.06
Mean TST	0.00	0.00	378.00	2.22	0.03*
Mean TST * Fluid cognition	0.00	0.00	378.00	-3.50	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

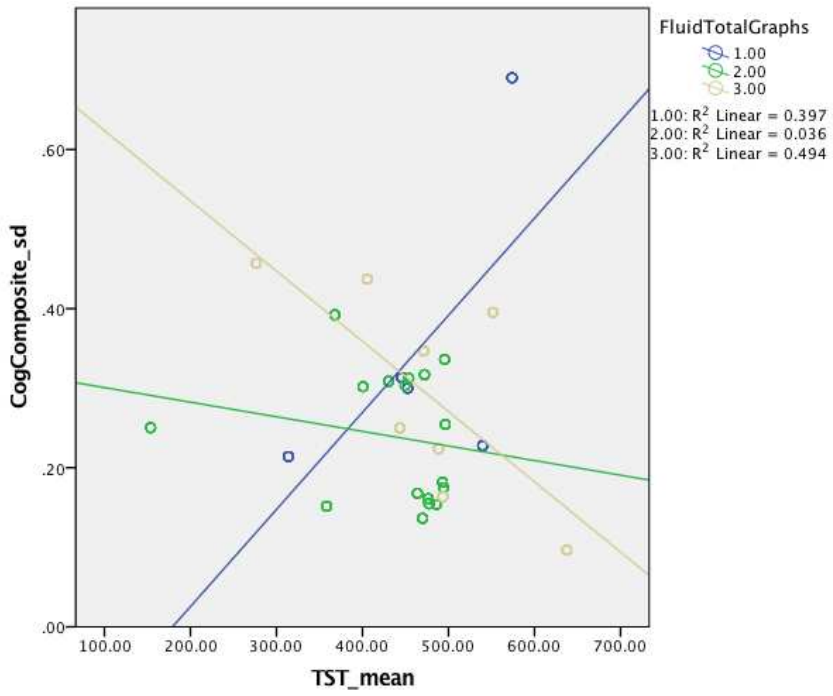

Figure 30. Moderation of mean TST-cognitive variability by fluid baseline cognition.

Table 38

Moderation of TWT-Cognitive Variability by Fluid Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.44	0.11	378.00	4.07	0.01**
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	-1.76	0.08
Gender	0.01	0.02	378.00	0.67	0.50
Education	-0.01	0.00	378.00	-1.85	0.06
Mean TWT	0.00	0.00	378.00	-4.51	0.01**
Mean TWT * Fluid cognition	0.00	0.00	378.00	4.50	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

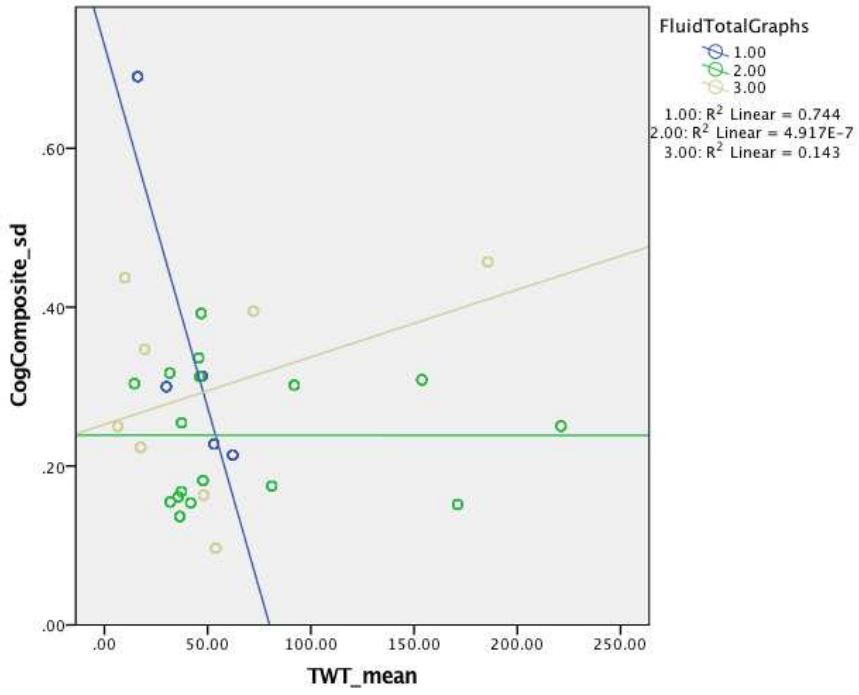

Figure 31. Moderation of mean TWT-cognitive variability by fluid baseline cognition.

Table 39

Moderation of SEI-Cognitive Variability by Fluid Baseline Cognition

	β	*SE*	*df*	*t*	*p*-value
	Fixed Effects				
Intercept	0.19	0.12	378.00	1.57	0.12
Day	0.00	0.00	378.00	0.00	1.00
Age	0.00	0.00	378.00	-0.04	0.97
Gender	0.06	0.02	378.00	3.22	0.01**
Education	-0.01	0.01	378.00	-1.93	0.05*
Mean SEI	0.00	0.00	378.00	2.12	0.03*
Mean SEI * Fluid cognition	0.00	0.00	378.00	-2.65	0.01**

Note: * denotes significant at $p < 0.05$; ** denotes significant at p<0.01

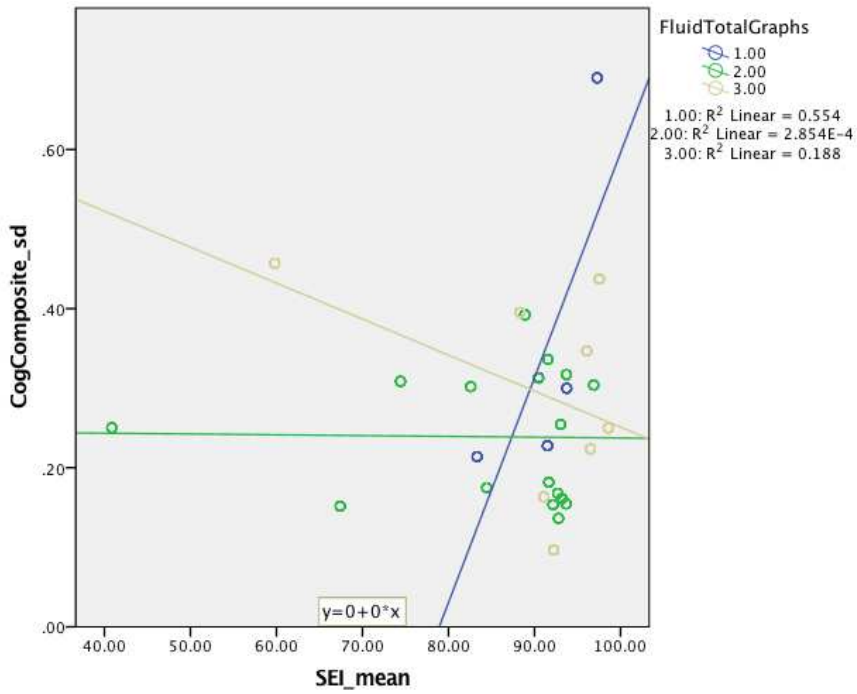

Figure 32. Moderation of mean SEI-cognitive variability by fluid baseline cognition.

CHAPTER 4

DISCUSSION

Overall, the contextual factors of pain, stress, and sleep were predictive of cognitive performance. However, these associations varied depending on the level of measurement (e.g. baseline, daily, or mean performance across 14 days) and were frequently conditional upon cognitive status measured at baseline. Furthermore, in addition to varying in terms of the significance of the associations, the directionality of these associations also differed depending on the level of measurement. A summary and the implications of findings are presented below, with a discussion of main effects and moderations by cognitive status for each contextual variable. Finally, a discussion of reoccurring themes, conclusions, and future directions are presented.

Associations Between Pain and Cognition

Main Effects of Pain on Cognition. There were several associations between pain and both cognitive performance and cognitive variability. These associations were examined at within- and between-person levels of analyses. At the between-person level across the entire sample, greater baseline pain predicted greater cognitive variability. In line with the hypothesis, and previous research findings linking pain and cognition, pain predicted cognition in the form of greater cognitive variability, which is associated with poorer cognition overall. In addition, at the within-person level across the entire sample, days with more pain were associated with better cognitive performance. This is a puzzling finding that, as detailed below, did not hold for most

participants when moderation analyses were conducted, suggesting it may depend on the cognitive status of participants.

Moderation of Pain-Cognition Association by Cognitive Status. The results for the moderation of the association between pain and cognitive performance by cognitive status partially support the hypotheses regarding pain-cognition associations. Individuals with below average cognitive status did display worse cognitive performance if they experienced greater pain. However, this association was also found for individuals with above average cognitive status. Importantly, the association between greater pain and worse cognitive performance was also found for individuals with below average crystallized status, but not individuals with above average crystallized status. Perhaps a global composite representing cognitive status unwittingly complicates the present results. It is possible that the underlying association of import is actually between a specific subset of cognition, namely crystallized cognition, and pain. Further analyses could determine if this is the case by examining the pain-cognitive performance association with a moderator of combined below average overall and crystallized cognitive status. In other words, it may be that greater pain is significantly associated with worse cognitive performance only in individuals with both overall and crystallized scores that fall in the below average range. There may be a third factor at play in this association, such as motivation or anxiety related to the experience of pain that in turn influences one's crystallized cognitive performance. Another possible explanation is that medication usage in individuals with pain plays a role in the associations found.

The findings regarding moderation of the pain-cognitive variability association by cognitive status partially support the hypothesis that individuals with compromised cognitive status would be differentially impacted by greater levels of pain; this association was indeed

found for below average individuals, but was also found, and to a greater degree, for above average individuals. It is possible that individuals with above average cognition are more attuned to the pain they experience, or experience pain differentially than average and below average individuals, thus reacting more strongly to pain than the other groups of participants. Interestingly, individuals with average cognitive status actually displayed less variability with greater pain. There are several possible explanations for the pain-cognition associations found in the present study. One possibility is there may be an issue of measurement error or bias in the way pain was measured. Daily pain was measured with one question each day as compared to multiple questions assessing stress and sleep. In addition, participants may have interpreted the daily question differently, such that some reported on pain across the entire previous day and other reported on pain over the previous night (e.g., the question asked, "How much pain have you had since yesterday?"). The sample reported moderate, but not especially high levels of pain overall (M = 1.90, SD = 0.68, out of a maximum five points), so it is possible the level of pain was not high enough to uncover the expected associations between pain and cognition.

