The Relation of College Students’ Sleep Behavior to ADHD Symptom Reporting, Cognitive Performance, and Neurophysiological Parameters

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of the requirements for the degree
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This dissertation titled
The Relation of College Students’ Sleep Behavior to ADHD Symptom Reporting,
Cognitive Performance and Neurophysiological Parameters

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Abstract

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The Relation of College Students’ Sleep Behavior to ADHD Symptom Reporting, Cognitive Performance and Neurophysiological Parameters (126 pp.)

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Sleep loss and ADHD have overlapping attention-related symptoms and similar cognitive consequences. Given the robust findings within the experimental sleep literature, current critiques of sleep research have called for naturalistic examination of sleep loss. The present study aimed to add to the sleep literature by examining undergraduate students’ self-reported sleep data (i.e., average sleep duration over one week) in relation to three broad issues related to attention: 1) complaints of ADHD symptoms, 2) focused and sustained attention, and 3) an objective assessment of wakefulness (i.e., EEG measures) during an ecologically valid sustained attention task (i.e., attending to a mock lecture). Consistent with prior sleep findings, students who slept less on average over one week self-reported more attention-related difficulties. In contrast, students who slept less took less time to react and demonstrated better accuracy performance on a measure of focused attention (sleep was not related to other cognitive measures or to spectral power on the EEG). Exploratory and supplemental analyses demonstrated that self-reported sleep quality was highly related to self-reported attentional difficulties, positively related to lapsing performance on the focused attention task, and negatively related to EEG spectral power. Meanwhile, more variability in sleep duration over the week was related to more lapsing on a focused attention task, as well as
slower reaction times on both focused and sustained attention tasks. Although higher negative mood was related to slower reaction time on the sustained attention task, and state alertness was found to be related to lower EEG spectral power during the mock lecture task, these findings are likely unstable due to the limited findings when compared to the number of comparisons explored. Implications of these findings, as well as limitations and future directions, are discussed.

Approved:

________________________________________

Julie A. Suhr
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Introduction

More undergraduate students are reporting decreasing sleep durations, erratic sleep schedules, and high rates of sleep difficulties (Hicks, Fernandez, & Pellegrini, 2001). Concomitantly, they are increasingly referring themselves for ADHD evaluations (Harrison, 2004; Jachimowicz & Geiselman, 2004; Suhr, Zimak, Buelow, & Fox, 2009). These concurrent trends are noteworthy, as both sleep loss and ADHD have overlapping attention-related symptoms and similar cognitive consequences. Specifically, attention-related performance decrements, including sustained attention (i.e., vigilance), are among the most robust sleep-deprivation-related findings (Mallis, Banks, & Dinges, 2007), while attention related difficulties—such as absent-mindedness and difficulties with multi-tasking—are a group of symptoms used to identify the attention deficit component of ADHD (Barkley, Murphy, & Kwasnik, 1996). Of note, a third of healthy young adults have been estimated to experience insufficient sleep, averaging less than 6.5 hours, while circadian rhythm (please see Appendix A for a more detailed explanation of underlined terms) disturbances may also occur as a result of their erratic sleep schedules (Oken, Salinsky, & Elsas, 2006). The “sleep debt” incurred from such sleep habits may contribute to the difficulties in attention and cognitive performance, particularly during the peaks of sleep pressure overnight and midday (Oken et al., 2006). Not surprisingly, individuals experiencing sleep problems often report attentional and concentration difficulties (Carskadon, 2002). The perception of these sleep-related attentional difficulties may be falsely attributed to ADHD as a result of increased public awareness of the persistence of ADHD into adulthood (Reilley, 2005; Roy-Byrne, Scheele,
Brinkley, & Ward, 1997). Given the possible contribution of poor sleep habits to the clinical presentation of students who self-refer for ADHD evaluations, it is surprising that little to no research has addressed the importance of sleep problems in the differential diagnosis of adult ADHD.

Most studies examining the effect of sleep on cognitive ability are experimental in nature. Typically, sleep loss has been experimentally manipulated using total sleep deprivation—continuous wakefulness for at least 21 hours—or, less frequently, partial sleep deprivation (i.e., sleep restriction, consisting of restricted sleep to 1 to 7 hours of time-in-bed each night, over single to multiple days). Of the three meta-analyses examining the available literature, the best controlled meta-analysis, in which cognitive categories were delineated and the quality of studies were controlled for, revealed that sleep deprivation had a moderate to large effect on focused attention tasks (e.g., Psychomotor Vigilance Test, lapsing and reaction time variables, $d = -0.762$ and $-0.732$, respectively), and a moderate effect on sustained attention tasks (e.g., Continuous Performance Test, accuracy and reaction time, $d = -0.479$ and $-0.312$, respectively; Lim & Dinges, 2010). Although Lim and Dinges (2010) did not examine the effects of sleep restriction, an earlier meta-analysis demonstrated that cognitive tasks appeared to be more affected by partial sleep deprivation (i.e., less than 5 hours of sleep in a 24-hour period, $d = -3.01$) than by either shorter- or longer-term total sleep deprivation (i.e., less than or equal to 45 hours, $d = -1.36$, and more than 45 hours, $d = -1.04$; Pilcher & Huffcutt, 1996). Moderate to large effect size findings were also illustrated by both the earlier meta-analyses. Specifically, sleep deprivation was moderately related to decreased
speed (range in $rs = 0.39$ to $0.62$) and accuracy (range in $rs = 0.32$ to $0.58$), without
delineating the type of cognitive task represented (Koslowsky & Babkoff, 1992), while
both sleep deprivation and restriction were revealed to have moderate to strong effects
(range in $d = -0.36$ to $-3.78$) on cognitive performance regardless of length of sleep
deprivation, type of task, or duration of task (Pilcher & Huffcutt, 1996).

Given these robust and consistent findings, recent critiques of the sleep literature
have related to the lack of naturalistic studies, in which individuals engage in their typical
sleep habits, as well as the lack of more ecologically valid cognitive tasks in existing
studies (Waters & Bucks, 2011). Specifically, experimentally induced sleep restriction
studies may not reflect the real-life sleep habits of individuals, particularly given the
number of controls placed upon individuals leading up to the experiment sessions (e.g.,
maintenance of a prescribed regular sleep-wake schedule and abstaining from habitual
napping and substance use) and within the experiment sessions (e.g., abstaining from
substance use and strenuous activities, while engaging in prescribed mundane activities).
A naturalistic means of examining sleep loss may be the sleep deprivation that results
from being on overnight call among physicians and residents-in-training. A meta-analysis
of this literature established moderate to large effect sizes of acute sleep loss of 24 to 30
hours among medical practitioners on their clinical performance ($d = -1.54$), cognitive
functioning ($d = -0.56$), and measures of vigilance ($d = -0.90$; Philibert, 2005).
Moreover, undergraduate students’ erratic sleep schedules may result in circadian rhythm
disturbances similar to those of shift workers; shift work literature has also consistently
documented the detrimental effects of shiftwork in general, and that of the night shift in
particular, on attention tasks (Mitler et al., 1988; Rosekind et al., 1995). Although minimal in number, some naturalistic studies examining college students’ sleep in relation to academic outcomes, such as exam grades or grade point averages (GPA), have also illustrated the potential relationship between sleep and academic performance. Specifically, shorter sleep duration and later wake- and bed-times have been demonstrated to be related to poorer academic performance (Medeiros, Mendes, Lima, & Araujo, 2001; Thacher, 2008).

Not only are experimentally controlled studies not reflective of the real-life environment, but the structured neurobehavioral attentional tasks used in experimental studies may not reflect the fluid and dynamic cognitive and behavioral needs in the real world (Waters & Bucks, 2011), and hence may warrant further study. One way to examine attention-related parameters naturalistically may be to monitor physiologic correlates of vigilance using electroencephalography (EEG) while individuals are attending to their work. For example, power spectral analyses have been used to examine neural activation across time while performing various sustained attention tasks (e.g., Loo et al., 2009), including simulated driving tasks (e.g., Boyle, Tippin, Paul, & Rizzo, 2008). Although there are multiple bands within the EEG, theta (i.e., brain waves at 4 to 8 Hz) and alpha (i.e., brain waves at 8 to 12 Hz) markers have been demonstrated to be consistently related to drowsiness, early stages of sleep, and sustained attention performance (Oken et al., 2006). Specifically, decreased alertness is typically associated with increased alpha wave activity when the individual’s eyes are open (e.g., during a vigilance task) and decreased alpha wave activity when the individual’s eyes are closed.
(e.g., early stages of sleep; Oken et al., 2006). Meanwhile, increased theta wave activity is typically associated with increased drowsiness across both situations (Oken et al., 2006). Hence, when measuring sustained attention performance in a sleep deprived person, one may expect increased alpha and theta activity across time, demonstrating increased sleepiness and/or poorer vigilance. The attenuation of alpha activity however, may be expected with the corresponding increase in theta activity when eyes begin to close as the task progresses. Across various studies conducted by Makeig and colleagues, within-subject correlation between increases in theta activity and attenuation of alpha activity was consistently demonstrated while participants performed a vigilance task, indicating increasing drowsiness with task progression (Makeig & Inlow, 1993; Makeig & Jung, 1995; Makeig & Jung, 1996). These findings are further bolstered by those found from naturalistic studies, in which progressive slowing of the EEG occurs (i.e., increase in theta power, with a corresponding decrease in alpha power) as the sleep deprived individual falls asleep (e.g., Torsvall & Akerstedt, 1988).

**ADHD, Attention and Sleep**

There is ample evidence within the ADHD literature to indicate a relationship between ADHD and sleep, particularly within child samples (Cortese, Konofal, Yateman, Mouren, & Lecendreux, 2006). A meta-analysis showed significant relationships between ADHD on subjective (i.e., parent and self-reports) and objective measures (i.e., polysomnography and actigraphy) of sleep (Cortese et al., 2006). In children with ADHD, there is evidence of both child and parent report of significantly higher bedtime resistance (Standardized Mean Difference; SMD = -0.86), more difficulty with morning
awakenings (SMD = -0.83), more sleep onset difficulties (SMD = -0.73), more sleep disordered breathing (SMD = -0.37), more nighttime awakenings (SMD = -0.21), and more daytime sleepiness (SMD = -0.19; Cortese et al., 2006). Meanwhile, analyses of objective measures revealed that children with ADHD experienced more stage shifts per hour of sleep on the polysomnograph (SMD = -0.59), higher apnea-hypopnea index on the polysomnograph (SMD = -0.52), greater sleep onset latency on actigraphy (SMD = -0.36), shorter sleep duration on actigraphy (SMD = -0.36), and poorer sleep efficiency on polysomnography (SMD = 0.25; Cortese et al., 2006). Furthermore among children not diagnosed with ADHD, sleep parameters as measured by actigraphy revealed that sleep efficiency and sleep duration was negatively related to performance on the continuous performance test ($r_s = -.30$ and -.23, respectively), while number of night awakenings was positively related to commission errors on the continuous performance test ($r = .25$; Sadeh, Gruber, & Raviv, 2002). When categorized as “good sleepers” or “poor sleepers,”—at least three awakenings per night, each lasting 5 minutes or longer, and sleep efficiency at or below 90%—poor sleepers were found to have more commission errors on the continuous performance test (Sadeh et al., 2002). Within a more limited adult ADHD literature, similar findings have been noted; a recent study revealed similar increases in nocturnal motor activity among adults with ADHD as measured with polysomnography, which was related to self-reported sleep duration (Philipsen et al., 2005), while another study found that young adults who scored as “highly likely” and “probably” having ADHD self-reported higher current and lifetime sleep problems than individuals who scored as “non-ADHD” (Gau et al., 2007).
Cognitive findings in ADHD also parallel those in the sleep deprivation literature. Specifically, children and adults with ADHD have been found to demonstrate weaknesses in the cognitive domains of attention (child $d = 0.52$ to 0.72, adult $d = 0.38$ to 0.79), vigilance (child $d = 0.51$ to 0.64, adult $d = 0.52$), overall executive functioning (child $d = 0.46$ to 0.69, adult $d = 0.21$) and response inhibition (child $d = 0.32$; adult $d = 0.20$ to 0.56), with effect sizes ranging within the small to moderate range (Barkley, 1997; Frazier, Adams, Stauss, & Redline, 2001; Lansbergen, Kenemans, & van Engeland, 2007; Lijffijt, Kenemans, Verbaten, & van Engeland, 2005; Schoechlin & Engel, 2005; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Similarly, there are overlaps in EEG findings between ADHD and sleep deprivation. Recent reviews concur that a common finding from spectral power analysis is increased theta activity (particularly in frontal and central regions), both at rest and during cognitive activity, among children with ADHD when compared to controls (di Michele, Prichep, John, & Chabot, 2005; Willis & Weiler, 2005), reflecting decreased alertness. Among adults who met criteria for ADHD both during childhood and adulthood, EEG data collected while resting with eyes-closed and while attending to a sustained attention task revealed lower levels of alpha activity at frontal regions when compared to adult controls (Loo et al., 2009), indicating poorer attentive parameters. When adults with ADHD were compared to adult controls at rest with eyes open, absolute theta, and alpha power were higher in individuals with ADHD when compared to controls (Bresnahan & Barry, 2002). Overall, these are similar patterns of findings as that of the sleep restriction literature.
Taking all these ADHD-sleep findings together, one may surmise that college students who are experiencing sleep difficulties and sleep-related cognitive changes may be more likely to attribute them to ADHD (due to familiarity with this “cause” for attentional problems) rather than to their sleep (due to lack of knowledge about sleep’s contribution to attention and other cognitive abilities). Additionally, there are benefits that can be derived from an ADHD diagnosis, namely prescription stimulants and academic support services, which are particularly relevant and enticing to undergraduate students who are struggling academically (Weyandt & DuPaul, 2008). Furthermore, prescribed stimulants may be addressing attentional difficulties resulting from sleep habits and as a result feel effective, but may not be addressing the actual underlying sleep habits that result in attentional difficulties. The overlapping symptoms of sleep and ADHD also make accurate diagnosis of ADHD in adulthood difficult, especially when there is so much reliance on only self-reported ADHD symptoms for diagnosis in this age group (Johnson & Conners, 2002). While known medical and psychiatric difficulties such as chronic pain conditions, learning disorders, mood disturbances, and anxiety disorders are often considered while diagnosing ADHD (Connors, Erhardt, & Sparrow, 1999; Goodman, 2009; McGough & Barkley, 2004), sleep habits and the quality of sleep have typically not been included when considering alternative reasons for self-reported “ADHD” symptoms.