Associations Between Stress and Cognition

Moderation of Stress-Cognition Association by Cognitive Status. No main effects were found linking stress to cognitive performance, suggesting that this association was dependent on cognitive status within the present sample. Examining moderation by cognitive status, within- and between-level associations were found between stress and both cognitive performance and cognitive variability. At the within-person level, the finding that below average crystallized cognitive status individuals exhibit poorer cognitive performance on days when he or she experiences greater stress supports the hypothesis that individuals with compromised baseline cognition will be more affected by daily stress than individuals with better cognitive status.

At the between-person level, only crystallized baseline cognitive status was found to moderate the relation between stress and cognitive performance. The findings regarding the moderation of the stress-cognitive performance association by crystallized cognitive status partially support the hypothesis that higher stress would be associated with poorer cognitive performance, but this was not found across the sample, and the effect was actually strongest in individuals with above average crystallized cognition. However, the fact that this association was found for both above and below average groups speaks to the possibility that these two groups are more sensitive than the average group to such effects. Overall, the sample reported low levels of daily stress; perhaps the stress they experienced was not severe enough to negatively impact cognitive performance. Notably, there was a large amount of within-person variability in stress (i.e. 72% of all variance), which may have influenced the results. A significant negative correlation was found between mean stress and the amount of variability in daily reports of stress ($r = -0.21$, $p < 0.01$), such that more stress was associated with less variability in stress reported on a daily basis. In other words, the stress for individuals experiencing higher levels was relatively stable, at a higher level. Conversely, individuals with lower overall stress were more likely to experience days of respite from higher stress levels.

Based on Yerkes-Dodson law, there is an optimal level of arousal at which performance peaks, with over or under stimulation leading to a reduction in performance (Cohen, 2011). Accordingly, another possible explanation is that there is an optimal level of stress at which cognitive performance peaks; lower or higher levels of stress would be expected to be associated with lower cognitive performance. Therefore, the relationship between stress and cognitive performance may not be linear and the optimum stress level may vary based on cognitive status

Regarding cognitive variability, the finding that baseline overall and crystallized cognitive status moderated the stress-cognitive variability association supports the hypothesis that greater stress will predict greater variability in cognition; however, the effect was stronger in individuals with average crystallized cognition as compared to below average. In addition, greater stress predicted less cognitive variability for above average crystallized status individuals. Essentially, stress was associated with different outcomes depending on cognitive status. For average individuals, stress predicted greater variability in cognitive performance but not significantly worse or better performance. For those above and below average cognitive status, higher levels of stress may predict a stable, lower level of cognitive performance (hence the lack of significant variability).

Associations Between Sleep and Cognition

There were no significant within-person associations found in the present study between sleep variables derived from the sleep diary and cognitive performance or variability. There were, however, a number of significant findings at the between-person level for both cognitive performance and cognitive variability as discussed below.

Main Effects of Sleep on Cognitive Performance. Across the entire sample, greater total sleep time predicted lower cognitive performance. Given recent studies have found a link between sleep duration and health outcomes (e.g. Altman et al., 2012), and the well established link between sleep and depression (Cho et al., 2008), sleeping for longer amounts of time could be indicative of health problems or emotional distress, which would explain the relation between sleeping longer and having lower cognitive performance. Of note, the total sleep time range for the sample was 1.3 hours – 10.63 hours, with a mean of 7.57 hours. The National Sleep Foundation recently released sleep duration recommendations and suggested that a duration of 7

to 8 hours is recommended for older adults (with a range of 5 to 9 hours to accommodate individual differences in sleep need). As such, a portion of this sample of older adults is spending an insufficient and an excessive amount of time sleeping.

Main Effects of Sleep on Cognitive Variability. Poorer mean sleep as measured by the daily diaries predicted more cognitive variability. This finding is in line with the hypothesis that individuals with worse sleep overall would exhibit more variability in their cognitive performance across 14 days. It is well established that poor sleep can impact cognition (Ohayon & Vecchierini, 2002), and the findings in the present study suggests one way this manifests is instability in cognitive performance. More specifically, taking longer to fall asleep was associated with greater variability.

Moderation of Sleep-Cognitive Performance Association by Cognitive Status. After breaking the sample into groups based on cognitive status, some results confirmed the hypotheses of the present study while others warrant further explanation and investigation. For example, while the association between better sleep and higher cognitive performance in average and above average individuals is intuitive, the association between better sleep and poorer cognitive performance in below average individuals is less so. It is possible below average individuals are not as reliable reporters of their sleep quality compared to those of better cognitive status. There was a general finding across all cognitive status groups that greater total sleep time was associated with lower cognitive performance. It is possible that individuals spending more time sleeping have mental or physical complaints that influence their cognitive performance, and that this underlying association is constant regardless of cognitive status.

When the sample was grouped based on baseline overall cognitive status, sleep variables associated with good sleep (e.g. SQR, SEI, and TST) predicted lower cognitive performance for

individuals with below average overall cognition. Interestingly, sleep efficiency predicted higher cognitive performance in the average group but lower performance in the above average group. The results for sleep efficiency is an example of a pattern found several times in the results of the present study, such that above and below average individuals seem to "hang together", displaying similar results that are inconsistent with the associations found for average cognitive status individuals.

For crystallized cognitive status, sleep variables associated with good sleep (e.g. SQR, SEI, and TST) were associated with lower cognitive performance in the above and below average crystallized cognitive status groups. Total wake time, an indicator of poor sleep, was associated with higher cognitive performance in these groups. The opposite pattern of results was found for individuals with average crystallized cognition. The results for the average group seem intuitive; however, the findings for the above and below average groups warrant further explanation. McCrae, Vatthauer, Dzierzewski, and Marsiske (2012) found similar results in a microlongitudinal study examining associations between sleep and cognition. The authors report that more TWT during the night was associated with higher processing speed scores, and suggest individuals may be aware of their poor sleep and therefore increase effort in an attempt to compensate for any deleterious effects of a poor night of sleep. It is possible that these individuals could compensate for lack of sleep on the daily cognitive assessments given that the assessments are a discrete, time-limited task, lasting no more than one hour. Detriments may exist in other areas of daily functioning that were not assessed by the study.

Moderation of Sleep-Cognitive Variability Association by Cognitive Status. When the sample was grouped based on baseline cognitive status, sleep variables associated with poor sleep (e.g. SOL, TWAK, TWT) predicted less variability for individuals with below average

overall cognition. Sleep variables associated with good sleep (e.g. SQR, SEI, and TST) predicted more variability for this group. Generally speaking, the opposite pattern of results was found for individuals with average and above average overall cognition. The results for the average and above average groups seem intuitive given a relation between poor sleep during the night and lower cognition would be expected. However, the findings for below average individuals warrant further explanation. One possibility is that variability in cognition in the below average group is actually a positive outcome, such that in order to have "good days" of cognition, variability is necessary. However, the opposite might be true for average and above average individuals, such that variability is a negative outcome. In other words, when operating at an average or above average level, it may be beneficial to stay at that level of functioning, while when operating at a below average level, it may be beneficial to deviate from that level of functioning, especially if that deviation is in a positive direction. For example, deviation for individuals with depression can be viewed as a positive outcome if the deviation is in the direction of improved mood or functionality.

The results for groups based on crystallized cognition are less clear; however, two patterns seemed to emerge. In one case, individuals with above average crystallized cognition seem to display findings discrepant from the rest of the sample. In the other case, individuals with below average crystallized cognition displayed discrepant findings from the rest of the sample. Regarding fluid cognition, the same two patterns of results were observed, with the majority of findings setting below average individuals apart. Only time spent awake in bed in the morning was discrepant for the above average individuals.

Conclusions and Reoccurring Themes

One important factor to consider when examining the results of the present study is that the contextual variables might fluctuate on different timescales and these varying fluctuations may contribute to different findings for pain, stress, and sleep. For example, sleep is a circadian process (i.e. primarily occurs once a day), while pain and stress are ultradian processes (i.e. probably fluctuate at multiple points in the day). Although the contextual variables of interest likely fluctuate differently with respect to time, the present study employed a uniform measurement approach (i.e. daily) in order to reduce participant burden. The trade-off for a less burdensome approach to daily measurement of pain and stress may be less precise measurements of some variables. That is to say, the associations found for pain and stress, which were reported with respect to the previous day, may be grosser approximations than the associations between sleep and cognition, as sleep was reported immediately upon awakening.

Furthermore, some of the counterintuitive results may be explained by compensatory behaviors. For example, greater stress may lead to compensatory behaviors, such as better sleep habits, that result in higher cognitive performance or lower cognitive variability. Ideally, pain and stress would also be measured at the time of administration of the daily cognitive diary, thus reducing bias and error by not requiring participants to report retroactively on their stress and pain the previous day.

Across findings, the below average cognitive status group exhibited a different pattern of results than the average and above average individuals, supporting the hypothesis that individuals with compromised cognitive integrity may be more susceptible to the influence of contextual variables. However, the above average group also seemed to display sensitivity to contextual variables, and even displayed effects similar to the below average group. It is

possible this is simply an artifact of the smaller sample size in the below and above average groups when the entire sample was split based on cognitive status. Another possible explanation is that a regression to the mean effect is occurring. The cognitive status variables are based on standardized norms such that "above average" represents "above average" in the population as a whole. That is to say, the high daily performance may be difficult to maintain and individuals who fall in this category may be more susceptible to contextual factors than the average group because they have more room to move or worsen.

Another interesting finding was the greater number of significant moderations by crystallized cognitive status as compared to fluid cognitive status. Given that crystallized cognition remains relatively stable across the lifespan, while fluid cognition is known to decline with age, one might predict a stronger association between fluid cognition and daily cognition. However, this was not the case, which raises the question of what crystallized cognition in this sample actually represents. One possibility is that crystallized cognition, which is often defined as accumulated facts and knowledge, is a representation of education quantity or quality. Another possibility is that crystallized cognition is a representation of cognitive reserve capacity. In other words, individuals who have below average crystallized cognitive status may have poor reserve and thus be unable to compensate for cognitive deficits.

Finally, the present results comprised mainly associations between mean-level variables and cognition, not daily-level variables. It is important to note, however, that the mean-level variables that were calculated from aggregating data across 14 days were often associated with cognitive performance and variability while baseline measures of the same constructs were not. There are several explanations for this trend. One explanation is that the mean-level variables calculated from the daily diary uncovered associations that would be overlooked in traditional

one-time assessments due to improved validity or a more reliable measure of the constructs of interest. Another possibility is that the daily measures and baseline measures are actually measuring different constructs or different facets of the same constructs. Further research examining the validity of daily measures of pain, stress, sleep, and cognition is warranted.