The Current Study

In considering these literatures and findings together, the present study examined undergraduate students’ sleep behaviors in a naturalistic manner (i.e., college students
slept as usual, and reported their sleep habits). Specifically, participants’ self-reported sleep data (i.e., average sleep duration over the week) was used to address the relationship between sleep duration and three broad issues related to attention: 1) complaints of ADHD symptoms, 2) focused and sustained attention, and 3) an objective assessment of wakefulness (i.e., EEG measures) during an ecologically valid sustained attention task (i.e., attending to a mock lecture). Generally, it was hypothesized that students with less sleep would report more ADHD symptoms, perform worse on focused and sustained attention tasks, and demonstrate increased frontal theta, and posterior alpha and theta spectra power levels in their EEG measures while attempting to sustain attention during a mock lecture. To our knowledge, the current study is the first to use measures of naturalistic sleep behaviors over a one-week span, while concurrently examining self-reported attention difficulties, attention-related performance, and neurophysiological measures while attending to an ecologically valid task.
Method

Participants

Participants in the final sample included 67 undergraduates (43 females, 24 males) at a Midwestern university, aged between 18 and 23 years ($M = 19.54, SD = 1.32$). Participants self-identified as Caucasian ($n = 55$), African-American ($n = 2$), Asian ($n = 7$), American Indian/Alaska Native ($n = 1$), and other ($n = 2$); of these individuals, three identified as bi-racial.

103 participants were initially recruited through an undergraduate psychology participant pool and through advertisements posted at various on-campus locations. Students who were recruited through the participant pool participated for credit toward their course requirements and also received $10$ for completing the second session, while students who were recruited through advertisements participated for a total compensation of $50$. Participants were initially recruited into the study if, on initial screening, they were between the ages of 18 and 23 and did not self-report: 1) excessive substance use (i.e., drink more than five alcoholic drinks four or more days per week, use drugs more than twice a month, smoke more than 15 cigarettes per day), 2) frequent nightmares (i.e., more than 4 times a week), 3) current experience of sleep disorders (i.e., narcolepsy, sleep-walking, sleep-talking, bed-wetting, night terrors), 4) a history of medical disorders, 5) current use of medications that affect sleep, 6) a history of neurological disorders, 7) a history of Attention Deficit Disorder or Attention Deficit Hyperactivity Disorder, and 8) elevated scores on any of the three sleep disorder screeners. These exclusionary criteria were assessed using a symptom checklist and three sleep disorder
screeners. Specifically, participants recruited through the participant pool completed a pre-screen on the online system, while participants recruited through advertisements were screened over the phone, prior to participation.

Recruitment measures were also re-administered to the participants at their first attended session. Participants who did not continue to meet criteria for the study were excluded from analyses ($N = 16$; 14 with PSQI scores above a 5, one for recreational drug use, and one for sleepwalking). In addition, 17 participants dropped out from the study after the first session. This resulted in a sample of 70 participants who completed both sessions. Of the 70 participants, 47 were compensated with credit and $10, while 23 were paid $50. Analyses to compare completers ($n = 70$) and non-completers ($n = 17$) in regard to their demographic, sleep, and psychological characteristics, as well as performance on session one measures were performed. No group differences were found in sex, $\chi^2(1, N = 87) = 0.02, p = .89$, morningness-eveningness, $\chi^2(2, N = 87) = 0.40, p = .82$, trait sleepiness, $t(85) = 0.45, p = .66$, intelligence, $t(84) = 0.37, p = .71$, depression, $t(85) = 0.42, p = .67$, anxiety, $t(85) = 0.17, p = .87$, factor derived inattention/memory problems, $t(18) = -0.56, p = .59$, or DSM-IV inattentive symptoms, $t(17) = -0.41, p = .69$.

However, the groups did differ in age; completers ($M = 19.51, SD = 1.31$) were older than dropouts ($M = 18.76, SD = 0.66$), $t(50) = -2.29, p = .002$.

Outlier analysis for average sleep duration over the week revealed three participants who were outliers (i.e., sleep duration longer than 10 hours); they were excluded from further analysis. This resulted in a final sample of 67 individuals, who averaged 7.85 hours of sleep per night ($SD = 0.83$, range = 6.25 to 9.93) over the week.
Measures

Measures used in the current investigation are briefly summarized below. Please see Appendix B for a more detailed narrative regarding the psychometric properties of individual measures, as well as copies of non-copywrited measures.

Exclusion criteria: Session one self-reports. All measures described in the current section were administered during the pre-screen and were re-administered at the first session to ensure that participants continued to be eligible for the study. A 28-item symptom checklist was used to assess for exclusion criteria 1 through 7 listed in the previous section. If participants endorsed any of these exclusion criteria, they were excluded from the study.

The Berlin Questionnaire (Netzer, Stoohs, Netzer, Clark, & Strohl, 1999) is a 12-item screener for the presence of sleep-disordered breathing. Scores are based on behaviors that have consistently predicted sleep-disordered breathing, such as snoring, daytime drowsiness, hypertension, and body mass index (Netzer et al., 1999). Internal consistency of this questionnaire has been demonstrated, with high Cronbach’s alpha correlations for respective subscales (i.e., snoring and apnea, sleepiness and fatigue, hypertension and obesity) ranging from .86 to .92 (Netzer et al., 1999). Internal consistency for respective subscales within the current study, as measured by Cronbach’s alpha, were .51, .75, and .82. Of note, participants within the current study responded within a restricted range (i.e., no, never/almost never, 1-2 times/month), while Cronbach’s alpha values from other studies were based on at least a thousand individuals, including individuals with sleep disorders (Netzer et al., 1999), which likely explains the
lower internal consistency in the present data. Per the questionnaire, individuals are
categorized as “high risk” when they endorsed frequently occurring symptoms from two
of the three subscales. Categorization of individuals as “high risk” has been found to be
predictive of other physiological indicators of sleep apnea. Therefore, within the current
study, participants were excluded if they endorsed frequently experiencing symptoms in
more than two categories.

The International Restless Legs Syndrome screening criteria (Gao, Schwarzschild,
Wang, & Ascherio, 2009) is a 4-item screener for the presence of restless legs syndrome-
specific symptoms and the frequency of these symptoms. This screener was modified
from its original form to better reflect new knowledge and to clarify the wording from the
original criteria (Allen, Picchietti, Hening, Trenkwalder, Walters, &Montplaisi, 2003),
and was used in the Nurses’ Health Study II and the Health Professionals Follow-up
Study (Gao et al., 2009). An individual is likely to experience restless legs syndrome if
he/she answers “yes” to all four questions, and as such, participants within the current
study were excluded if they answered “yes” to all four questions. Although criterion
validity data is not available for this measure, the measure is based on clinical criteria for
Restless Legs Syndrome that have been agreed upon by the RLS Study group.
Cronbach’s alpha for all four items for the current study was .84.

The Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, &
Kupfer, 1989) is 9-item screener for the presence of significantly disturbed sleep within
the past month that is indicative of disordered sleep. Scores are based on seven
“component” scores, which are added to yield one global score (Buysse et al., 1989). A
global score of more than five distinguishes non-disordered sleepers from disordered sleepers, with a sensitivity of 89.6% and specificity of 86.5% (Buysse et al., 1989). Participants who scored more than five on this measure were excluded from the present study. Internal consistency has been demonstrated, with an overall Cronbach’s alpha of .83 (Buysse et al., 1989). The overall Cronbach’s alpha for the current study was .38. Closer examination revealed that component scores for participants’ within the current study ranged between 0-2, indicating responses within a restricted range.

**Covariates: Session one self-reports.** Several tests of constructs that were potential covariates (i.e., sleep quality, state sleepiness, time-of-day preference, depression, and anxiety) in the present study were administered during session one.

**Sleep quality.** The Epsworth Sleepiness Scale (Johns, 1994) is an 8-item measure that conceptualizes and assesses sleepiness during the day as a trait (i.e., a steady and constant aspect of an individual). Item scores are summed to obtain a total score, with higher scores representing higher trait sleepiness. The scale was validated by demonstrating significant differences between groups, and as a result distinguishing between healthy individuals and individuals with various sleep disorders (Johns, 1994). Scores on the measure are also significantly correlated with sleep latency as measured by the Multiple Sleep Latency Test and night-time polysomnography (Johns, 1994). Cronbach’s alpha was found to be .74 to .86 for 244 sleep disordered patients, and .75 for 87 healthy medical students (Johns, 1994). The overall Cronbach’s alpha for the current study was .73. The dependent variable for this measure was the total score.
The Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976) is a 19-item measure that assesses alertness upon awakening, and time-of-day preference for wake time, bed time, and physical and mental activity. Item scores are summed to obtain a total score used to categorize individuals as either morning types, neither types, or evening types. Construct validity was established by demonstrating group differences in bed and wake times, as well as preference for time-of-day. Convergent validity has also been established by demonstrating that groups differ, depending on the time-of-day that related measures, such as cognitive performance and body temperature, are tested (Horne & Ostberg, 1976; Schmidt, Collette, Cajochen, & Peigneux, 2007). Individuals grouped based on these categories have also been found to demonstrate differences in sleep pressure throughout the day, as measured by electroencephalograph (Ehlers, Kupfer, Buysse, Cluss, Miewald, Bisson, et al., 1998; Kerkhof, 1991; Kerkhof & Lancel, 1991; Mongrain, Carrier, & Dumont, 2005; Taillard, Coste, Sagaspe, & Bioulac, 2003). Cronbach’s alpha for the current study was .74. The dependent variable for this measure was the total score, and the categorization of individuals based on their total score (i.e., Morning types = 59-86, Neither types = 42-58, Evening types = 16-41).

Mood. The Beck Depression Inventory – Version II (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item measure that assesses for the presence and severity of current symptoms of depression among individuals aged 13 years and older. The inventory has been constructed to reflect the criteria for diagnosing depressive disorders found in the DSM-IV. Item scores are summed to yield a total score, with higher scores representing greater symptom severity. The BDI-II has been normed with large outpatient samples.
(N=500) and college students (N=120), and has demonstrated sound psychometric properties (Beck et al., 1996). Cronbach’s alpha for this measure within the current study is .87. The dependent variable for this measure was the total score.