Limitations

There are several limitations of the present study. First, the sample size, while adequate for multilevel modeling analyses, was small for other types of analyses. Second, the daily sleep, stress, and pain variables used self-report, which introduces the possibility of response bias. In addition, pain, stress, and sleep were measured the morning of the next day using retroactive daily diaries, while cognition was measured each day over the phone. Furthermore, the use of the phone for the daily cognitive diaries may have introduced error in the form of poor connections, inadequate enunciation by research assistants, or error through compromised validity of measures modified for phone administration. Importantly, the present study did not analyze lagged effects. It is possible that the pattern of results between the variables investigated would unfold differently over time. That is to say, sleep may affect cognition the day after next instead of the next day. In addition, it is possible that the contextual variables examined may work indirectly through each other to influence cognition. For example, pain might affect sleep, which in turn affects cognitive performance. Further research examining these complex and potentially bidirectional relationships could advance our understanding of the complex factors that influence cognition in older adults. Finally, the classification of cognitive status in the present study was based on the NIH toolbox measures and standardized values, which is valid and reliable but not equal to a comprehensive neuropsychological diagnostic evaluation.

Future Directions

There are many possible avenues of future research using the current dataset. For example, examination of associations between contextual variables and specific cognitive domains, such as memory or executive function may further clarify the associations found in the present study. Another unexplored area is variability in the contextual factors themselves, and if that variability is associated with cognitive performance or cognitive variability. Additionally, one might examine the discrepancy between crystallized and fluid baseline cognition as a proxy for cognitive impairment, and investigate associations between this discrepancy and the contextual variables of interest.

Future research with a larger sample size would be beneficial to examine associations best suited to analyses requiring a larger sample size. In addition, variables such as stress and pain which may fluctuate several times a day would optimally be measured multiple times each day, instead of retroactively once a day as in the present study. Overall, the present study found that contextual factors such as pain, stress, and sleep are associated with daily cognition, but these associations are complex, often dependent on measurement level and the cognitive status of individuals. These findings highlight the need for continued examination of these associations to expand our understanding of cognition in older adults and to discover potential targets for interventions to attenuate cognitive decline.

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APPENDICES

Appendix I

Daily Cognitive Diary Study—Telephone Screening Form

To be filled out prior to screening by staff:

Name: _____, ____, _____ **Sex: M F**
First M.I. Last

Phone Number: (_____) _____-_____

Address: _____ _____ _____ _____
Street Address City State Zip

Script

Hi Mr/Ms. _____. My name is _____ and I am calling to discuss the new Daily Cognition Diary Study. If now is a good time, I can tell you about the study and we can complete the telephone questions which will help us determine if you are eligible to come in for an in-person visit if you are interested in participating. These questions will take approximately 20 minutes. Are you able to talk with me for that amount of time?

Yes ____ No _____ (Rescheduled for: _____)

If yes**: In this study, we are trying to determine what factors impact stability in cognitive performance. Participants will be given initial baseline testing, during which they will complete several tests of memory and thinking, lasting about an hour. They will then be introduced to the daily diary assessments, which will be conducted over the phone for 14 consecutive days. Participants will be given specific instructions regarding when and how they will be contacted each day for their daily assessments. The assessments will require no written or computerized tasks, as all of the questions will be asked over the phone by a researcher. These assessments will be completed at the same time each day and participants will be allowed to choose the time of day most convenient for them. At the end of the two-week daily diary period, participants will receive a small token of appreciation and be given a chance to ask any questions that might have come up during the study. Does this sound like something you would be willing to participate in.**

If no**: Thank you for your time and consideration, Mr./Mrs. _____. We often have several studies going on at the same time, so would it be okay to keep your contact information to notify you of other research studies you may be interested in?**

Yes_____No_____**Again, thank you for your time, and have a nice day!**

If yes: **Before we begin, I want to let you know that the information and responses you provide are kept strictly confidential. If at any time you do not feel comfortable answering a question, please let me know.**

Age Screener

1. **Are you at least 65 years of age?** Yes ____No ____

If no, proceed to Ineligible Script.

Hearing Screener

2. Do you use a hearing device?

Yes ____ No ____

If yes, **Is it in place?** Yes ____ No ____ N/A ____

2. I need to make sure you can hear me well enough. Will you repeat this statement… I have a cat so all I need is a dog.

Individual repeated properly Yes ____ No ____

If no: **Thank you very much Mr./Ms._____ but I am concerned you may not be able to hear me well enough to complete the questions so I will not continue at this time. I would like to thank you for your interest in the Daily Cognitive Diary study and for taking the time to speak with me today.**

Introduction

Great. Now I will begin by asking you various questions related to your thinking and cognitive activities. Some questions could possibly be asked more than once. The questions will require concentration, so it is important that you are in a quiet environment and not disturbed. All of the questions are designed to be asked over the telephone. Your responses should be provided according to your thinking and knowledge. Therefore, pencil/paper is not needed so I need for you to remove pens, pencils, paper, calendars or newspapers.

Permanent Exclusions

I have a few questions for you regarding your plans and physical health. Please answer the best you can.

	Yes	*No*	*N/A*
1. Do you plan to leave the area for over a week within the next month and a half?			

If yes: **When? _____ For how long? _____**

2. Have you ever been told by your doctor that you have:

3a. Parkinson's disease?			
3b. Alzheimer's disease or some other form of dementia?			
3c. Multiple sclerosis?			
3d. ALS/Lou Gehrig's disease?			
3e. Schizophrenia?			
3f. Bipolar disorder?			
4. Have you ever been hospitalized for a stroke?			
5. Have you ever suffered from head trauma?			
6. Are you taking any medications for your memory?			

If yes, specify:

How long have you been taking this medication?

Must have been on medication for at least 8 weeks.

8. Are you able to see and read words on a computer or in a newspaper or magazine?			

If no, proceed to Ineligible Script.

9. Would you be willing to complete a written agreement called informed consent that gives us permission to let you participate in the study? Yes ____ No ____

Is this person still eligible? Yes ____ No ____

Memory/Cognition

All older adults experience some decline in memory and other cognitive abilities as they age. I want to ask you a few questions to learn about how much decline you may be having and whether it causes problems.

	Yes	***No***	***N/A***
1. Has a doctor or specialist ever evaluated or diagnosed you for problems with memory or thinking?			

If yes: **What was his opinion/diagnosis? _____**

2. Has your doctor or specialist ever diagnosed you with:

2a. Dementia?

2b. Mild cognitive impairment?

2c. Other neurological/cognitive disorder?

3. During the past 6 months, have you been hospitalized for TIA/mini-stroke?

Is this person eligible? Yes ____ No ____

If person is still eligible, proceed with TICS-M.

If person is not eligible, proceed to Ineligibility Script below.

Ineligible Script

Mr/Mrs ____, I appreciate your willingness to participate in our study. We are seeking participants who fit several characteristics. Unfortunately, based on your answers, I cannot enroll you in this study. I would, however, like to include you in our directory of people who would like to be contacted about different studies. May I do that? Thank you very much.

Yes _____ No _____

Appendix II

-TELEPHONE INTERVIEW FOR COGNITIVE STATUS – MODIFIED (TICS-M)-

I would like to ask you some questions to check your memory and concentration. Some of the questions may be easy and some will be harder. Take your time if you need to. We can skip over questions if you don't understand them.

1. **Please tell me your full name.** (Prompt: **Your name as it appears on your birth certificate.**)
You may ask the client to provide his first or last name if he does not provide both automatically.

	Circle:	Correct	Incorrect	DK	Refused
First:	_____	1	0	7	8
Middle:	_____	1	0	7	8
Last:	_____	1	0	7	8

		Circle:	Correct	Incorrect	DK	Refused
2.	**What is your age?** Age _____		1	0	7	8
3.	**Without looking at a calendar or watch, what is today's date?**					
	Month:	_____	1	0	7	8
	Day:	_____	1	0	7	8
	Year:	_____	1	0	7	8
4.	**What day of the week is it?**	_____	1	0	7	8
5.	**What season is it?**	_____	1	0	7	8
6.	**Without looking at your phone, can you tell me your phone number?**		1	0	7	8

Maximum of two attempts on Item # 7:

7.	**Now I would like you to count backwards from 20 to 1.**	2	0	7	8

Indicate Errors:

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Administer a 2nd time if 1st attempt was incorrect:

OK. Let's try this one more time. 1 0 7 8

Indicate Errors:

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

8a. **Now I'm going to read you a list of 10 words. Please listen carefully. When I am done, tell me as many words as you can, in any order. [Please do not write anything down.] I will read the list only once. If you don't understand a word, that's all right. Just try to repeat what you heard. If you're ready, I'll begin.**

(You can repeat the instructions but not the word list. Read the words at the rate of one word every two seconds.)

The words are:

Cabin…….Pipe……..Elephant……..Chest……..Silk……..
Theatre……..Watch……..Whip……..Pillow……..Giant

Now please repeat the words that you remember.

(Record all words up to 20 words even if not on the list. Only the words from the list are scored as correct. Repeated words are recorded but not scored.)

1_____	6_____	11_____	16_____
2_____	7_____	12_____	17_____
3_____	8_____	13_____	18_____
4_____	9_____	14_____	19_____
5_____	10_____	15_____	20_____

TOTAL OF CORRECT RESPONSES (Max. of 10 pts.): _____

Was the client speaking nonsense words? Circle: Yes No

		Correct	Incorrect
9. **Please subtract 7 from 100 and then subtract 7 from that number until I tell you to stop.**	1_____	1	0
Record exact responses. Do not inform client of errors. Stop client after five responses. If client refuses to complete the task ask them: "What is 100-7?" Record the response. Then say: "Subtract seven from that number."	2_____	1	0
	3_____	1	0
	4_____	1	0

	Record each response. If the client refuses to continue after first response, score remaining items as incorrect	5_____	1	0	
		Correct	Incorrect	DK	Refused
10.	**What do people usually use to cut paper?** (Accept only "scissors" or "shears" as correct.)	1	0	7	8
11.	**How many things are in a dozen?** (Accept only "12" as correct.)	1	0	7	8
12.	**What do you call the kind of prickly plant that lives in the desert?** (Accept only "Cactus" or a kind of cactus, e.g. "Prickly Pear" as correct.)	1	0	7	8
13.	**What animal does wool come from?** (Accept only "sheep" or "lamb" as correct.)	1	0	7	8
14.	**Please say this exactly as I say it: "No ifs, ands, or buts."**	1	0	7	8
15.	**Say this: "Methodist Episcopal."** (Listen carefully. Each word must be said clearly and distinctly. Eg. Methodis Epistopal would be scored as incorrect.)	1	0	7	8
16.	**Who is the President of the United States right now?**				
	First: _____	1	0	7	8
	Last: _____	1	0	7	8
17.	**Who is the current Vice-President?**				
	First: _____	1	0	7	8
	Last: _____	1	0	7	8

For Item # 18: Do not repeat the instructions. You may say, **"Just try to do what you think I said."**)

18.	**With your finger, please tap 5 times on the part of the phone that you speak into.** [or **With your finger, please tap 5 times on the top of the table.**]	1	0	7	8

19. **Now I'm going to say a word and I want you to say its opposite. For example, I might say "hot" and you would say "cold." What is the opposite of "east"?**
(Accept only "west" as correct.)