The Beck Anxiety Inventory (BAI; Beck, 1993) is a 21-item rating scale that assesses for the presence and severity of current symptoms of anxiety among individuals 17 and older. The measure was designed to reduce the overlap between depression and anxiety scales. Item scores are added to yield a total score, with higher scores representing greater symptom severity. The BAI has been normed with outpatients from the Center for Cognitive Therapy in Philadelphia (N=1086), and has demonstrated sound psychometric properties (Beck, 1993). Cronbach’s alpha for the BAI within the current study is .89. The dependent variable for this measure was the total score.

**Covariates: Session one neuropsychological instruments.**

**Intelligence.** The Matrix Reasoning (MR) subtest from the Wechsler Abbreviated Scale of Intelligence (WASI) is a test of perceptual reasoning ability that was used to estimate general intelligence (The Psychological Corporation, 1999). MR consists of a series of increasingly complex colored patterns that have a component part missing. Participants selected one of five possible component choices that best completes the matrix. The MR subtest was normed on an adult sample and has demonstrated acceptable reliability and validity (The Psychological Corporation, 1999). The dependent variable for this measure was the total score.
**Variables of interest: Session one self-reports.**

**Attention.** The Conners Adult ADHD Rating Scales (CAARS; Conners et al., 1999) is a 66-item measure that assesses for the presence of ADHD related symptoms and behaviors. Scores from these 66 items are delineated into nine subscales, four symptom based subscales, four DSM-IV based subscales and one inconsistency index. This measure has been normed with large community-based samples of nonclinical adults, 18 years and older (N=1026), and has demonstrated sound psychometric properties (Conners et al., 1999). Among individuals aged 18-29 years who completed the measure, Cronbach’s alpha for the factor derived Inattention/ Memory Problems subscale was .89, and ranged from .81 to .84 for the DSM-IV criteria based Inattentive Symptoms subscale. Of note, the DSM-IV ADHD symptom subscales, which were developed later, had a smaller normative sample of 226 individuals (Conners et al., 1999). The Cronbach’s alphas for these two subscales within the current study were .81 and .74, respectively. The dependent variables for this measure were the raw scores from the factor-derived scale of Inattention/Memory Problems, and the ADHD symptom specific subscale of Inattentive Symptoms.

**Variables of interest: Week prior to session two.** Information from sleep diaries completed the week prior to the second session was used to derive night-time sleep duration (i.e., sleep latency and time awake during the night subtracted from time-in-bed).

**Sleep diaries.** Participants completed a sleep-wake diary twice each day, one week prior to the second experiment session; once before sleep and once upon awakening.
in the morning. Recordings before bedtime included daytime parameters (i.e., planned and unplanned naps, caffeinated and alcoholic drinks, cigarettes smoked), while recordings upon awakening included information about the previous night’s sleep (i.e., bed and wake time, sleep duration, and awakenings). Participants were provided a reminder call the day of the diary start date in order to increase adherence. In addition, participants were asked to call by 5:00 PM daily to provide their wake-up time, bedtime, sleep latency, and night-time awakenings, in order to increase adherence. If participants failed to call, experimenters followed-up with participants sometime in the afternoon or the evening that same day. The dependent variable for the study’s hypotheses is total night time sleep duration (i.e., time-in-bed minus sleep latency and total time spent awake at night) averaged over the week, while sleep duration the night before the second session and standard deviation of total sleep duration were used in supplemental analyses.

**Covariates: Session two self-reports.** Several self-report measures were administered at session two in order to check for compliance to session 2 procedures, and measure potential constructs that could be covariates to analyses.

**Personal demographics questionnaire.** Participants completed a personal demographics questionnaire assessing Hispanic or Latino heritage, racial self-identification, relationship status, and experiment day health behaviors (i.e., last meal, last caffeinated beverage, and last cigarette). The experiment day health behaviors items allowed for checking participants’ compliance to experimental day preparation instructions. The dependent variable for this measure was race.
**Sleep quality.** The Adult Sleep-Wake Scale (Fortunato, LeBourgeois, & Harsh, 2008) is a 25-item inventory measuring perceived sleep quality among adults that has been psychometrically examined in college samples. Construct validity was demonstrated by examining convergent and discriminant validity with two dispositional constructs (i.e., positive and negative affect), three stress-related constructs (i.e., interpersonal conflict, workload, and job ambiguity), and three strain-related constructs (i.e., depression, health complaints, and frustration). The measure consists of scores for five subscales—nighttime re-initiation of sleep, returning to wakefulness, bedtime sleep need, nighttime awakenings, sleep latency—and a total score. Higher scores for each subscale and total score are indicative of better sleep quality. In prior college samples, coefficient alphas ranged from .83 to .90 for the five subscales (Fortunato et al., 2008). Cronbach’s alphas within the current study were .80 for the re-initiation subscale, .87 for the wakefulness subscale, .88 for the going to bed subscale, .45 for the sleep maintenance subscale, and .71 for the sleep latency subscale. The lower internal consistencies may reflect restricted range of responses on the sleep maintenance scale. The dependent variables for this measure were the five individual subscale scores and the total score.

**Sleepiness and tiredness.** The Sleepiness and Tiredness Visual Analogue Scale (VAS) is a 2-item analogue scale assessing for state sleepiness/alertness and tiredness/energeticness. The VAS score for each item allows for a continuum of responses, which may be more sensitive when measuring nonpathological levels of subjective sleepiness, and has been shown to be sensitive to partial or total sleep deprivation (Monk, 1987). Lower scores on the sleepiness and tiredness scale represent
more sleepiness and tiredness. This measure was implemented before and after all the cognitive tasks. The dependent variable for this measure was the score for each item.

**Mood.** The Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) is a 20-item checklist that assesses positive and negative state affect (i.e., current, momentary mood). The PANAS has demonstrated good internal consistency and convergent validity across clinical and non-clinical samples, with coefficient alpha values ranging from 0.84 to 0.90 for the two subscales (e.g., Crawford & Henry, 2004; Watson et al., 1988). The PANAS was administered before and after all the cognitive tasks. Cronbach’s alpha for positive affect prior to attentional tasks within the current study was .87, and .91 after engaging in all tasks. Meanwhile, Cronbach’s alpha for negative affect was .59 prior to attentional tasks, and .69 after attentional tasks. Negative affect responses ranged from 1 to 3, prior to the task, when compared to positive affect responses that ranged from 1 to 5. Similarly, negative affect responses by participants were more limited in range after the task, ranging from 1 to 2. The dependent variables for this measure are the total individual scores for positive and negative affect, respectively.

**Variables of interest: Session two neuropsychological instruments.**

**Vigilance.** The Psychomotor Vigilance Test is a simple reaction time test designed to examine vigilant attention and has been a marker of attentional deficits within the sleep literature (Lim & Dinges, 2008). The standard task consists of reacting to a cue (i.e., a counter that appears on a small, rectangular area on a dark screen) that occurs at random inter-stimulus intervals of 2 to 10 seconds, by pressing a button. The
total task duration is 10 minutes (Lim & Dinges, 2008). Most studies utilize the number of lapses (typically defined as responses greater than 500 ms) as the primary dependent variable, with other accompanying variables such as mean reaction time, errors of commission, and variability in reaction time (Lim & Dinges, 2008). Convergent validity for this task has been demonstrated through its sensitivity to both total and chronic partial sleep deprivation, and intervention with psychoactive and wake-promoting drugs (Lim & Dinges, 2008).

The current study utilized the PEBL Psychological Test Battery’s version of the Psychomotor Vigilance Test, which they named Psychomotor Vigilance Task (Mueller, 2008). Just like the Psychomotor Vigilance Test, the Psychomotor Vigilance Task by PEBL (Mueller, 2008) is composed of a target image (i.e., a red circle) that appears on an area of a dark screen, at random inter-stimulus intervals of 1 to 10 seconds. Participants were asked to react to the stimulus as fast as possible by pressing the space bar on the keyboard, with total task duration of 10 minutes. Feedback on reaction time was provided to participants. The dependent variables for this test were mean reaction time, lapse (i.e., >500 ms), and accuracy (# correct / # completed * 100). Although EEG measures were collected during the task, the current study did not analyze EEG parameters.

**Sustained attention.** The Test of Variables of Attention (TOVA) is a continuous performance test that measures sustained attention (Strauss et al., 2005). The TOVA has been found to consist of three factors, namely response time (i.e., reaction time, and reaction time variability), errors of commission, and errors of omission. Although minimal convergent data currently exists (no published data has compared the test with...
other continuous performance tests) an unpublished study described the accurate identification of 90% of children with attention deficit hyperactivity disorder with this test (Strauss et al., 2005). Furthermore, as with most continuous performance tests, although the test’s correlations with self-reported ADHD rating scales are not high, the test’s ADHD score was found to be highly concordant with the Diagnostic and Statistical Manual of Mental Disorders 4th edition (DSM-IV) criteria for ADHD and with physician based diagnosis (Strauss et al., 2005). Correlational analyses examining internal consistency for the visual test for reaction time, reaction time variability and omissions were moderate to high (range of .75 to .88), while commissions and d’ (i.e., errors of omission and commission) were less optimal (range of .57 to .60; Strauss et al., 2005).

The current study utilized the PEBL Psychological Test Battery’s version of the Test of Variables of Attention, which they named the Test of Attentional Vigilance (Mueller, 2008). Just like the Test of Variables of attention, the Test of Attentional Vigilance by PEBL (Mueller, 2008) is composed of two simple geometric forms presented for 100 milliseconds every 2 seconds for 22.5 minutes. However, instead of being displayed at four intervals, the test by PEBL displayed the geometric forms in two intervals; the target (one of the two forms) appears on 22.5% of the trials during the first interval (stimulus infrequent condition), while appearing 77.5% during the second interval (stimulus frequent condition). Just like the Test of Variables of Attention (Strauss et al., 2005), the test by PEBL also loads on sustained attention, eliciting errors of omission during the first half of the test, while loading on inhibitory control during the second half, eliciting errors of commission. The dependent variables for this test were
accuracy (correct responses to both targets and foils), errors of omission during the first half, and mean response time (of both correct and incorrect responses). Although EEG measures were collected during the task, the current study did not analyze EEG parameters.

Variables of interest: Session two neurophysiological measure.

Electroencephalograph during an attention task. Participants were asked to attend to a 26-minute mock lecture task consisting of a 26-minute pre-recorded psychophysiology lecture detailing the physiology of vision and consequences of eye disease. Prior to the mock lecture, they were told that they would be completing a short quiz after the mock lecture. They were also told that the answers would be evident from the mock lecture that they will be viewing. They were then shown the 10 questions. While participants were attending to the mock lecture, electroencephalographic measures were recorded. After the mock lecture, participants were asked to select the best of four choices for each of the 10 questions that were shown prior to the lecture viewing. The dependent variables of interest for this measure were frontal theta, and posterior alpha and theta.

Setting and Apparatus

Setting. Participants were seated at a desk on a chair that is a common seating option at the Midwestern university. The room was a light-, temperature- and humidity-controlled room that was maintained at a temperature of 70°F (±2°F). The room contained two desks, one that was set up with a computer assembled with a keyboard, a mouse and a pair of speakers, and another that allowed for written work as well as
administration of neuropsychological instruments. The room also contained three chairs and a surveillance camera with audio and speaker capability to allow for communication between the experimenters and the participant.

**Electroencephalogram and electrooculogram.** Both electroencephalogram (EEG) and electrooculogram (EOG) data were recorded using an MP100 System (Biopac, Inc) interfaced with a Dell Optiplex computer running AcqKnowledge v 4.1 with a sampling rate of 500 samples per second. EEG100 amplifiers from Biopac, Inc were used to amplify the EEG signal, and the data was stored to the hard drive of the Dell Optiplex. Two of the 20 Ag/AgCl surface electrodes that were embedded in an electrode cap (ElectroCap, Eaton, OH) in the International 10/20 system (Klem, Luders, & Jasper, 1999) were referenced to the right earlobe. Specifically, a 2-channel monopolar montage was recorded from a frontal scalp site (i.e., Fz) and a posterior scalp site (i.e., Pz), referenced at A2, and grounded at A1 (see Figure 1, Klem et al.,1999). All EEG electrode sites were prepped with abrasive pads, PDI electrode prep pads (i.e., pads containing 70% alcohol with pumice), and Nuprep EEG skin prep gel. EOG was also recorded to monitor eye movement artifacts and to allow for offline artifact rejection. EOG electrode sites were prepped with abrasive pads, and PDI electrode prep pads. Surface Ag-AgCl electrodes were attached to the sites using disposable self-adhesive electrode collars and electrode gel. Specifically, the electrodes were placed above and below the left eye, and at the left and right outer canthus. For both EEG and EOG, impedance of less than 30 kΩ was ensured, and a 60-Hz notch data filter was employed to minimize the 60-cycle interference, while gain settings were set at 10000K and 2000K, respectively. As a
baseline, six 10-second recordings of frontal and posterior EEG activity were taken while the participant looked at a red dot on a blank screen with eyes open and eyes closed.

*Figure 1.* The ten-twenty electrode system of the International Federation.

**Procedure**

At the first orientation session, participants completed informed consent procedures. They then completed the exclusion criteria and covariate self-report measures, as well as the CAARS. Following these questionnaires, participants completed the Matrix Reasoning (MR) subtest from the Wechsler Abbreviated Scale of Intelligence (WASI; The Psychological Corporation, 1999). They were then provided directions for completing the sleep diaries, once at bedtime and once upon awakening in the morning, over the week prior to attending the second experimental session. The second experimental session was scheduled at least one week after the first orientation session, with start times between 2 and 3 PM. Participants were also provided preparation instructions for the experiment day, and provided an instruction sheet to take home.
Preparation instructions included waking up by 10:00 AM the morning of the experiment session, refraining from drinking caffeine and smoking 5 hours prior to the session, and refraining from drinking alcohol and ingesting drugs 24 hours prior to the session. See Table 1 for the order of administration.

Table 1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 minutes</td>
<td>Informed consent</td>
</tr>
<tr>
<td>20 minutes</td>
<td>Self-report measures</td>
</tr>
<tr>
<td>15 minutes</td>
<td>Wechsler Abbreviated Scale of Intelligence – Matrix Reasoning task</td>
</tr>
<tr>
<td>5 minutes</td>
<td>Sleep diary and experimental session preparation instructions</td>
</tr>
</tbody>
</table>

Upon arrival to the experimental session, participants were re-engaged in the informed consent process, after which they completed the self-report measures. After a short introduction about the recording devices, four 4-mm Ag-AgCl surface electrodes were placed above and below the left eye, and at the left and right outer canthus (Gotlib, Ranganath, & Rosenfeld, 1998). This was followed by the placement of the reference and ground electrodes and the electrode cap, which were placed and secured with straps following guidelines provided by ECI Electro-cap Electrode System (ElectroCap, Eaton, OH). After a short introduction to the vigilance task, participants completed the vigilance task described above. The participants then engaged in a 1-minute baseline measurement. After the baseline, participants completed two approximately 25-minute tasks; the 25-minute continuous performance test described above and the 26-minute mock lecture attending task detailed above. During both 25-minute tasks, experimenters noted sleep
behaviors (i.e., eyes closed, nodding, relaxed jaw) using a non-recording camera placed in the room. If participants engaged in sleep behaviors that extended beyond 10 seconds, the experimenter said “sleep check” via the intercom. No participant continued sleep behaviors when provided with the prompt across both tasks. Participants then completed the mock lecture questionnaire, as well as a second mood, sleepiness and tiredness visual analogue scale measures. After all tasks and questionnaires, recording devices were removed. Participants were debriefed regarding objectives of the current study, and provided with a debriefing form to take with them.

Due to extenuating circumstances, and after a pre-analysis that demonstrated little to no power in EEG data, the neurophysiological measures were discontinued after having administered the protocol to 50 eligible participants. Procedures were altered in order to maintain the integrity of the vigilance and continuous performance task. Therefore, the mock lecture and its related questionnaire were completed prior to the vigilance task, taking the place of electrode placement, which resulted in a briefer protocol. See Table 2 for the order of administration before and after changes.
### Table 2.

**Timeline for Session 2 Before and After Procedural Changes**

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Time</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 minutes</td>
<td>Re-visit informed consent</td>
<td>5 minutes</td>
<td>Re-visit informed consent</td>
</tr>
<tr>
<td>5 minutes</td>
<td>Collection of sleep diaries</td>
<td>5 minutes</td>
<td>Collection of sleep diaries</td>
</tr>
<tr>
<td>5 minutes</td>
<td>Self-report measures</td>
<td>5 minutes</td>
<td>Self-report measures</td>
</tr>
<tr>
<td>30 minutes</td>
<td>Placement of electrodes</td>
<td>30 minutes</td>
<td>Mock lecture task and self-report questions</td>
</tr>
<tr>
<td>10 minutes</td>
<td>Vigilance task</td>
<td>10 minutes</td>
<td>Vigilance task</td>
</tr>
<tr>
<td>1 minute</td>
<td>Baseline task</td>
<td>1 minute</td>
<td>Baseline task</td>
</tr>
<tr>
<td>25 minutes</td>
<td>Continuous performance task</td>
<td>25 minutes</td>
<td>Continuous performance task</td>
</tr>
<tr>
<td>26 minutes</td>
<td>Mock lecture task</td>
<td>5 minutes</td>
<td>Self-report questionnaires</td>
</tr>
<tr>
<td>5 minutes</td>
<td>Mock lecture questions and self-report questionnaires</td>
<td>5 minutes</td>
<td>Debriefing</td>
</tr>
<tr>
<td>15 minutes</td>
<td>Removal of recording devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 minutes</td>
<td>Debriefing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electroencephalograph Data Reduction

Recorded EEG and EOG data from baseline and the mock lecture task were compressed and resampled at 200 samples per second. All channels of continuous EEG and EOG were segmented into 1 second epochs and examined for severe artifacts that resulted from participants blinking, yawning or nodding. Channels and epochs that contained severe artifacts were rejected semi-automatically (i.e., via software and visual inspection) before further analysis using the AcqKnowledge v 4.1 software. Artifact from the EOG was reduced within the EEG using the 1 second epochs that were linked into a two-dimensional matrix. The two-dimensional matrix was then delineated with Independent Component Analysis (ICA; for ICA details see Onton, Westerfield,
Townsend, & Makeig, 2006). Visual examination of EOG data post ICA analyses was conducted, and any remaining EOG artifact was removed.

**Computation of alpha and theta power.** To compute estimates of baseline frontal theta power, and posterior alpha and theta power, the independent components of the continuous EEG from the two active sites of each of the eight baseline epochs were transformed using a Fast Fourier Transform (FFT) algorithm employing linear scaling. The FFT algorithm decomposed the continuous EEG waveform into its sine wave components of 3-100 Hz. For the current study, FFT output set for 1-Hz bins and the 5-bin alpha (8-13 Hz), as well as the 4-bin theta (4-7 Hz) frequency bands were examined for analysis. A Hamming window was used to minimize artificial attenuation of the transformed EEG wave function due to the non-overlapping endpoints. Power density was averaged across the 5 FFT and 4 FFT output bins, yielding a power density function in $\mu V^2/Hz$ for the baseline recordings from each of the 2 active sites (Tomarken, Davidson, Wheeler, & Kinney, 1992).

To compute estimates of frontal theta, and posterior alpha and theta power during the mock lecture task, three time samples were examined from the 26-minute task, namely the first, middle and last 5-minutes of the task. In a similar manner, the independent components from the two active sites during these periods were transformed using a FFT algorithm. Power density was then averaged across these three periods to yield a total mean power density in $\mu V^2/Hz$ for the mock lecture recordings from each of the two active sites (Tomarken et al., 1992).
Results

Examination for Covariates

Data were entered into the Statistical Package for the Social Sciences (SPSS, 2008). In order to determine potential covariates, the relationship of average sleep duration to sex of participants, age, race/ethnicity, and means of compensation, as well as morningness-eveningness, trait sleepiness, sleep quality, state positive and negative mood, intelligence, state sleepiness, state tiredness, depression, and anxiety scores was examined. No differences in sleep duration were found between the sexes, \( t(65) = 0.19, p = .85 \), race/ethnicity (majority and minority), \( t(65) = 0.17, p = .87 \), means of compensation, \( t(65) = -0.47, p = .64 \), and morningness-eveningness categories, \( F(2, 66) = 2.25, p = .11 \). Sleep duration was also not related to age, \( r(67) = -.03, p = .84 \), trait sleepiness, \( r(67) = -.15, p = .22 \), sleep quality, \( r(67) = .12, p = .33 \), state positive mood, \( r(67) = -.17, p = .16 \), state negative mood, \( r(67) = .02, p = .90 \), intelligence, \( r(67) = .04, p = .72 \), state sleepiness, \( r(67) = .13, p = .28 \), state tiredness, \( r(67) = .01, p = .94 \), depression, \( r(67) = -.20, p = .11 \), or anxiety, \( r(67) = -.08, p = .54 \).

Hypotheses

Outliers within each dependent variable were removed prior to analyses. See Table 3 for the summary of findings between sleep duration and the variables of interest (including means and standard deviation of the variables).

Hypothesis I: ADHD symptom reporting. Consistent with hypotheses, a significant negative relationship was revealed between average sleep duration and the factor-derived Inattention/Memory Problems Scale of the CAARS, indicating that
individuals with shorter sleep durations reported more inattentive or memory symptoms. The DSM-IV factor derived ADHD Inattentive Symptoms approached significance.

**Hypothesis II: Cognitive performance.** Contrary to hypotheses, average sleep duration was found to be positively related to mean reaction time on the PVT, and negatively related to accuracy on the PVT, indicating that shorter sleep duration was related to shorter reaction time and better accuracy performance. No significant relationship was demonstrated between average sleep duration and lapsing performance on the PVT, or accuracy, reaction time, and error performance on the TOVA.

**Hypothesis III: Resting state arousal.** In regard to resting state arousal, no relationship was found between average sleep duration and frontal theta, and posterior alpha and theta.

**Hypothesis IV: Activation during mock lecture task.** As resting state arousal was not significantly related to sleep duration, baseline EEG variables were not controlled for in the analysis of activation during the mock lecture task. No relationship was demonstrated between average sleep duration and frontal theta, and posterior alpha and theta during the mock lecture task.
Table 3.

**Summary of Main Hypotheses Findings**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pearson’s $r$</th>
<th>p-value</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAARS Inattention/Memory problems ($n = 67$)</td>
<td>-.287</td>
<td>.02*</td>
<td>7.07</td>
<td>4.27</td>
</tr>
<tr>
<td>DSM-IV inattentive symptoms ($n = 67$)</td>
<td>-.220</td>
<td>.07</td>
<td>5.31</td>
<td>2.92</td>
</tr>
<tr>
<td>PVT Mean reaction time ($n = 65$)</td>
<td>.297</td>
<td>.02*</td>
<td>360.71</td>
<td>55.86</td>
</tr>
<tr>
<td>Lapse ($n = 66$)</td>
<td>.141</td>
<td>.26</td>
<td>6.48</td>
<td>7.76</td>
</tr>
<tr>
<td>Accuracy ($n = 63$)</td>
<td>-.249</td>
<td>.05*</td>
<td>94.36</td>
<td>6.24</td>
</tr>
<tr>
<td>TOVA Accuracy ($n = 66$)</td>
<td>.056</td>
<td>.65</td>
<td>712.50</td>
<td>16.12</td>
</tr>
<tr>
<td>Mean reaction time ($n = 66$)</td>
<td>.140</td>
<td>.26</td>
<td>365.14</td>
<td>53.34</td>
</tr>
<tr>
<td>1st half, omission errors ($n = 59$)</td>
<td>-.064</td>
<td>.63</td>
<td>2.80</td>
<td>2.70</td>
</tr>
<tr>
<td>Baseline Frontal theta ($n = 49$)</td>
<td>.024</td>
<td>.87</td>
<td>-3.20</td>
<td>0.18</td>
</tr>
<tr>
<td>Parietal alpha ($n = 49$)</td>
<td>.081</td>
<td>.58</td>
<td>-3.05</td>
<td>0.40</td>
</tr>
<tr>
<td>Parietal theta ($n = 49$)</td>
<td>.149</td>
<td>.31</td>
<td>-3.13</td>
<td>0.35</td>
</tr>
<tr>
<td>Mock lecture task Frontal theta ($n = 49$)</td>
<td>.080</td>
<td>.58</td>
<td>-3.11</td>
<td>0.14</td>
</tr>
<tr>
<td>Parietal alpha ($n = 49$)</td>
<td>-.124</td>
<td>.40</td>
<td>-3.13</td>
<td>0.26</td>
</tr>
<tr>
<td>Parietal theta ($n = 49$)</td>
<td>-.045</td>
<td>.76</td>
<td>-3.08</td>
<td>0.19</td>
</tr>
</tbody>
</table>

*Note. CAARS = Conners’ Adult ADHD Rating Scale; PVT = Psychomotor Vigilance Task; TOVA = Test of Variables of Attention; * = $p < .05$*

**Exploratory Analyses**

Given that self-reported sleep quality and ADHD symptoms are measures of an individual’s *perceptions* of sleep and attentional abilities respectively, poor perception of one may be related to the other. As the sleep maintenance subscale demonstrated poor reliability within the current study (i.e., Cronbach’s alpha of .45), the exploratory correlational analyses were conducted between the other five dependent variables of the ADSWS (i.e., 4 subscales, and 1 total score), and two dependent variables from the CAARS (i.e., 1 factor derived subscale, and 1 DSM-IV derived subscale). As BDI and
BAI scores were also found to be significantly related to ADSWS and CAARS scores, BDI and BAI scores were partialled out. Given that these analyses are exploratory, no corrections were made for the number of correlations.