1 0 7 8

20. **What is the opposite of "generous"?**

1 0 7 8

Score any of the following as correct:

NIGGARDLY	SELFISH	MISERLY	NOT GENEROUS	SPARSE
SCROOGE	GREEDY	MEAN	UNGENEROUS	CHINTZY
TIGHTWAD	STINGY	MEAGER	PENURIOUS	FRUGAL
HOARDING	TIGHT	SKIMPY	PARSIMONIOUS	SCOTCH
RESTRICTIVE	SKINFLINT	CHEAP		

Record any other word: _____

21. **A few minutes ago, I read you a list of ten words and asked you to repeat them back to me. Please tell me all of those words you can still remember.**

1_____	6_____	11_____	16_____
2_____	7_____	12_____	17_____
3_____	8_____	13_____	18_____
4_____	9_____	14_____	19_____
5_____	10_____	15_____	20_____

TOTAL OF CORRECT RESPONSES (Max. of 10 pts.): _____

Was the client speaking nonsense words? Circle: Yes No

TICS-M TOTAL SCORE: _____

(*Total Possible = 50; Cut-off < 20)*

Use the following table and the individual's education level from the screening form to determine the appropriate education adjusted score.

Level of Education	Point Adjustment
< 8 years	+5
8 to 10 years	+2
11 to 12 years	No point change
≥ 13 years (excluding technical college)	-2

EDUCATION ADJUSTED SCORE: _____

Sleep Questionnaire

Now I have a few questions about your sleep… (No Rule Outs—Informational)

Are you currently experiencing difficulty with your sleep at night?___ YES___NO

If yes, describe:

Do you have difficulty falling asleep at night? ___ YES ___NO

If yes, approximately how long does it take you to fall asleep at night?
___hr ___ min

Do you wake up frequently during the night? ___ YES ___NO

If yes, approximately how many times do you awaken? _____

How much time do you spend awake during the night? _____

Do you wake up early in the morning and are unable to go back to sleep?
___ YES___NO

If yes *(to any of the above problems)*, how many nights per week? _____

If yes, how long have you had this problem? _____ years _____ months

Have you ever received treatment for a sleeping problem? ___ YES ___NO

If yes, when did you receive treatment and what type of treatment was involved *(have individual be specific regarding the type of treatment received)*

_____

Do you have any impaired daytime functioning, due to your sleeping difficulty *(check off any symptoms endorsed by the individual)*.

_____ Sleepy during the day.

_____ Lack of motivation.

_____ Lack of energy.

_____ Increased fatigue.

_____ Malaise.

_____ Problems with mood (irritability).

_____ Decreased attention span.

_____ Poor Concentration.

_____ Other.

Explain_____

Do you fall asleep while watching TV, reading, or driving a car? ___YES ___NO

If yes, how often do you do this? _____

(Only ask if they are currently employed)
Does your occupation require you to work shift work? ___YES ___NO

If yes, what hours do you work _____

Rule out other sleep disorders. Has either the participant or their partner noticed any of the following:
(If the participant responds yes, ask how often the sleep problem occurs.)
These are rule outs…if unclear, ask Kristy or Natalie

Do you snore? ___ YES ___ NO ___ DON'T KNOW

If yes, is snoring ___ MILD ___ MODERATE ___ SEVERE

Do you wake up gasping for breath or do you quit breathing during the night *(has bed partner noticed these)*? ___ YES ___ NO

Does your mouth feel dry during the night or in the morning?
NOT AT ALL___ MILDLY___ MODERATELY___ SEVERELY___

Do you have any unusual sleep experiences? ___ YES ___ NO

If yes explain: _____

Do your legs jerk during the night? ___YES ___ NO

Do your legs feel restless before sleep onset? ___YES ___NO

Do you have sleep attacks during the day? ___YES___NO

Do you have paralysis at sleep onset? ___YES___NO

If yes to any of the above questions explain:

_____
_____
_____
_____

What time do you usually go to bed? _____

What time do you usually get up in the morning? _____

If Education Adjusted Score is equal to or above 20 AND there are no sleep disorders:

Thank you for taking the time to speak with me today and for your interest in the Daily Cognitive Diary Study. Our study will consist of a total of 16 sessions, including an introductory visit and baseline testing, two weeks of daily assessments, and a follow up session. The baseline assessment will last about _____. The daily assessments you complete over the phone each day will last_____. Do you have any questions about this schedule?

I would like to schedule a time for one of our researchers to meet with you to do some additional testing and to discuss the daily diary portion of the study. In general, what days and times would be best for someone to contact you to schedule this appointment?

Participant's preferred times:

_____
_____

If none is desired, reason: _____

Okay, Mr./Mrs. _____, someone will be contacting you shortly to schedule an appointment. We also have some questionnaires that we would like for you to fill out prior to this appointment that we will be sending you in the mail in the next couple of days.

Participants Mailing Address:

_____

_____

Do you have any other questions about the study?

Thank you and have a nice day!!

If Education Adjusted Score is below 20 OR there are sleep disorders:

Mr./Mrs. _____, unfortunately it seems you are not eligible for participation in this study. Based on your score on this cognitive screening tool, which is NOT intended for diagnostic purposes, you may be experiencing cognitive decline sufficient to hinder your participation…

I strongly encourage you to seek additional evaluation through your primary care doctor or a mental health professional (if excluded because of mental capacity).

Do you have a primary care doctor, or mental health professional that you can contact?

If yes: Okay. Thank you for your time Mr./Mrs. _____. Please don't hesitate to contact the principal investigator of this study, Kristy Shoji, if you have any further questions or concerns. Her number is 336-380-1582.

If no: Okay. We would be happy to send you a list of local health care/mental health providers. Would that be all right with you?

OR we are looking for people who have not been previously diagnosed with sleep disorders or who meet criteria for sleep disorders.

Although you are not eligible for this study, I would like to include you in our directory of people who would like to be contacted about different studies. May I do that? Thank you very much.

Appendix III

Demographics and Health Survey

Demographics

What is your date of birth? __ __ / __ __ / __ __ __ __

What is your age? _____

What is your height? _____ feet _____ inches

What is your weight? _____ lbs.

What is your sex (check one)? _____ male _____ female

How would you identify your cultural background (e.g. white, black, Chinese American)?

_____

What is your highest level of education?

_____

If you are in a relationship, what is your spouse/partners highest level of education?

_____

What is your marital status?

____ married ___ single ___ common-law ___widowed ___ divorced ___separated

What is your primary language?

_____

Does anyone live with you? _____ yes _____ no

If so, who?

_____

What county do you live in?

_____

What state do you live in?

_____

Are you presently employed? _____ yes _____ no

If yes, where?

_____

Health Survey

Do you drink alcohol?_____ yes _____ no

If yes, how many drinks do you have per day on average? _____

Do you consume caffeine (e.g. coffee, soda, chocolate, tea)? _____ yes _____ no

If yes, how much caffeine do you consume each day?

_____

Do you smoke cigarettes? _____ yes _____ no

If yes, how many cigarettes do you smoke per day on average? _____

What time do you usually go to bed? __ __ : __ __ AM/PM

What time do you usually wake up? __ __ : __ __ AM/PM

In general would you say that your health is (check one):

___ poor ___ fair ___ good ___ very good ___ excellent

Do you currently have heart disease? _____ yes _____ no

If yes, please explain:

_____

Do you currently have cancer? _____ yes _____ no

If yes, please explain:

_____

Do you currently have AIDS? _____ yes _____ no

If yes, please explain:

_____

Do you currently have high blood pressure? _____ yes _____ no

If yes, please explain:

_____

Do you currently have a neurological disease (e.g. Parkinson's disease or seizures)?

_____ yes _____ no

If yes, please explain:

_____

Do you currently have breathing problems (e.g. asthma or emphysema)?

_____ yes _____ no

Do you currently have diabetes? _____ yes _____ no

If yes, please explain:

_____

Do you currently have chronic pain (e.g. arthritis, back pain, migraines)?

_____ yes _____ no

If yes, please explain:

_____

Do you have difficulty walking? _____ yes _____ no

If yes, please explain:

_____

Do you have gastrointestinal problems such as stomach pain, irritable bowels, or ulcers?

_____ yes _____ no

If yes, please explain:

_____

Do you currently have urinary tract problems? _____ yes _____ no

If yes, please explain:

_____

Do you currently have any other medical problems or handicaps?

_____ yes _____ no

If yes, please explain:

_____

Have you experienced a stressful or disruptive life event (e.g. move, birth, death, illness, marriage, divorce) over the past:

Year? _____ yes _____ no

If yes, please explain:

_____

Month? _____ yes _____ no

If yes, please explain:

_____

Week? _____ yes _____ no

If yes, please explain:

_____

Day? _____ yes _____ no

If yes, please explain:

_____

Has someone you know experienced a stressful or disruptive life event (e.g. move, birth, death, illness, marriage, divorce) over the past:

Year? _____ yes _____ no

If yes, please explain:

_____

Month? _____ yes _____ no

If yes, please explain:

_____

Week? _____ yes _____ no

If yes, please explain:

_____

Day? _____ yes _____ no

If yes, please explain:

_____

Do you frequently feel nervous or depressed? _____ yes _____ no

If yes, please explain:

_____

Please list the number of mental disorders you have and the number of years you have had the disorder:

Number of mental disorders: _____

Number of years you have had each disorder:

_____

_____

_____

In the past, has a mental health professional (psychiatrist, psychologist, or social worker) ever treated you? _____ yes _____ no

If yes, please describe the treatment:

_____

_____

Are you currently being treated by a mental health professional?

_____ yes _____ no

If yes, please describe the treatment:

_____

_____

Please list all medications (including vitamins and over-the-counter medications) taken in the past month, how often you take them (e.g. daily, weekly), the time of day you take them, and the purpose of the medication:

Medication 1:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 2:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 3:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 4:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 5:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 6:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 7:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 8:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 9:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 10:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 11:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Medication 12:

Name of medication:

_____

Frequency:

_____

Time of day:

_____

Purpose:

_____

Appendix IV

Epworth Sleepiness Scale (ESS)

Name: _____ Age: _____

Date:_____ Sex: Male ____ Female ____

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the *most appropriate number* for each situation and write it in the blank space provided.