Morning wakefulness, bedtime habits, and total score from the ADSWS were negatively related to the factor-derived Inattention/Memory Problems Scale of the CAARS, with partial $r$'s ranging from -.52 to -.40 ($n=69$). Meanwhile morning wakefulness, bedtime habits, and total score from the ADSWS were also negatively related to the DSM-IV factor derived ADHD Inattentive Symptoms of the CAARS, with partial $r$'s ranging from -.41 to -.38 ($n=69$). Of note, when average sleep duration (i.e., objective sleep measure) was examined in relation to perceived sleep quality based on self-reported ADSWS scores, no relationship was revealed, $r$'s ranged from -.01 to .21, $p > .05$. Table 4 notes correlations between variables of these two measures when BDI and BAI scores were controlled and not controlled for. Taken together, these correlational analyses demonstrated that, in general, worse self-reported sleep quality (lower ADSWS scores) was associated with more self-reported inattention/memory problems (higher CAARS scores). With closer examination and while controlling for depressive and anxiety symptom reporting, how one feels upon awakening (i.e., not alert, not rested) and poor night-time sleep habits (i.e., delaying bed time), were most associated with higher self-reported inattention/memory problems and ADHD inattentive symptoms scores.
Table 4.

*Correlation Matrix of CAARS Subscales and ADSWS Variables when BDI and BAI are not Controlled for (not in bold; n=73), and when BDI and BAI are Controlled for (in bold; n=69)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>CAARS: Inattention/ Memory Problems</th>
<th>CAARS: DSM-IV Inattentive Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSWS: Sleep re-initiation</td>
<td>-.324**</td>
<td>-.272*</td>
</tr>
<tr>
<td></td>
<td>-.220</td>
<td>-.164</td>
</tr>
<tr>
<td>ADSWS: Morning wakefulness</td>
<td>-.479**</td>
<td>-.449**</td>
</tr>
<tr>
<td></td>
<td>-.403**</td>
<td>-.375**</td>
</tr>
<tr>
<td>ADSWS: Bedtime sleep habits</td>
<td>-.552**</td>
<td>-.472**</td>
</tr>
<tr>
<td></td>
<td>-.480**</td>
<td>-.390**</td>
</tr>
<tr>
<td>ADSWS: Sleep initiation</td>
<td>-.285*</td>
<td>-.166</td>
</tr>
<tr>
<td></td>
<td>-.235</td>
<td>-.103</td>
</tr>
<tr>
<td>ADSWS: Total score</td>
<td>-.601**</td>
<td>-.506**</td>
</tr>
<tr>
<td></td>
<td>-.519**</td>
<td>-.407**</td>
</tr>
</tbody>
</table>

*Note. ADSWS = Adult Sleep-Wake Scale; CAARS = Conners’ Adult ADHD Rating Scale; r values when BDI and BAI are controlled for are in boldface (n = 69); * = p < .05, ** = p < .01*

**Other Supplemental Analyses and Considerations**

Three subscales of the ADSWS (i.e., morning wakefulness, night-time sleep habits and sleep initiation) are more likely to capture the concept of poor sleep habits. Hence, these three subscales and overall sleep quality (i.e., total score) as measured by the ADSWS were also examined in relation to cognitive performance and EEG findings. BDI and BAI scores were also partialled out for these analyses. In regard to cognitive performance, better bedtime sleep habits were related to more lapses on the PVT (please refer to Table 5 in Appendix C for all findings). Sleep initiation was negatively related to posterior alpha at baseline, as well as posterior alpha and theta during the mock lecture (please refer to Table 6 in Appendix C for all findings). These correlational analyses suggest that less difficulty with sleep onset was associated with lower posterior alpha
power at baseline, as well as lower posterior alpha and theta power during the mock lecture. However, given the number of comparisons made, it is unlikely that these findings are stable.

Given research showing the vulnerability of neuropsychological and neurophysiological measures to state variables such as sleepiness and mood (e.g., Dinges, Pack, Williams, Gillen, Powell, Ott, & Pack, 1997; Gilet & Jallais, 2012), the relationship of other sleep parameters—such as sleep duration the night before the second session—and state measures—such as state alertness and negative state mood—to performance on the PVT and TOVA, as well as EEG parameters, were examined. Sleep duration the night before was not related to the performance variables on the PVT and TOVA or the EEG parameters. State alertness prior to cognitive tasks as measured by the visual analogue scale was related to two EEG measures, namely frontal and posterior theta power during the mock lecture task. These findings indicate that the less alert individuals self-reported to be, the more theta power they exhibited while watching the mock lecture. After controlling for depressive and anxiety symptoms (i.e., BDI and BAI), negative state mood prior to cognitive tasks was related only to longer reaction time on the TOVA. Please refer to Table 7 and 8 for statistical findings.

Another potentially important sleep variable is variability in sleep duration over time. The insomnia literature has just begun to attempt establishing standards for characterizing variability in sleep experienced by individuals with insomnia (Buysse, Cheng, Germain, Moul, Franzen, Fletcher, & Monk, 2010; Vallieres, Ivers, Bastien, Beaulieu-Bonneau, & Morin, 2005). Specifically, voluntary sleep-wake behaviors, such
as irregular sleep-wake schedules, have been implicated as a contributor to the development of insomnia (Buysse et al., 2010; Vallieres et al., 2005). Since the college population has also increasingly self-reported variability in bed- and wake-times, in addition to shorter sleep duration (Hicks et al., 2001), as well as characteristics meeting the criteria for Delayed Sleep Phase Syndrome (Brown, Soper, & Buboltz, 2001), variability in sleep duration may be a sleep variable pertinent to college students. As a result, we examined whether variability in sleep duration over the week of sleep data was related to performance on the PVT, TOVA and EEG, while controlling for average sleep duration. While controlling for sleep duration, more variability in sleep over the week was related to more lapsing (PVT), and slower mean reaction time on the PVT and the TOVA. No relationship was found for EEG parameters. Please see Table 9 in Appendix C for correlations between variables of these measures when sleep duration over the week was controlled for. We also examined whether variability in sleep duration was related to self-reported ADHD symptoms, after controlling for sleep duration. There was no relationship of variability with either the factor-derived Inattention/Memory Problems Scale of the CAARS, partial r of -0.03, or the DSM-IV factor derived ADHD Inattentive Symptoms of the CAARS, partial r of -0.08.

As discussed in the introduction, diagnosis of ADHD is made difficult by overlapping symptoms of ADHD with other known medical and psychiatric difficulties. This is especially difficult when self-reported ADHD symptoms are relied upon for diagnosing adults (Johnson & Conners, 2002), which can often result in misdiagnosis (Manuzza, Klein, Klein, Bessler, & Shrout, 2002; Murphy, Barkley, & Bush, 2001; Suhr,
Zimak, Buelow, & Fox, 2009). However, neuropsychological evaluation of adults with ADHD-like complaints can be used in conjunction with interviews and self-report rating scales in order to provide objective evidence of impairment. Hence, we also explored the relationship between CAARS scales and PVT and TOVA performance. After controlling for BDI and BAI scores, higher scores on the Inattention/Memory Problems Scale of the CAARS was related to better reaction time on the PVT, while the DSM-IV factor derived ADHD Inattentive Symptoms was not related to any performance variables. Please see Table 10 in Appendix C for correlations between variables of these measures when BDI and BAI scores have been controlled for. Please also see Table 11 in Appendix C for the means and standard deviations of all dependent variables used in exploratory and supplemental analyses.
Discussion

The current study examined the relationship of naturalistic sleep behaviors among undergraduates to self-reported attention difficulties, neurobehavioral performance and neurophysiological parameters. Given the overlap between Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms and sleep deprivation/restriction symptoms, it was hypothesized that individuals who slept less would self-report more attention-related symptoms. Furthermore, as sleep deprivation and sleep restriction studies consistently demonstrate the impact of poor sleep on attention (Lim & Dinges, 2010), it was hypothesized that shorter sleep durations would also be related to worse attentional performance. Finally, it was hypothesized that EEG alpha and theta power assessed during a naturalistic sustained attention task (i.e., watching a mock lecture) would be negatively related to sleep duration. To our knowledge, the current study is the first to use measures of naturalistic sleep behaviors over a one-week span, while concurrently examining self-reported attention difficulties, attention-related performance, and EEG spectral power while attending to an ecologically valid task.

Attention-related Symptom Reporting

As hypothesized, students who slept less over the week prior to the experiment session self-reported more attention-related difficulties on the CAARS (medium effect size). Although the findings for DSM-IV derived Inattentive Symptoms subscale of the CAARS was only approaching significance (i.e., $p = .07$), the relationship was in the same negative direction with a medium effect size. These findings were independent of self-reported mood and sleepiness, as these constructs were not found to be related to sleep
duration. Furthermore, these findings are further bolstered by the exploratory analyses that demonstrated significant negative relationships between perceived sleep quality and self-reported inattention indices, with medium to large effect sizes, given that no relationship was found between overall perceived sleep quality and sleep duration. In contrast, variability in sleep duration over the week was not related to either CAARS subscales after controlling for sleep duration.

Taken together, our findings are consistent with the existing experimental sleep literature and suggest that sleep difficulties are yet another potential contributor to the misdiagnosis of ADHD in young adults, particularly when diagnosis is based only on self-reported symptoms. Given these findings, sleep behaviors should also be considered while diagnosing ADHD by obtaining objective and subjective sleep reports as part of the clinical interview for differential diagnosis. Physicians and researchers may have individuals report on their perceived sleep quality as well as objective sleep measures on sleep diaries over a period of one to two weeks to determine if sleep behaviors are impacting the individual’s perception of attentional difficulties.

**Cognitive Performance**

In regard to cognitive performance, our only findings were contrary to previous findings within the sleep literature, while the others were not replicated. Specifically, students who slept less had faster reaction times and demonstrated better accuracy on the PVT, while no other significant relationships were found from analyses examining performance on the TOVA. Of note however, although sleep duration the night before the second session was not related to any of the performance variables, more variable sleep
duration over the week was revealed to be related to more lapsing behavior on the PVT, as well as slower reaction times on the PVT and TOVA, with medium effect sizes, after controlling for sleep duration. Taking these findings together, variability in sleep within real-world sleep behaviors may be an important factor to consider in future studies of the impact of naturalistic sleep behavior on cognitive performance. Furthermore, sleep variability may be particularly relevant to college students’ sleep habits, due to the various extrinsic influences common within college life, such as the college psychosocial milieu (i.e., peer-related activities), independence from parental influences, and exams that may result in decreased sleep duration or “all-nighter” decisions among college students (Buboltz, Brown & Soper, 2001; Carskadon, 2002; Engle-Friedman & Riela, 2004; Thacher, 2008). Given the current findings, variability in sleep due to college students’ sleep decisions may be impacting their academic performance negatively. Of further note, the literature regarding insomnia has implicated the irregularity of sleep-wake schedules as a significant contributor to the development of insomnia, as well as distress due to unpredictability of anticipated sleep (Buysse et al., 2005).