0 = would *never* doze

1 = *slight* chance of dozing

2 = *moderate* chance of dozing

3 = *high* chance of dozing

SITUATION	**CHANCE OF DOZING**
1. Sitting and reading	_____
2. Watching TV	_____
3. Sitting inactive in a public place (e.g. a theatre or meeting)	_____
4. As a passenger in a car for an hour without a break	_____
5. Lying down to rest in the afternoon when circumstances permit	_____
6. Sitting and talking to someone	_____
7. Sitting quietly after a lunch without alcohol	_____
8. In a car, while stopped for a few minutes in the traffic	_____

Johns, M.W. (1991). A New Method for Measuring Daytime Sleepiness: The Epworth Sleepiness Scale. *Sleep, 14,* 540-545.

Appendix V

Fatigue Severity Scale (FSS) (Krupp, 1989)

Please answer the following questions regarding how fatigue may impact your life by selecting a number from 1 to 7, with 1 indicating you strongly disagree with the statement, and 7 indicating that you strongly agree with the statement.

If you do not experience any fatigue you may skip this portion of the questionnaires and check the box below.

☐ **I do not experience fatigue.**

	Strongly Disagree						Strongly Agree
My motivation is lower when I am fatigued.	1	2	3	4	5	6	7
Exercise brings on my fatigue.	1	2	3	4	5	6	7
I am easily fatigued.	1	2	3	4	5	6	7
Fatigue interferes with my physical functioning.	1	2	3	4	5	6	7
Fatigue causes frequent problems for me.	1	2	3	4	5	6	7
My fatigue prevents sustained physical functioning.	1	2	3	4	5	6	7
Fatigue interferes with certain duties and responsibilities.	1	2	3	4	5	6	7
Fatigue is among my disabling symptoms.	1	2	3	4	5	6	7
Fatigue interferes with my work, family, or social life.	1	2	3	4	5	6	7

Appendix VI

Geriatric Depression Scale (Short Form)—(GDS-SF)

Patient's Name: Date:

Instructions: Choose the best answer for how you felt over the past week. Note: when asking the patient to complete the form, provide the self-rated form (included on the following page).

No.	Question	Answer	Score
1.	Are you basically satisfied with your life?	YES / ***NO***	
2.	Have you dropped many of your activities and interests?	***YES*** / NO	
3.	Do you feel that your life is empty?	***YES*** / NO	
4.	Do you often get bored?	***YES*** / NO	
5.	Are you in good spirits most of the time?	YES / ***NO***	
6.	Are you afraid that something bad is going to happen to you?	***YES*** / NO	
7.	Do you feel happy most of the time?	YES / ***NO***	
8.	Do you often feel helpless?	***YES*** / NO	
9.	Do you prefer to stay at home, rather than going out and doing new things?	***YES*** / NO	
10.	Do you feel you have more problems with memory than most people?	***YES*** / NO	
11.	Do you think it is wonderful to be alive?	YES / ***NO***	
12.	Do you feel pretty worthless the way you are now?	***YES*** / NO	
13.	Do you feel full of energy?	YES / ***NO***	
14.	Do you feel that your situation is hopeless?	***YES*** / NO	
15.	Do you think that most people are better off than you are?	***YES*** / NO	
TOTAL			

(Sheikh & Yesavage, 1986)

Scoring:

Answers indicating depression are in bold and italicized; score one point for each one selected. A score of 0 to 5 is normal. A score greater than 5 suggests depression.

Sources:

- Sheikh JI, Yesavage JA. Geriatric Depression Scale (GDS): recent evidence and development of a shorter version. *Clin Gerontol.* 1986 June;5(1/2):165-173.

- Yesavage JA. Geriatric Depression Scale. *Psychopharmacol Bull.* 1988;24(4):709-711.

- Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res.* 1982-83;17(1):37-49.

Appendix VII

Name:_____ Date: _____

Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. **Please answer all questions.**

1. During the past month, what time have you usually gone to bed at night? _____
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night? _____
3. During the past month, what time have you usually gotten up in the morning? _____
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) _____

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe:				
6. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
8. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?				
	Very good	Fairly good	Fairly bad	Very bad
9. During the past month, how would you rate your sleep quality overall?				

	No bed partner or room mate	Partner/room mate in other room	Partner in same room but not same bed	Partner in same bed
10. Do you have a bed partner or room mate?				
	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
If you have a room mate or bed partner, ask him/her how often in the past month you have had:				
a. Loud snoring				
b. Long pauses between breaths while asleep				
c. Legs twitching or jerking while you sleep				
d. Episodes of disorientation or confusion during sleep				
e. Other restlessness while you sleep, please describe:				

Scoring the PSQI

The order of the PSQI items has been modified from the original order in order to fit the first 9 items (which are the only items that contribute to the total score) on a single page. Item 10, which is the second page of the scale, does not contribute to the PSQI score.

In scoring the PSQI, seven component scores are derived, each scored 0 (no difficulty) to 3 (severe difficulty). The component scores are summed to produce a global score (range 0 to 21). Higher scores indicate worse sleep quality.

Component 1: Subjective sleep quality—question 9

Response to Q9	Component 1 score
Very good	0
Fairly good	1
Fairly bad	2
Very bad	3

Component 1 score:_____

Component 2: Sleep latency—questions 2 and 5a

Response to Q2	Component 2/Q2 subscore
≤ 15 minutes	0
16-30 minutes	1
31-60 minutes	2
> 60 minutes	3

Response to Q5a	Component 2/Q5a subscore
Not during past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Sum of Q2 and Q5a subscores	Component 2 score
0	0
1-2	1
3-4	2
5-6	3

Component 2 score:_____

Component 3: Sleep duration—question 4

Response to Q4	Component 3 score
> 7 hours	0
6-7 hours	1
5-6 hours	2
< 5 hours	3

Component 3 score:_____

Component 4: Sleep efficiency—questions 1, 3, and 4

Sleep efficiency = (# hours slept/# hours in bed) X 100%

hours slept—question 4

hours in bed—calculated from responses to questions 1 and 3

Sleep efficiency	Component 4 score
> 85%	0
75-84%	1
65-74%	2
< 65%	3

Component 4 score:_____

Component 5: Sleep disturbance—questions 5b-5j

Questions 5b to 5j should be scored as follows:

Not during past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Sum of 5b to 5j scores	Component 5 score
0	0
1-9	1
10-18	2
19-27	3

Component 5 score:_____

Component 6: Use of sleep medication—question 6

Response to Q6	Component 6 score
Not during past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Component 6 score:_____

Component 7: Daytime dysfunction—questions 7 and 8

Response to Q7	Component 7/Q7 subscore
Not during past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Response to Q8	Component 7/Q8 subscore
No problem at all	0
Only a very slight problem	1
Somewhat of a problem	2
A very big problem	3

Sum of Q7 and Q8 subscores	Component 7 score
0	0
1-2	1
3-4	2
5-6	3

Component 7 score:_____

Global PSQI Score: Sum of seven component scores:_____

Citation: Buysse, DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ: The Pittsburgh Sleep Quality Index (PSQI): A new instrument for psychiatric research and practice. Psychiatry Research 28:193-213, 1989

Appendix VIII

Philadelphia Geriatric Center Pain Scale (Parmelee, 1994)

Now I have some questions about any pain you might have. There are no right or wrong answers. Just tell me the response that best represents how you feel.

Tell Participant Possible Responses: 1 = NOT AT ALL
2 = A LITTLE
3 = MODERATELY
4 = QUITE A BIT
5 = EXTREMELY

	Not at all (1)	A Little (2)	Moderately (3)	Quite A Bit (4)	Extremely (5)
DURING THE PAST MONTH…					
In general, how much have you been bothered by pain?					
How much are you bothered by pain right now?					
How much are you bothered by pain when it is at it's worst?					
How much are you bothered by pain when it is at it's least?					
How much has pain interfered with your day-to-day activities?					

2. How many days a week does your pain get really bad?
_____ DAYS

Now I'm going to read a list of types of pain people may have. After each, please tell me if you are bothered by that type of pain.

Are you bothered by pain in each of the following places?

		YES	NO
3.	Headaches	1	0

4.	Neck aches or Pains	1	0
5.	Arm or Leg aches and pains (probe for type):	1	0
6.	Backaches	1	0
7.	Intestine or stomach pain	1	0
8.	Pain, burning or discomfort in urinating	1	0
9.	Aches or pains in your hands or feet	1	0
10.	Chest pains	1	0
11.	Burning, tingling or crawling feelings in your skin	1	0
12.	Pain in your bones	1	0
13.	Pain in your knees	1	0
14.	Pain in any other joints? (specify)_____	1	0
15.	Pain in your muscles	1	0
16.	Any other pain? (specify) _____	1	0

Appendix IX

Example of NIH Toolbox Measures Stimuli

Figure 1. Example of stimuli for the Picture Vocabulary measure

Congruent item: < < < < <

Incongruent item: < < > < <

Figure 2. Example of Flanker task showing both an incongruent item and a congruent item.

List 1: **Bee** **Elephant** **Turtle** **Pig**

List 2: **Orange** **Camel** **Monkey** **Raspberry**

Figure 3. Example of List Sorting task. In List 1 trials, participants see *either* names of fruit or animals and put them in order from smallest to largest. In List 2 trials, participant see *both* fruits and animals, and put first the fruits in order from smallest to largest, then put the animals in order from smallest to largest.

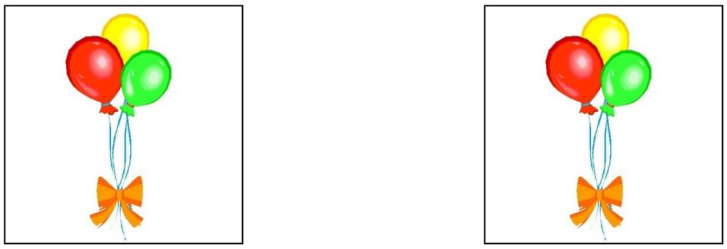


Figure 4. Example stimuli for the Pattern Comparison task. Participants respond whether or not the pictures are the same.

Figure 5. Example of the pictures a participant might see in the Picture Sequence task (e.g. how to bake a cake). The participant would be shown these pictures in a particular order and then asked to reproduce that sequence.

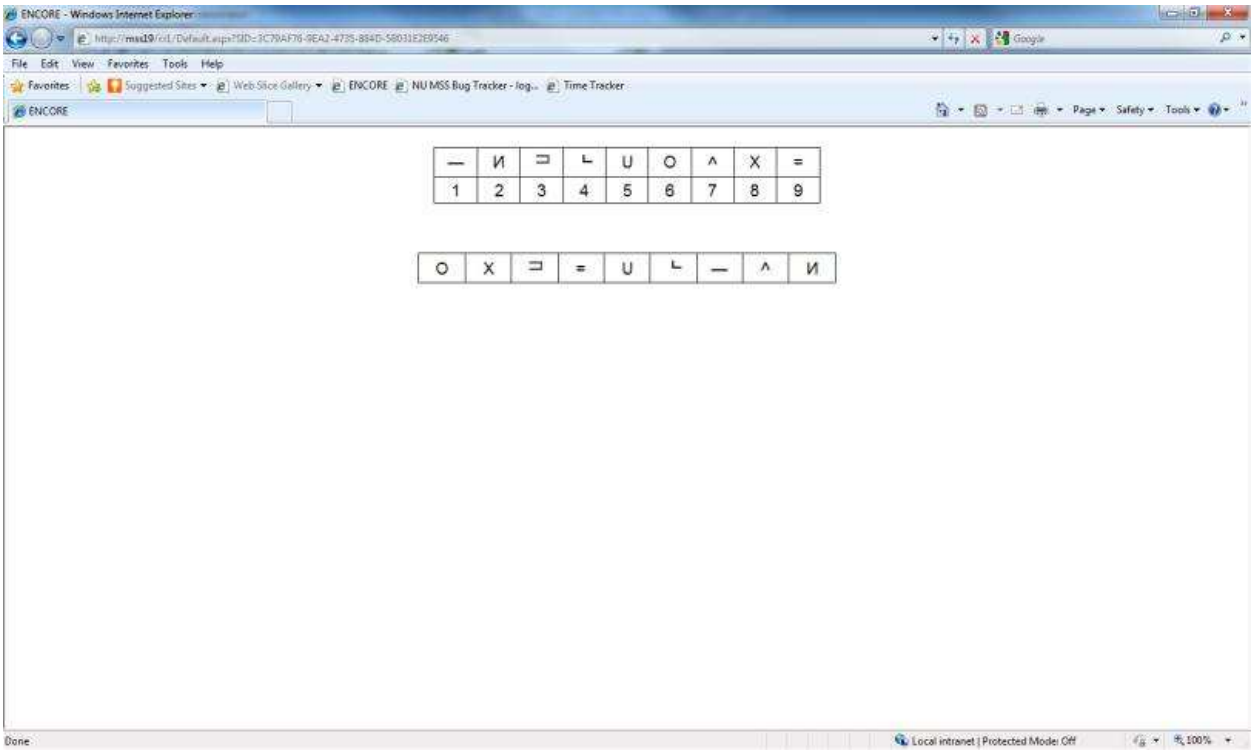
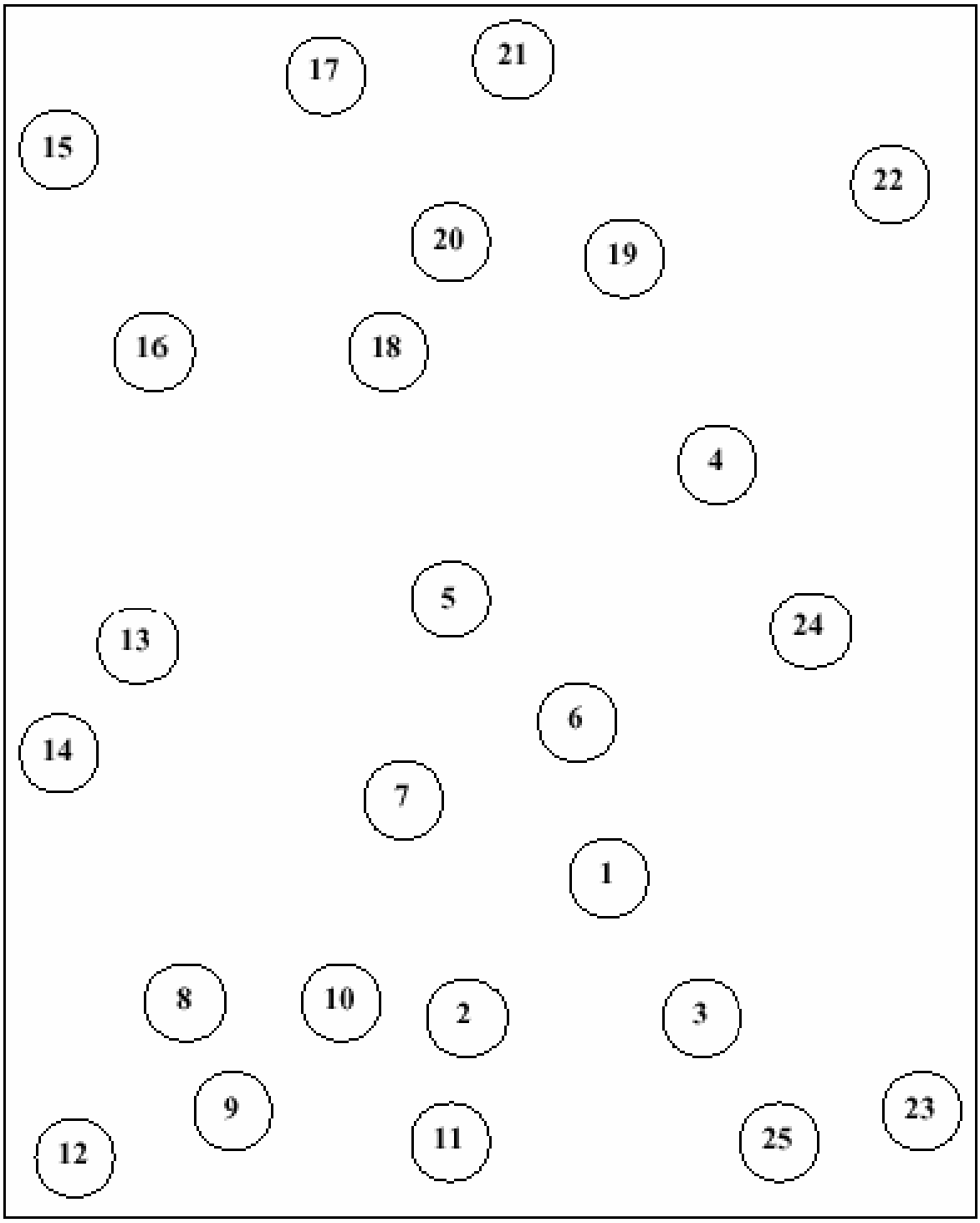


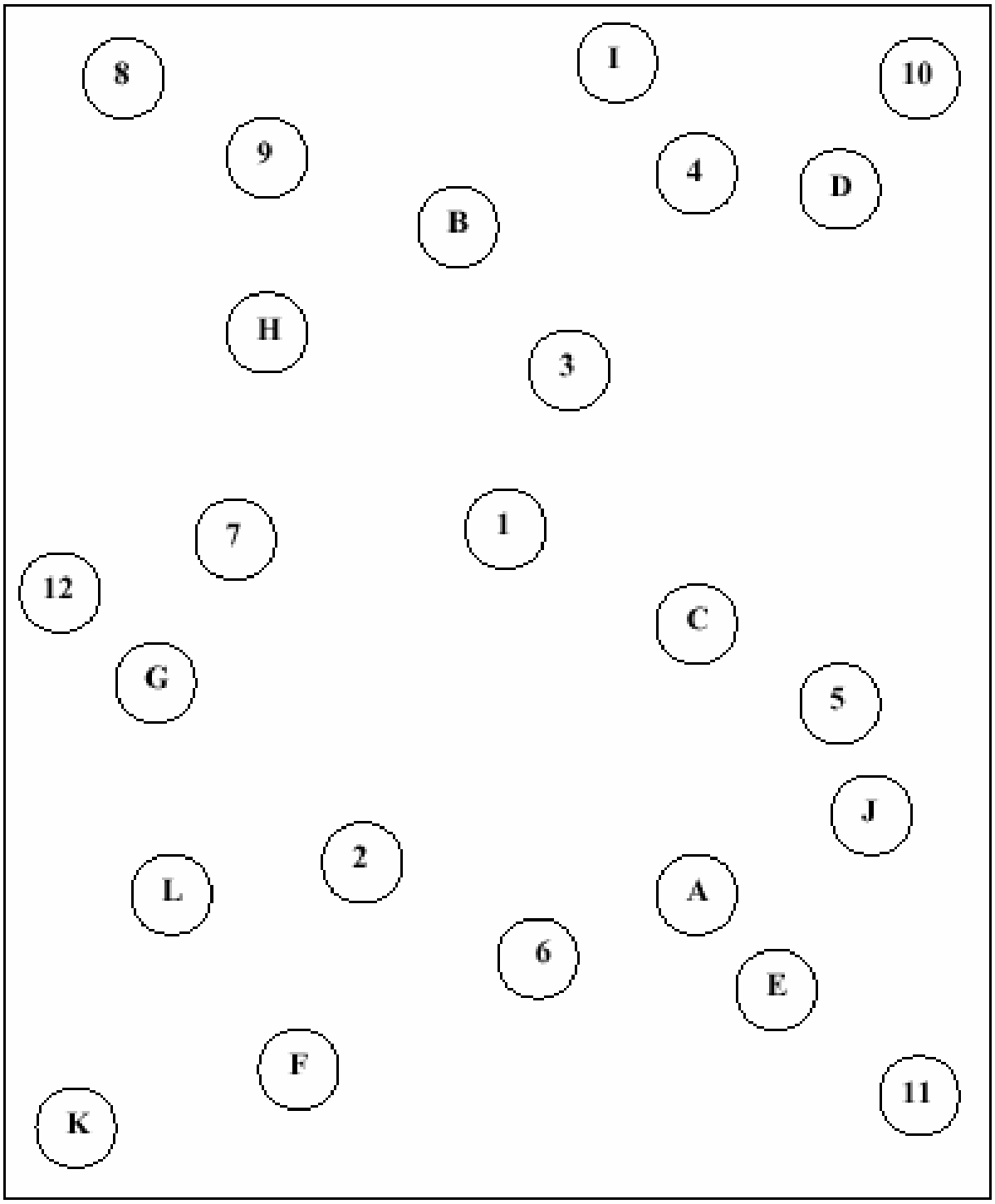
Figure 6. Oral Symbol Digit Key and Practice Trials

Appendix X

Trail Making Test Part A Example



Trail Making Test Part B Example



Appendix XI

Stroop Example

Example of Stroop Part 1: read color words

RED	GREEN	BLUE	RED
GREEN	BLUE	GREEN	GREEN
BLUE	RED	BLUE	BLUE

Example of Stroop Part 2: name ink color

XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX

Example of Stroop Part 3: name ink color ignoring color word printed

RED	GREEN	BLUE	RED
GREEN	BLUE	GREEN	GREEN
BLUE	RED	BLUE	BLUE

Appendix XII

Daily Sleep, Stress, and Pain Diary

Please fill out one form each morning for 14 consecutive days. This diary asks about your sleep and napping behavior, any pain you may have had yesterday, and any stress you experienced yesterday. Please read each question carefully and respond with the answer that best represents your experience.