With regard to perceived sleep quality, bedtime sleep habits was the only sleep quality measure on the ADSWS to reveal a positive relationship to lapses on the PVT, with medium effect size, where better bedtime sleep habits was related to poorer lapsing performance. In regard to other self-reported measures and performance, state alertness was not related to the performance variables on the PVT and TOVA. Negative state mood however, was positively related to reaction time on the TOVA, with medium effect size, after controlling for depressive and anxiety symptom reporting. Given the limited
number of findings, while considering the number of comparisons explored with these three variables, it is likely that these findings are unstable, and therefore speculative in nature.

Independent of self-reported mood and sleepiness, self-reported attention difficulties on the CAARS were also related to better reaction time on the PVT, with medium effect size, a finding contrary to expectations given the ADHD literature (Barkley, 1997; Sadeh et al., 2002; Seidman et al., 1997). Given the number of correlations, this may be a spurious finding; however it does provide further support for the utilization of other means of assessing for ADHD in addition to self-reported measures, such as neurobehavioral measures, observer reports, and developmental evidence of ADHD, as well as assessing for evidence of other differential diagnoses, including sleep difficulties.

**Electroencephalography: Alpha and Theta Power**

Analyses examining the relationship between average sleep duration and neurophysiological measures of attention (i.e., EEG collected while attending to a mock lecture task) resulted in no significant relationships. Similarly, sleep duration the night before the second session and variability in sleep duration, after controlling for average sleep duration, were not related to the EEG parameters. Furthermore, sleep quality as measured by the ADSWS revealed that less difficulty with sleep onset was associated with lower posterior alpha power at baseline as well as lower posterior alpha and theta power during the mock lecture, with medium effect size. In regard to other self-reported measures, negative state mood was not related to the EEG parameters, while higher state
alertness was found to be related to lower theta power during the mock lecture task (i.e., frontal and posterior theta), with medium effect size. When taken together, the EEG findings were minimal given the number of comparisons explored, and therefore interpretation of the findings would not be warranted.

**Limitations and Future Directions**

A few factors related to the present study need to be noted, given the limited findings from the main hypotheses, particularly those pertaining to cognitive performance. As indicated in the introduction, robust findings of performance decrements in reaction time and lapsing have been demonstrated in sleep studies with high intensity sleep loss (e.g., Killgore, McBride, Killgore, Balkin & Kamimori, 2008). That is, individuals were deprived from 24 to 88 hours of sleep, or restricted of at least 3 of the 8 hour night’s sleep over 1-7 days. Although the current study adds to the literature by examining naturalistic sleep behavior choices on various constructs impacted by sleep as demonstrated within the literature, the limited range in overall sleep duration amongst study participants likely contributed to the minimal cognitive performance and EEG findings. Specifically, participants within the current study only experienced on average 1 hour of sleep restriction per night, if compared to the 8-hour norm within the literature, due to the current study’s naturalistic procedures. Furthermore, participants may also be “making up” for their sleep, given that participants were allowed to nap, and napped on average approximately 15 minutes per day over the week, with a standard deviation of 20 minutes. As a result, participants who slept shorter durations may not have experienced “enough” restricted sleep, especially since they were able to “make up” for their lack of
sleep via napping during the days throughout the week. Furthermore, despite controlling for substance use up to 24 hours prior to the day of the experiment, the current study was unable to confirm that participants followed the study restrictions on use of these substances.

Another limitation within the current study may be the accuracy of the sleep information provided by the participants via sleep diaries. Despite various means that were taken to ensure reliability of the information provided, including reminder calls and daily reports by the participants, a more accurate and reliable means of obtaining home sleep data would be via actigraphs. It should be noted however, that sleep diaries completed with daily reminders and call-ins have been demonstrated by others to be as reliable as actigraphs (Jiang, VanDyke, Zhang, Li, Gozal, & Shen, 2011). Although decreasing the naturalistic nature of the current study, future studies could use in-home sleep restriction designs. For example, a recent published study utilized an in-home 2-hour sleep restriction protocol (i.e., 6 hour time-in bed), where participants were allowed to engage in all their regular activities, except consuming caffeinated beverages, alcohol, or medications, and taking daytime naps (Jiang et al., 2011). Sleep behaviors were monitored by both sleep diaries and actigraphs, and despite finding no impact of sleep on accuracy for working memory tasks, reaction times increased after sleep restriction (Jiang et al., 2011).

Another limitation is in regard to the timing of administration of the CAARS, which was administered during the first session, prior to the objective sleep data from participants’ sleep diaries. Hence, implications regarding the directionality (i.e.,
causality) of the current findings are limited. However, the bi-directionality of the sleep-ADHD relationship—whereby sleep loss may result in attentional symptoms, while ADHD diagnosis and treatment may result in sleep difficulties—has been noted within the ADHD literature (including diagnostic criteria) and may be difficult to tease apart (Owens, 2005). Despite the noted limitation however, the CAARS assesses for symptoms typical of ADHD in general, rather than only at the present moment, and therefore is not considered a state measure. Depending on the nature of future studies, particularly if the examination of relationships pertains to objective sleep data obtained prior to performance variables, the administration of the CAARS should occur during the second session to address this limitation. Furthermore, future research may also examine objective and subjective sleep in relation to worries about ADHD-like symptoms and being diagnosed with ADHD.

Other factors to consider with regard to the current findings include inter-individual differences (i.e., traits). Although previously ignored in sleep research, studies have recently examined the possibility of trait factors influencing the effects of sleep loss on cognitive performance using similar management of state factors, such as not allowing for caffeine intake, and limiting physical activity. For example, a study categorized participants based on their worst reaction time and reaction time variability performance during the psychomotor vigilance task over the sleep deprivation period, as either resistant (top 25% performers) or vulnerable (bottom 25% performers) to sleep loss (Killgore, Grugle, Reichardt, Killgore & Balkin, 2009). Results based on this group designation indicated that the resistant group performed better on all other executive
cognitive tasks (i.e., Stroop, color-trails test, and the controlled oral word association test) at baseline, when compared to the vulnerable group, while not differing on visuospatial ability, the timed aspects of the Stroop subtests, or the psychomotor speed portion of the color-trails test, indicating that these differences in executive performance findings are likely not due to superior processing speed or simple motor superiority (Killgore et al., 2009). Killgore and colleagues (2009) concluded that individuals with better executive functioning at baseline, irrespective of psychomotor and processing speed abilities, appear to be less vulnerable to the effects of sleep loss, while individuals with poorer executive functioning at baseline appear to be more vulnerable to sleep loss. Naturalistic experiments have also found significant individual variability in attentional performance with sleep loss. For example, in a study with military fighter pilots, some pilots were able to sustain their performance after 38 hours of sleep deprivation, appearing unaffected by sleep loss, while others demonstrated severe performance decrements (Van Dongen, Caldwell, & Caldwell, 2006).

This factor is typically not a topic of concern in sleep research, as the expectation is that it will be controlled for with random assignment within experimental protocols. Given that the current study is a naturalistic study however, there is a potential that differences in inter-individual “sleep hardiness” were not controlled for and may have resulted in the minimal cognitive performance and EEG findings. Specifically, sleep hardy individuals may have experienced little, if any, impact of sleep loss and as a result, chose to sleep shorter hours on a regular basis. Relatedly, sleep hardy individuals may also choose to engage in more daytime behaviors, such as work (i.e., part-time and full-
time), that may further interfere with their sleep schedule. Individuals may also differ in how efficiently they recover from poor sleep, which may be another indicator of “sleep hardiness.” Hence, future studies should consider measures of sleep hardiness, premorbid cognitive functioning, and EEG measures during recovery sleep, in order to address these issues.

As participants in the current study consisted of young adults who were undergraduates attending a four-year university, the majority of whom were Caucasian, age may be a factor to consider in future studies, particularly in relation to recovering from poor sleep. Specifically, future studies may consider examining the differences between younger, middle, and older adults’ recovery from poor sleep in relation to their cognitive performance and neurophysiological parameters. Furthermore, given the current study’s participant demographics, the findings from the current study may not generalize to a more diverse sample of young adults outside of college, who may demonstrate differing sleep habits and patterns, as well as neurobehavioral and neurophysiological profiles. Future studies should recruit more generally within the young adult population to further clarify the impact of sleep behaviors on these various constructs. Future studies may also consider examining the impact, if any, of phase shift related difficulties as a result of sleep habits engaged by these young adults (Brown et al., 2001). Furthermore, although data collection procedures were altered two-thirds of the way through the data collection period given extenuating circumstances and resource limitations, the small effect sizes resulting from EEG data (i.e., baseline partial eta squared = 0.007 and mock lecture partial eta squared = 0.017) indicated that further data
collection would not be warranted. Of note however, in addition to spectral power
analyses, future directions may include EEG tracings to identify microsleeps, which
consist of very short periods of “sleep” (Boyle, Trick, Johnsen, Roach, & Rubens, 2008).
Microsleeps have been found to occur concurrently with marked reduction in behavioral
responsiveness and are associated with sleepiness (Boyle et al., 2008; Moller, Kayumov,
Bulmash, Nhan, & Shapiro, 2006). Specifically, field studies utilizing the various
durations of microsleeps have demonstrated sleep intrusions during night work among
process operators (Torsvall & Akerstedt, 1987), and during power plant operations
(Gillberg, Kecklund, Göransson, & Åkerstedt, 2003). Microsleeps have also been shown
to be associated with poorer driving performance (Lal & Craig, 2002; Moller et al.,
2006). Despite being minimal in number, these studies have illustrated the possibility that
microsleeps do occur with sleep loss, are related to alertness and attention performance
variables, and may also be a means of measuring alertness during attention to tasks.

Given that the current study has demonstrated the potential for a successful model
of a naturalistic study, future studies may be able to build upon and further examine the
impact of good and poor sleep habits on self-reported attention, objective attention
performance, and neurophysiological measures of attentive activities.
References


doi:10.1016/0165-1781(89)90047-4


doi: 10.1016/S0022-3999(97)00298-5


doi:10.1016/S0167-8760(03)00168-5


Johns, M. W. (1994). Sleepiness in different situations measured by the epworth sleepiness scale. *Sleep: Journal of Sleep Research & Sleep Medicine, 17*(8), 703-710.


Lim, J., & Dinges, D. F. (2008). Sleep deprivation and vigilant attention. In D. W. Pfaff (Ed), & B. L. Kieffer (Ed) (Eds.), *Molecular and biophysical mechanisms of arousal, alertness, and attention.; annals of the new york academy of sciences.* (pp. 305; xi,-322; 372)


Thacher, P. V. (2008). University students and "the all-nighter": Correlates and patterns of students' engagement in a single night of total sleep deprivation. *Behavioral Sleep Medicine, 6*(1), 16-31. doi: 10.1080/15402000701796114


Appendix A

Definitions of Underlined Terms

1) Circadian rhythm (sleep urge in Figure 2): The circadian rhythm is like an internal clock that is not influenced by sleep, but rather environmental cues within a 24-hour time-frame, such as the light-dark cycle (Rama, Cho, & Kushida, 2006). Sleep onset occurs as the circadian drive for arousal decreases (i.e., environmental light decreases), and awakening occurs when the circadian drive for arousal increases. The circadian rhythm works in tandem, but in the opposite direction of sleep pressure (see item 2).

2) Sleep pressure (sleep need in Figure 2): Sleep pressure is the homeostatic sleep-promoting process that is dependent on sleep. Daytime wakefulness (i.e., not sleeping) increases sleep pressure to promote sleep, while night-time sleep decreases sleep pressure. Hence, sleep onset occurs at the peak of sleep pressure, which increases while awake during the daytime, and sleep pressure dissipates with sleep, resulting in awakening at the nadir of sleep pressure (Rama et al., 2006).

Figure 2. The trends of the circadian rhythm and sleep pressure across the day.
3) Lapsing: Lapsing is a behavior that is measured on the Psychomotor Vigilance Test based on the speed of an individual’s response to a stimulus (Pilcher & Huffcutt, 1996). A lapse is a measure of attention and is defined as a response from an individual taking longer than 500 ms to execute.

4) Power spectral analysis: Power spectral analysis is a well-established method of analyzing electroencephalograph (EEG) signals. Specifically, it is a way of examining tonic changes (i.e., more stable change over time) in neural networks via EEG across various frequency bands, such as theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz) and gamma (>30 Hz; Finelli, 2005).