1) How much pain have you had since yesterday on a scale from 1 to 5 (circle the best answer to describe your pain):

1 = none **2** = a little **3** = a moderate amount **4** = a great deal **5** = extreme pain

Perceived Stress Scale- 4 Item

Instructions: The questions in this scale ask you about your feelings and thoughts during the past day. In each case, please indicate with a check how often you felt or thought a certain way.

1. In the past day, how often have you felt that you were unable to control the important things in your life?

___0=never ___1=almost never ___2=sometimes ___3=fairly often ___4=very often

2. In the past day, how often have you felt confident about your ability to handle your personal problems?

___0=never ___1=almost never ___2=sometimes ___3=fairly often ___4=very often

3. In the past day, how often have you felt that things were going your way?

___0=never ___1=almost never ___2=sometimes ___3=fairly often ___4=very often

4. In the past day, how often have you felt difficulties were piling up so high that you could not overcome them?

___0=never ___1=almost never ___2=sometimes ___3=fairly often ___4=very often

Consensus Sleep Diary-M (Please Complete Upon Awakening) **ID/NAME: ____________________**

Sample

Today's Date	4/5/11							
1. What time did you get into bed?	10:15 p.m.							
2. What time did you try to go to sleep?	11:30 p.m.							
3. How long did it take you to fall asleep?	55 min.							
4. How many times did you wake up, not counting your final awakening?	6 times							
5. In total, how long did these awakenings last?	2 hours 5 min.							
6a. What time was your final awakening?	6:35 a.m.							
6b. After your final awakening, how long did you spend in bed trying to sleep?	45 min.							
6c. Did you wake up earlier than you planned?	☑ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
6d. If yes, how much earlier?	1 hour							
7. What time did you get out of bed for the day?	7:20 a.m.							
8. In total, how long did you sleep?	4 hours 10 min.							
9. How would you rate the quality of your sleep?	☐ Very poor ☑ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good
10. How rested or refreshed did you feel when you woke-up for the day?	☐ Not at all rested ☑ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested

Consensus Sleep Diary-M Continued **ID/NAME: _____**

	Sample							
Today's Date	4/5/11							
11a. How many times did you nap or doze? 11b. In total, how long did you nap or doze?	2 times 1 hour 10 min.							
12a. How many drinks containing alcohol did you have? 12b. What time was your last drink?	3 drinks 9 :20 p.m.							
13a. How many caffeinated drinks (coffee, tea, soda, energy drinks) did you have? 13b. What time was your last drink?	2 drinks 3 :00 p.m.							
14. Did you take any over-the-counter or prescription medication(s) to help you sleep? If so, list medication(s), dose, and time taken	☑ Yes ☐ No Medication(s): Relaxo-Herb Dose: 50 mg Time(s) taken: 11 pm	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:	☐Yes ☐No Medication(s): Dose: Time(s) taken:
15. Comments (if applicable)	I have a cold							

Appendix XIII

Daily Cognitive Assessment Form (with Script)

Participant ID: **Date**: **Time**:__ __ : __ __ AM/PM

Participant reached? Yes / No

If No: Try to reach participant for 15 minutes and leave a message if appropriate. If you do not reach the participant after 15 minutes, record below.

Time of last contact attempt: __ __ : __ __ AM/PM

If Yes: Good morning/afternoon, Mr./Mrs. _____. This is _____, a student researcher working on the daily diary study with Mrs. Kristy Shoji. I am calling to conduct your daily assessment. The assessment takes about 20-30 minutes. Do you have time to complete today's assessment now? Yes / No

If No: What would be a good time to call back today? _____

Okay, I will have someone contact you at that time. Thank you!

If Yes: Continue with Daily Assessment

Questions about Medication and Substance Use:

Okay Mr./Mrs _____, first I have a couple of questions about any medications you are taking.

1) Are you currently taking all medications that have been prescribed? Yes _____ No _____

A) If no, what are your reasons for not taking all prescribed medications at this time?

_____
_____
_____

B) If yes, did you take your medications at the appropriate times yesterday?

Yes _____ No _____

a) If no, what got in the way of being able to take your medication at the appropriate time?

_____
_____
_____

Now I have a couple of questions about substance use.

1) Did you smoke cigarettes or cigars yesterday?
    a. If yes, about how many cigarettes or cigars did you smoke?

    _____

2) Did you drink any alcohol yesterday?
    a. If yes, what did you drink?

    _____
    _____

    b. If yes, about how many drinks did you have yesterday?

    _____

    c. If yes, what was the amount of time during which you had those drinks?

    _____

3) Did you use any recreational drugs yesterday?
    a. If yes, what drugs did you use?

    _____

Now I have some questions that will require you to remember and make judgments about words and numbers. Remember that your participation is voluntary, so if you decide you do not want to answer a question, just let me know and I will go on to the next question.

These questions should take about 20-30 minutes to complete.

If participant seems distracted, or there is noise or commotion in background such as young children, TV or radio, or other people talking, say "It is important that you are able to concentrate without being distracted while we do these exercises. Would it be better for me to call you back another time?" If so, make an appointment for another time.

First I would like to make sure that you are able to hear me clearly. Please repeat these words after me: apple, pen, tie, house, car. ***(If not loud enough, ask person to speak up clearly.)*** Could you hear me clearly?

Now you will hear some words and numbers. Please do not use a paper and pencil for any of the questions. You may want to close your eyes to help you concentrate as we do these exercises.

Some of the questions will be easy for you, and some will be harder. We do not expect anyone to get every question correct so just do your best!

WORD LIST RECALL Modified Rey Auditory-Verbal Learning Test (Lezak, 1983)

I am going to read a list of 15 words. Listen carefully. When I am finished, you are to repeat as many of the words as you can remember. It doesn't matter in what order you repeat them. Just try to remember as many as you can. I will say each word only one time, and I cannot repeat any words. You will have up to one and a half minutes, and I will not say anything until I tell you that your time is up. Do you have any questions? Are you ready?

(Read with one second interval between each word)

Word List	Trial 1	Trial 2	Trial 3
DRUM			
CURTAIN			
BELL			
COFFEE			
SCHOOL			
PARENT			
MOON			
GARDEN			
HAT			
FARMER			
NOSE			
TURKEY			
COLOR			
HOUSE			
RIVER			

Now tell me as many words as you can remember.

Record responses in order they are recalled by placing a 1 next to the first word recalled, a 2 next to the second word recalled, and so on.

If person stops before 1 1/2 minutes is up, say, "There's still time left, can you think of any more?"

REPEAT THIS PROCEDURE TWO MORE TIMES.

Good, now let's go on.

For Digits Forward, Backward, and Sequence: *Read in monotone, 1 sec per number…Drop your voice on the last digit to indicate it is time to respond. If they get the first trial on one level, move on to the next level. Discontinue after 2 trials missed on a level.*

DIGITS FORWARD (2.5 minutes) (Modified WAIS IV)

I am going to say some strings of numbers, and when I an done I want you to repeat them back to me. Just say what I say.

- 9-7 (9-7) 6-3 (6-3)
- 5-8-2 (5-8-2) 6-9-4 (6-9-4)
- 7-2-8-6 (7-2-8-6) 6-4-3-9 (6-4-3-9)
- 4-2-7-3-1 (4-2-7-3-1) 7-5-8-3-6 (7-5-8-3-6)
- 3-9-2-4-8-7 (3-9-2-4-8-7) 6-1-9-4-7-3 (6-1-9-4-7-3)
- 4-1-7-9-3-8-6 (4-1-7-9-3-8-6) 6-9-1-7-4-2-8 (6-9-1-7-4-2-8)
- 3-8-2-9-6-1-7-4 (3-8-2-9-6-1-7-4) 5-8-1-3-2-6-4-7 (5-8-1-3-2-6-4-7)
- 2-7-5-8-6-3-1-9-4 (2-7-5-8-6-3-1-9-4) 7-1-3-9-4-2-5-6-8 (7-1-3-9-4-2-5-6-8)

DIGITS BACKWARD (2.5 minutes) (Modified WAIS IV)

I am going to say some strings of numbers, and when I am done I would like you to repeat them backwards, in the reverse order from which I said them. So if I said "3, 8", you would say "8, 3". Do you understand? The sets will get larger as we go.

- 3-1 (1-3) 2-4 (4-2)
- 4-6 (6-4) 5-7 (7-5)
- 6-2-9 (9-2-6) 4-7-5 (5-7-4)

- 8-2-7-9 (9-7-2-8) 4-9-6-8 (8-6-9-4)
- 6-5-8-4-3 (3-4-8-5-6) 1-5-4-8-6 (6-8-4-5-1)
- 5-3-7-4-1-8 (8-1-4-7-3-5) 7-2-4-8-5-6 (6-5-8-4-2-7)
- 8-1-4-9-3-6-2 (2-6-3-9-4-1-8) 4-7-3-9-6-2-8 (8-2-6-9-3-7-4)
- 9-4-3-7-6-2-1-8 (8-1-2-6-7-3-4-9) 7-2-8-1-5-6-4-3 (3-4-6-5-1-8-2-7)

DIGIT SEQUENCE (2.5 minutes) (Modified WAIS IV)

I am going to say some strings of numbers, and when I am done I would like you to say the numbers in order from smallest to largest. So if I said "3, 1, 2", you would say "1, 2, 3". Do you understand? The sets will get larger as we go.

- 2-4 (4-2) 5-7 (7-5)
- 6-2-9 (9-2-6) 4-1-5 (5-1-4)
- 3-2-7-9 (9-7-2-3) 4-9-6-8 (8-6-9-4)
- 1-5-2-8-6(6-8-2-5-1) 6-1-8-4-3(3-4-8-1-6)
- 5-3-9-4-1-8(8-1-4-9-3-5) 7-2-4-8-5-6(6-5-8-4-2-7)
- 8 - 1 - 2 - 9 - 3 - 6 - 5 (5 - 6 - 3 - 9 - 2 - 1 - 8) 4 - 7 - 3 - 9 - 1 - 2 - 8 (8 - 2 - 1 - 9 - 3 - 7 - 4)
- 9 - 4 - 3 - 7 - 6 - 2 - 5 - 8 (8 - 5 - 2 - 6 - 7 - 3 - 4 - 9) 7 - 2 - 8 - 1 - 9 - 6 - 5 - 3 (3 - 5 - 6 - 9 - 1 - 8 - 2 - 7)

Good, now lets go on.