5) Delayed Sleep Phase Syndrome: Delayed Sleep Phase Syndrome is a type of Circadian Rhythm Sleep Disorder that is characterized by a persistent pattern of late bedtimes, long sleep-onset latency, minimal difficulty maintaining sleep, and late awakenings (American Psychiatric Association, 2000).
Appendix B

Review of Psychometric Properties of Measures

Measures

Exclusion criteria: Session one self-reports. A 28-item symptom checklist was used to assess for exclusion criteria, namely: 1) excessive substance use (i.e., drink more than five alcoholic drinks four or more days per week, use drugs more than twice a month, smoke more than 15 cigarettes per day), 2) frequent nightmares (i.e., more than 4 times a week), 3) current experience of sleep disorders (i.e., narcolepsy, sleep-walking, sleep-talking, bed-wetting, night terrors), 4) a history of medical disorders, 5) current use of medications that affect sleep, 6) a history of neurological disorders, 7) a history of Attention Deficit Disorder or Attention Deficit Hyperactivity Disorder, and 8) elevated scores on any of the three sleep disorder screeners. If participants endorsed any of these exclusion criteria, they were excluded from the study.

The Berlin Questionnaire (Netzer et al., 1999) is a 12-item screener for the presence of sleep-disordered breathing. Overall risk of sleep apnea categorization (i.e., high versus low) are based on behaviors that have consistently predicted sleep-disordered breathing as determined at the Conference on Sleep in Primary Care in April 1996 (Netzer et al., 1999). The first group of symptoms pertain to snoring behavior (e.g., loudness, frequency); individuals are noted as high risk when frequency of occurrence in two or more of these questions are rated higher than 3 to 4 times per week (Netzer et al., 1999). The second cluster of symptoms relate to waketime sleepiness, feeling drowsy while driving, or both; similarly, individuals are noted as high risk when frequency of
occurrence are rated as more than 3 to 4 times per week (Netzer et al., 1999). Finally, the third cluster of symptoms assess for the presence of high blood pressure history or a body mass index of more than 30 kg/m$^2$; individuals are noted as high risk when either symptoms exist (Netzer et al., 1999). Overall categorization of “high risk” for sleep apnea occurs when individuals endorse high risk symptoms in at least two of the symptom clusters (Netzer et al., 1999). Categorization of individuals as “high risk” for sleep apnea with this measure has been found to be predictive of other physiological indicators of sleep apnea, such as a respiratory disturbance index (i.e., an index of sleep apnea severity) of greater than 5, indicating at least mildly severe sleep apnea. Prediction of sleep apnea with the Berlin Questionnaire occurs with a sensitivity of 0.86, a specificity of 0.77, a positive predictive value of 0.89, and a likelihood ratio of 3.79 (Netzer et al., 1999). Internal consistency of this questionnaire has also been demonstrated, with high Cronbach’s alpha correlations for respective subscales (i.e., snoring and apnea, sleepiness and fatigue, hypertension and obesity) ranging from 0.86 to 0.92 (Netzer et al., 1999). These Cronbach’s alpha values from other studies were based on at least a thousand individuals, including individuals with sleep disorders (Netzer et al., 1999).

The formation of the International Restless Legs Syndrome (RLS) Study Group in 1995 resulted in the development of standardized criteria for RLS (Walters, 1995). The criteria has since been modified during a RLS diagnosis and epidemiology workshop at the National Institutes of Health to better reflect new knowledge since then and to clarify the wording from the original criteria (Allen et al., 2003). As a result, the International Restless Legs Syndrome screening criteria (Gao et al., 2009) is a 4-item screener for the
presence of restless legs syndrome-specific symptoms and the frequency of these
symptoms. These screener items have been used in the Nurses’ Health Study II and the
Health Professionals Follow-up Study (Gao et al., 2009). These questions inquire about
specific RLS symptoms, the nature of the symptoms (i.e., rest and time-of-day), and
frequency of the symptoms. An individual is likely to experience restless legs syndrome
if the participant answered “yes” to all four questions. Although criterion validity data is
not available for this measure, it is based on clinical criteria for Restless Legs Syndrome
that have been agreed upon by the RLS Study group.

The Pittsburgh Sleep Quality Index (Buysse et al., 1989) is 9-item screener for the
presence of significantly disturbed sleep within the past month that is indicative of
disordered sleep. Item scores are added to yield seven “component” scores, namely
subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep
disturbances, use of sleeping medications, and daytime dysfunction (Buysse et al., 1989).
These seven “component” scores are then added to yield one global score (Buysse et al.,
1989). A global score of more than five distinguished normal sleepers from disordered
sleepers (i.e., individuals with depression and sleep disorders), with a sensitivity of
89.6% and specificity of 86.5% (Buysse et al., 1989), while distinguishing normal
sleepers from individuals with primary insomnia with sensitivity of 98.7% and specificity
of 84.4% (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002). Validity of this
instrument has been demonstrated as control participants and patient participants
significantly differed in their global scores (Buysse et al., 1989). Construct validity has
also been demonstrated with among four patient populations, namely bone marrow
transplant patients \((n = 5155)\), renal transplant patients \((n = 556)\), women with breast cancer \((n = 5102)\), and women with benign breast problems \((n = 5159\); Carpenter & Andrykowski, 1998). Specifically, convergent validity was demonstrated by moderate to high correlations with related symptoms, such as sleep problems as measured by the Symptom Experience Report and the Centers for Epidemiological Studies Depression Scale with rs ranging from .69 to .75 (Carpenter & Andrykowski, 1998). Discriminant validity was demonstrated with low correlations with unrelated constructs, such as nausea, and taste changes with rs ranging from .03 to .37 (Carpenter & Andrykowski, 1998). Internal consistency has also been demonstrated with an overall Cronbach’s alpha ranging from .83 to .85 (Backhaus et al., 2002; Buysse et al., 1989). Furthermore, test-retest reliability was demonstrated among normal sleepers as well as individuals with depression and sleep disorders, with no significant differences for individuals between time 1 and time 2 (averaging 28.2 days apart), while the time 1-to-time 2 correlation coefficient for the global score was 0.85, and correlation coefficients for component scores ranged from 0.65 to 0.84 (Buysse et al., 1989). Among normal sleepers and individuals with primary insomnia, similar ranges in correlations were found within 2 days (i.e., global score \(r = .90\), and subscores rs ranging from .76 to .92; Backhaus et al., 2002). Although lower test-retest reliability was found for two subscales over a longer duration (45.6 ± 18 days), namely ‘‘sleep quality’’ and ‘‘sleep disturbance’’ \((rs = .23 \text{ and } .27, \text{ respectively})\), test-retest reliability remained high for the global score \((rs = .86)\) and the other subscales \((rs = .71 \text{ to } .83; \text{ Backhaus et al., 2002})\).
Covariates: Session one self-reports.

Sleep quality. The Epsworth Sleepiness Scale (Johns, 1994) is an 8-item measure that conceptualizes and assesses sleepiness during the day as a trait (i.e., a steady and constant aspect of an individual; (Curcio, Casagrande, & Bertini, 2001). Specifically, the likelihood that an individual will fall asleep in low stimulating situations demonstrates a constant level of sleepiness independent of circadian or homeostatic rhythms (Johns, 1994). Items are rated on a 4-point Likert scale, ranging from 0 to 3, and summed to obtain a total score; higher total scores indicate higher levels of daytime sleepiness. The scale was validated by demonstrating significant differences between groups, and as a result distinguishing between healthy individuals and individuals with various sleep disorders (Johns, 1994). Scores on the measure are also significantly correlated with sleep latency as measured by the Multiple Sleep Latency Test and night-time polysomnography (Johns, 1994). Cronbach’s alpha was found to be 0.74 to 0.86 for 244 sleep disordered patients, and 0.75 for 87 healthy medical students (Johns, 1994).

The Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976) is a 19-item measure that assesses alertness upon awakening, and time-of-day preference for wake time, bed time, and physical and mental activity. Item scores are summed to obtain a total score used to categorize individuals as either morning types, neither types, or evening types. Construct validity was established by demonstrating group differences in bed and wake times, as well as preference for time-of-day. Specifically, although Morning and Evening individuals do not differ in sleep length, Morning individuals go to sleep and awaken significantly earlier than Evening types (Horne & Ostberg, 1976).
Furthermore, Morning individuals have also been found to prefer engaging in activities, while Evening individuals prefer later activity times (Schmidt et al., 2007). Convergent validity has also been established by demonstrating that groups differ, depending on the time-of-day that related measures, such as cognitive performance and body temperature, are tested (Horne & Ostberg, 1976; Schmidt, Collette, Cajochen, & Peigneux, 2007). Specifically, morning types have a significantly higher overall daytime temperature, earlier peak temperature time, and lower post-peak temperature when compared to evening types (Horne & Ostberg, 1976). Furthermore, morning individuals perform better earlier in the day, while Evening individuals perform best in the evenings (Schmidt et al., 2007). Individuals grouped based on these categories have also been found to demonstrate differences in sleep pressure throughout the day, as measured by electroencephalograph (Ehlers, Kupfer, Buysse, Cluss, Miewald, Bisson, et al., 1998; Kerkhof, 1991; Kerkhof & Lancel, 1991; Mongrain, Carrier, & Dumont, 2005; Taillard, Coste, Sagaspe, & Bioulac, 2003). When compared to Evening types, Morning types have demonstrated faster dissipation of sleep pressure (Kerkhof, 1991; Kerkhof & Lancel, 1991; Mongrain et al., 2005), higher sleep pressure at bedtime (Ehlers et al., 1998), and faster build up of homeostatic pressure during the daytime (Mongrain et al., 2005; Taillard et al., 2003). Two factors were found for this measure utilizing principal factors and varimax rotation, namely the Morning Type that explains 16.2% of the item variance, and the Evening Type that explains 11.2% of the item variance, cumulatively explaining 27.4% of the item variance (Smith, Reilly, & Midkiff, 1989). Test-retest reliability over a 3-month period was .88 (Larsen, 1985).
**Mood.** The Beck Depression Inventory – Version II (BDI-II; Beck et al., 1996) is a 21-item measure that assesses for the presence and severity of current symptoms of depression among individuals aged 13 years and older. The inventory has been constructed to reflect the criteria for diagnosing depressive disorders found in the DSM-IV. Participants select one of four statements that best reflects their experience of the particular mood or functioning item being assessed, during the past two weeks. Item scores are summed to yield a total score, with higher scores representing greater symptom severity. The BDI-II has been normed with large outpatient samples (N=500) and college students (N=120), and has demonstrated sound psychometric properties (Beck et al., 1996). The BDI-II has also demonstrated high internal consistency, with a Cronbach’s alpha of .92 for college students and .93 for outpatients (Beck et al., 1996). Meanwhile, test-retest reliability in a clinical sample for a one week period was .93 (Beck et al., 1996). Construct validity of the BDI-II has also been demonstrated with adequate correlations with other depressive rating scales, such as a .71 correlation with the Revised Hamilton Psychiatric Rating Scale (Beck et al., 1996). Discriminant validity has been established with studies demonstrating its abilities to differentiate between psychiatric and non-psychiatric populations, as well as poorer correlations (i.e., .47) with the Hamilton Rating Scale for Anxiety (Beck et al., 1996).

The Beck Anxiety Inventory (BAI; Beck, 1993) is a 21-item rating scale that assesses for the presence and severity of current symptoms of anxiety among individuals 17 and older. The measure was designed to reduce the overlap between depression and anxiety scales. Item scores are added to yield a total score, with higher scores
representing greater symptom severity. The BAI has been normed with outpatients from the Center for Cognitive Therapy in Philadelphia (N=1086), and has demonstrated sound psychometric properties (Beck, 1993). Specifically, in a mixed sample of outpatients and another sample of individuals diagnosed with anxiety disorders, the BAI revealed high internal reliability ranging from .92 to .94 (Beck, 1993). Test-retest reliability at a one-week interval was .75 (Beck, 1993). Concurrent validity was also demonstrated with moderate relationships with other anxiety scales, such as the Hamilton Anxiety Rating Scale-Revised and the State-Trait Anxiety Inventory, ranging from .47 to .58 (Beck, 1993).