LETTER FLUENCY (1.5 minutes)

Now I am going to say a letter of the alphabet to you, and I want you to tell me as many words as you can think of that begin with that letter. None of the words can be proper names of people and places. For example, if I gave you the letter "B", you could say words like "baby, bottle, black" and so forth, but you could not say "Barbara" since that is a persons name, nor could you say "Boston" since that is the proper name of a place. Also, do not give me the same word with different endings, such as "big, bigger, biggest".

The letter we will use today is “F”. Go ahead and tell me as many words as you can think of that start with the letter “F”. Ready…Go! (Begin timing and allow one minute).

1. _____ _____ _____

2. _____ _____ _____

3. _____ _____ _____

4. _____ _____ _____

CATEGORY FLUENCY (1.5 minutes) Drachman & Leavitt (1972)

Now I am going to give you a category and you will name things that belong in that category. Let’s practice with the category “fruit”. You could say peach, or pear. Can you think of any other fruits? (wait *for 2 correct items).* In a moment I will give you another category. When I say begin, you will name all the things from this **new** category you can think, as fast as you can. You will have one minute to do this. I will let you know when your time is up. The new category is animals. Do you have any questions? Ready?

Begin. ***(Time for one minute).*** If person stops before 1 minute is up, say” There’s still more time, can you think of any more?”

Be sure to mark the 15, 30, and 45 second points.

(If person asks whether birds, fish, insects, reptiles, etc. are acceptable, say yes.)

_____ _____ _____
_____ _____ _____

Good, now let's go on.

STOP-GO TEST (3-3.5 minutes)

STOP-GO TASK: BASELINE NORMAL

Next I am going to see how quickly you can respond to the words RED and GREEN. Every time I say RED you will say STOP, and every time I say GREEN you will say GO. Try to be accurate, but respond as quickly as you can. So when I say RED you will say... And when I say GREEN you will say... Do you have any questions? Let's begin. This will last about 1 minute.

(Do 20 trials. Allow 1 second between response and next cue. Record accuracy with 1 for correct answers, 0 for incorrect or self-corrections, 2 for invalid trials.)

ALLOW 1 SECOND BETWEEN TRIALS

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

TOTAL NUMBER CORRECT: _____

STOP-GO TASK: REVERSE BASELINE

Now you will do just the reverse of what you have been doing. So when you hear RED you will say GO, and when you hear GREEN you will say STOP. Do you have any questions? When I say RED you will say... and when I say GREEN you will say... Try to be accurate, but answer as quickly as you can.

(Do 20 trials. Allow one second between response and next cue. Record accuracy with 1 for correct answers, 0 for incorrect or self-corrections, 2 for invalid trials.)

ALLOW 1 SECOND BETWEEN TRIALS

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

GREEN (STOP) Correct _____ Incorrect _____

RED (GO) Correct _____ Incorrect _____

TOTAL NUMBER CORRECT: _____

STOP-GO TASK: MIXED BASELINE

Now we are going to mix up these two types of responses. When I give the cue NORMAL, you will respond the way you did at first: red means stop, green means go. But when I say REVERSE, you will give the reverse responses: RED means GO, GREEN means STOP. We will alternate between the NORMAL and the REVERSE every few trials. Let's try a few for practice.

NORMAL RED (STOP) **GREEN** (GO) **RED** (STOP)

REVERSE GREEN (STOP) **RED** (GO) **RED** (GO)

NORMAL GREEN (GO) **RED** (STOP) **GREEN** (GO)

REVERSE GREEN (STOP) **RED** (GO)

Do you have any questions? Try to be accurate, but answer as quickly as you can. This will take about one minute.

(Allow one second between cue word (normal or reverse) and stimulus color item. Also allow one second between subject' s response and the next stimulus item. Record correct, incorrect, and invalid trials.)

NORMAL GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

REVERSE RED (GO) Correct _____ Incorrect _____

	RED (GO)	Correct _____	Incorrect _____
	GREEN (STOP)	Correct _____	Incorrect _____
	RED (GO)	Correct _____	Incorrect _____
	RED (GO)	Correct _____	Incorrect _____
NORMAL	RED (STOP)	Correct _____	Incorrect _____
	GREEN (GO)	Correct _____	Incorrect _____
	RED (STOP)	Correct _____	Incorrect _____
	GREEN (GO)	Correct _____	Incorrect _____
	GREEN (GO)	Correct _____	Incorrect _____
	RED (STOP)	Correct _____	Incorrect _____
REVERSE	GREEN (STOP)	Correct _____	Incorrect _____
	GREEN (STOP)	Correct _____	Incorrect _____
	RED (GO)	Correct _____	Incorrect _____
	GREEN (STOP)	Correct _____	Incorrect _____
NORMAL	GREEN (GO)	Correct _____	Incorrect _____
	RED (STOP)	Correct _____	Incorrect _____
	GREEN (GO)	Correct _____	Incorrect _____
	GREEN (GO)	Correct _____	Incorrect _____
	RED (STOP)	Correct _____	Incorrect _____
REVERSE	GREEN (STOP)	Correct _____	Incorrect _____
	GREEN (STOP)	Correct _____	Incorrect _____
	RED (GO)	Correct _____	Incorrect _____
	GREEN (STOP)	Correct _____	Incorrect _____
	RED (GO)	Correct _____	Incorrect _____
NORMAL	RED (STOP)	Correct _____	Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

RED (STOP) Correct _____ Incorrect _____

GREEN (GO) Correct _____ Incorrect _____

TOTAL NUMBER CORRECT: _____

NUMBER SERIES (2.5 minutes) Salthouse & Prill (1987)

In the next exercise I will read you a series of numbers that may get larger or smaller in value. At the end you will try to figure out what the next number would be. So if the numbers were 2,4,6,8,10, the next number would be 12. After I say each number I will pause for as long as you need, and then you should say "okay" when you are ready for me to go on to the next number in the group. So if I said 2, you should say "okay" when you are ready for me to go on to the next number, then I say 4, you say okay, 6, okay, 8, okay, 10, and at the end I will ask you what you think the next number would be. In this case the next number would be 12, as each number has increased by 2.

Let's try one for practice: 35 (okay), 30 (okay), 25 (okay), 20 (okay), 15 (okay) **AND** the next number would be....???? (The answer should be 10 as each number has decreased by 5). There will be different patterns, and some of these will be harder than others, so just do the best you can. If you are not sure of the answer, it is okay to guess. Do you have any questions? *(Pause after each of the first 4 items for okay response; after the last item, say **AND** the next number is...?).*

(1) 18, 20, 24, 30, 38.....(48) _____

Okay. Are you ready for another? The next set is

(2) 81, 78, 75, 72, 69.....(66) _____

Okay. Are you ready for another? The next set is

(3) 7, 12, 16, 19, 21.....(22) _____

Okay. Are you ready for another? The next set is

(4) 28, 25, 21, 16, 10.....(3) _____

Okay. Are you ready for another? The next set is

(5) 20, 37, 18, 38, 16.....(39) _____

Total Correct: _____

BACKWARD COUNTING (45 seconds)

Next, I would like to see how fast you can count backwards. When I give the signal to begin, start counting backwards from 100 out loud, as fast as you can. So you will say 100, 99, 98 and so on. You will have half a minute. Do you have any questions? I will let you know when the time is up.

Begin *(Time for 30 seconds)*

Record final number reached, and number of errors.

SHORT-DELAY WORD RECALL (40 seconds on average)

Do you remember the very first list of 15 words that I read to you in the beginning? It was the very first thing we did. (WAIT FOR SUBJECT TO RESPOND YES. MAKE SURE THEY UNDERSTAND THAT IT IS THE WORD LIST, NOT THE CATEGORY FLUENCY TEST). I want you to tell me as many of the words from that list as you can. You will have up to one minute. I will tell you when your time is up. *(Record words recalled, including intrusions and repetitions*)?"

DO NOT READ THE LIST OF WORDS TO THE PARTICIPANT!!

Record responses in order they are recalled by placing a 1 next to the first word recalled, a 2 next to the second word recalled, and so on.

If person stops before 1 1/2 minutes is up, say, "There's still time left, can you think of any more?"

Word List	Delayed Recall
DRUM	
CURTAIN	
BELL	
COFFEE	
SCHOOL	
PARENT	
MOON	
GARDEN	
HAT	
FARMER	

NOSE	
TURKEY	
COLOR	
HOUSE	
RIVER	

Okay, Mr./Mrs. _____, that was the end of today's assessment. Do you have any questions for me?

Is this scheduled time good to contact you tomorrow? Yes _____ No _____

If not…

What would be the best time to contact you tomorrow for your cognitive diary?

_____ AM/PM

****BE SURE TO CHANGE THIS ON THE SCHEDULE AND INFORM KRISTY SHOJI IF AN APPOINTMENT IS CHANGED****

Encouraging comments to be used if the person expresses concern about performance: During the test: "Just do the best you can."Remember, we do not expect anyone to get all of these questions correct."

"Don't worry. We have deliberately made these questions challenging. If people could get them all right, we would not learn anything. We're trying to find which questions are harder than others."

IRB Project #: 13-025-ME

UNIVERSITY OF ALABAMA
INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying information

	Principal Investigator	Second Investigator	Third Investigator
Names:	Kristy Shoji	Natalie Dautovich	
Department:	Clinical Psychology	Clinical Psychology	
College:	Arts & Sciences	Arts & Sciences	
University:	University of Alabama	University of Alabama	
Address:	355B Gordon Palmer Hall 505 Hackberry Lane	356B Gordon Palmer Hall 505 Hackberry Lane	
Telephone:	336-380-1582	205-348-1168	
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E-mail:	kdouglas@crimson.ua.edu	nataliedd@gmail.com	

Title of Research Project: Factors Influencing Intraindividual Cognitive Varaibility in Older Adults with Different Degrees of Cognitive Integrity

Date Submitted:
Funding Source: N/A

Type of Proposal ☒ New ☐ Revision ☐ Renewal Please attach a renewal application ☐ Completed ☐ Exempt
Please attach a continuing review of studies form
Please enter the original IRB # at the top of the page

UA faculty or staff member signature: _____

II. NOTIFICATION OF IRB ACTION (to be completed by IRB):
Type of Review: ✓ Full board _____ Expedited

IRB Action:
___ Rejected Date: _____
___ Tabled Pending Revisions Date: _____
___ Approved Pending Revisions Date: _____
✓ Approved-this proposal complies with University and federal regulations for the protection of human subjects.
Approval is effective until the following date: 8-8-14 KS
Items approved: ___ Research protocol (dated _____)
___ Informed consent (dated _____)
___ Recruitment materials (dated _____)
___ Other (dated _____)

Approval signature _____ Date 9-12-13 KS