**Covariates: Session one neuropsychological instruments.**

**Intelligence.** The Matrix Reasoning (MR) subtest from the Wechsler Abbreviated Scale of Intelligence (WASI) is a test of perceptual reasoning ability that was used to estimate general intelligence (The Psychological Corporation, 1999). MR consists of a series of increasingly complex colored patterns that have a component part missing. Participants selected one of five possible component choices that best completes the matrix. The MR subtest was normed on an adult sample and has demonstrated acceptable reliability and validity, with an internal reliability coefficient for individuals aged 20-24 at 0.88, while the test-retest reliability coefficient for the 17-54 age group is 0.72 (The Psychological Corporation, 1999).

**Variables of interest: Session one self-reports.**

**Attention.** The Conners Adult ADHD Rating Scales (CAARS; Conners et al., 1999) is a 66-item measure that assesses for the presence of ADHD related symptoms
and behaviors. Scores from these 66 items are delineated into nine subscales: 1) The four factor-derived scales are Inattention/Memory Problems, Hyperactivity/Restlessness, Impulsivity/Emotional Lability, and Problems with Self-Concept, 2) the three ADHD symptom specific subscales based on DSM-IV criteria are Inattentive Symptoms, Hyperactive-Impulsive Symptoms, and Total ADHD Symptoms, 3) and the final two subscales are the ADHD Index, which allows for distinguishing individuals with ADHD from non-clinical individuals, and the Inconsistency Index, which allows for the identification of individuals who respond in a random or careless manner (Conners et al., 1999). This measure is suitable for individuals 18 years and older, and has been normed with large community-based samples of nonclinical adults (N=1026); notably, the DSM-IV ADHD symptom subscales which were developed later had a smaller normative sample of 226 individuals (Conners et al., 1999). The confirmatory factor analysis of the four-factor structure met the criteria standards for good fit (i.e., Goodness of Fit of .979, Adjusted Goodness of Fit of .977, Non-Normed Fit Index of .983, and Confirmatory Fit index of .984), regardless of the individuals’ sex and age (Conners et al., 1999). Discriminant validity has also been demonstrated as individuals with ADHD scored significantly higher than controls on the four factor-derived scales, with a correct classification rate of 73%, while the ADHD index demonstrated sensitivity of 71%, specificity of 75%, and correct classification rate of 73% (Conners et al., 1999). Among individuals aged 18-29 years who completed the measure, Cronbach’s alpha for the factor derived Inattention/ Memory Problems subscale was 0.89, and ranged from 0.81 to 0.84 for the DSM-IV criteria based Inattentive Symptoms subscale (Conners et al., 1999).
Variables of interest: Week prior to session two.

*Sleep diaries.* Participants completed a sleep-wake diary twice each day, one week prior to the second experiment session; once before sleep and once upon awakening in the morning. Recordings before bedtime included daytime parameters (i.e., planned and unplanned naps, caffeinated and alcoholic drinks, cigarettes smoked), while recordings upon awakening included information about the previous night’s sleep (i.e., bed and wake time, sleep duration, and awakenings). Participants were provided a reminder call the day of the diary start date in order to increase adherence. Similarly, participants were asked to call by 5:00 PM daily to provide their wake-up time, bedtime, sleep latency, and night-time awakenings, in order to increase adherence. If participants failed to call, experimenters followed-up with participants sometime in the afternoon or the evening that same day.

**Covariates: Session two self-reports.**

*Personal demographics questionnaire.* Participants completed a personal demographics questionnaire assessing Hispanic or Latino heritage, racial self-identification, relationship status, and experiment day health behaviors (i.e., last meal, last caffeinated beverage, and last cigarette). The experiment day health behaviors items allowed for checking participants’ compliance to experimental day preparation instructions.

*Sleep quality.* The Adult Sleep-Wake Scale (Fortunato, LeBourgeois, & Harsh, 2008) is a 25-item inventory measuring perceived sleep quality among adults that has been psychometrically examined in college samples. The measure consists of scores for
five subscales—nighttime re-initiation of sleep, returning to wakefulness, bedtime sleep need/habits, nighttime awakenings, sleep latency—and a total score. Higher scores for each subscale and total score are indicative of better sleep quality. Utilizing the five-factor solution over two studies, the Adult Sleep-Wake Scale was established as one that is composed of five factors, with substantial amounts of item variance accounted for (i.e., cumulatively explained between 66-73% of item variance where Reinitiating Sleep explained between 32.61%-36.99%, Returning to Wakefulness explained between 14.05%-19.83%, Going to Bed explained between 7.08%-9.02%, Falling Asleep explained between 4.96%-6.69%, and Maintaining Sleep explained between 4.21%-5.06%; Fortunato, LeBourgeois, & Harsh, 2008). Construct validity was demonstrated by examining convergent and discriminant validity with two dispositional constructs (i.e., positive and negative affect), three stress-related constructs (i.e., interpersonal conflict, workload, and job ambiguity), and three strain-related constructs (i.e., depression, health complaints, and frustration). Specifically, as predicted, scores of negative affect, stressors and strain variables related negatively to the sleep quality scores, while positive affect scores related positively to sleep quality scores (Fortunato et al., 2008). The sleep quality subscales also correlated positively with one another with correlation coefficients ranging from .08 to .61, while coefficient alphas ranged from .83 to .90 for the five subscales (Fortunato et al., 2008). Furthermore, test-retest reliability coefficients over five and ten weeks ranged from .67 to .82.

**Sleepiness and tiredness.** The Sleepiness and Tiredness Visual Analogue Scale (VAS) is a 2-item analogue scale assessing for state sleepiness and tiredness. The VAS
score for each item allows for a continuum of responses, which may be more sensitive when measuring nonpathological levels of subjective sleepiness, and has been shown to be sensitive to partial or total sleep deprivation (Monk, 1987). Lower scores on the sleepiness and tiredness scale represent more sleepiness and tiredness.

**Mood.** The Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) is a 20-item checklist that assesses positive and negative state affect (i.e., current, momentary mood) that has been psychometrically tested with college students. The Positive and Negative Affect Schedule was demonstrated to be comprised of two factors, using principal factor analyses, with a cumulative variance ranging from 87.4% to 96.1% (Watson et al., 1988). These two factors comprise of positive affect (e.g., enthusiasm, alertness) and negative affect (e.g., anger, guilt). Convergent and discriminant validity was also demonstrated by comparisons with other mood measures with expected results where similar affective valence measures demonstrated high correlations while dissimilar affective valence measures demonstrated low correlations, respectively (Watson et al., 1988). For example, perceived stress was also more strongly correlated with Negative Affect than Positive Affect, while social activity was more related to Positive Affect than Negative Affect (Watson et al., 1988). The mood subscales were also found to be uncorrelated with one another (Watson et al., 1988). The PANAS has demonstrated good internal consistency across clinical and non-clinical samples, with coefficient alpha values ranging from 0.84 to 0.90 for the two subscales (e.g., Crawford & Henry, 2004; Watson et al., 1988). Furthermore, the measure is able to detect mood
fluctuations when used with short term instructions such as right now, while longer term instructions such as the past year generate more traitlike responses (Watson et al., 1988).

**Variables of interest: Session two neuropsychological instruments.**

**Vigilance.** The Psychomotor Vigilance Test is a simple reaction time test designed to examine vigilant attention and has been a marker of attentional deficits within the sleep literature (Lim & Dinges, 2008). The standard task consists of reacting to a cue (i.e., a counter that appears on a small, rectangular area on a dark screen) that occurs at random inter-stimulus intervals of 2 to 10 seconds, by pressing a button. The total task duration is 10 minutes (Lim & Dinges, 2008). Some modified versions of the test have had participants respond to a target image, rather than a counter, with task duration of 5 minutes (e.g., Killgore et al., 2009). Most studies utilize the number of lapses (typically defined as responses greater than 500 ms) as the primary dependent variable, with other accompanying variables such as mean reaction time, errors of commission, and variability in reaction time (Lim & Dinges, 2008). Convergent validity for this task has been demonstrated through its sensitivity to both total and chronic partial sleep deprivation, and intervention with psychoactive and wake-promoting drugs (Lim & Dinges, 2008).

The current study utilized the PEBL Psychological Test Battery’s version of the Psychomotor Vigilance Test, which they named Psychomotor Vigilance Task (Mueller, 2008). Just like the Psychomotor Vigilance Test, the Psychomotor Vigilance Task by PEBL (Mueller, 2008) is composed of a target image (i.e., a red circle) that appears on an area of a dark screen, at random inter-stimulus intervals of 1 to 10 seconds. Participants
were asked to react to the stimulus as fast as possible by pressing the space bar on the keyboard, with total task duration of 10 minutes. Feedback on reaction time was provided to participants.

**Sustained attention.** The Test of Variables of Attention (TOVA) is a continuous performance test that measures sustained attention in neuropsychological evaluation screens for attentional disorders (Strauss et al., 2005). Continuous performance tests are frequently used to obtain quantitative information about an individual’s ability to sustain attention over time (Riccio, Reynolds, Lowe, & Moore, 2002). The TOVA specifically, is one of the longest commercially available continuous performance tasks, and its strengths lie in its nonverbal format, its minimal need for other complex cognitive processes as it is a very simple discrimination task, and short inter-stimulus presentations (Straus et al., 2005). The TOVA has been found to consist of three factors, namely response time (i.e., reaction time, and reaction time variability), errors of commission, and errors of omission. Although minimal convergent data currently exists,—no published data has compared the test with other continuous performance tests—an unpublished study described the accurate identification of 90% of children with attention deficit hyperactivity disorder with this test (Strauss et al., 2005). Furthermore, as with most continuous performance tests, although the test’s correlations with self-reported ADHD rating scales are not high, the test’s ADHD score was found to be highly concordant with the Diagnostic and Statistical Manual of Mental Disorders 4th edition criteria for ADHD and with physician based diagnosis (Strauss et al., 2005). Correlational analyses examining internal consistency for the visual test for reaction time, reaction time
variability and omissions were moderate to high (range of .75 to .88), while commissions and $d'$ (i.e., errors of omission and commission) were less optimal (range of .57 to .60; Straus et al., 2005).

The current study utilized the PEBL Psychological Test Battery’s version of the Test of Variables of Attention, which they named the Test of Attentional Vigilance (Mueller, 2008). Just like the Test of Variables of attention, the Test of Attentional Vigilance by PEBL (Mueller, 2008) is composed of two simple geometric forms presented for 100 milliseconds every 2 seconds for 22.5 minutes. However, instead of being displayed at four intervals, the test by PEBL displayed the geometric forms in two intervals; the target (one of the two forms) appears on 22.5% of the trials during the first interval (stimulus infrequent condition), while appearing 77.5% during the second interval (stimulus frequent condition). Just like the Test of Variables of Attention (Strauss et al., 2005), the test by PEBL also loads on sustained attention, eliciting errors of omission during the first half of the test, while loading on inhibitory control during the second half, eliciting errors of commission.

**Variables of interest: Session two neurophysiological measure.**

*Electroencephalograph during an attention task.* Electroencephalograph (EEG) measures have been used extensively to examine neural network activation while performing various sustained attention tasks (e.g., Corsi-Cabrera, Snchez, del-Ro-Portilla, Villanueva, & Prez-Garci, 2003), including simulated driving tasks (e.g., Boyle et al., 2008). The sleep literature has also adopted this technique as a means of exploring changes in brain activation resulting from sleep deprivation (e.g., Corsi-Cabrera et al., 1992) as well as during sustained attention tasks with sleep loss (e.g., Corsi-Cabrera et
al., 1996). Furthermore, drowsiness (i.e., awake-sleep transition) is also relevant to changes in alertness and sustained attention, and therefore has been found to be associated with well-established EEG changes (Rechtschaffen & Kales, 1968; Santamaria & Chiappa, 1987). Normal human EEG while awake lies between 0.1 Hz and 100 Hz (Finelli, 2005). Various frequency bands within the normal waking EEG have been delineated within the literature, with the most common being theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (>30 Hz; Finelli, 2005). Changes to these EEG rhythms have been examined in two forms, namely phasic and tonic changes (Klimesch, 1999). Phasic changes are examined as event-related potentials (i.e., change in specific EEG bands), before, during and after a specific stimulus onset, while tonic changes are more stable and reflective of traits that change more slowly over time as examined with power spectral analyses (Klimesch, 1999). Eye activity is also commonly measured when EEG activity is a variable of interest because it needs to be controlled for within EEG data, but is also a measure of wakefulness (Pivik, 2000). Specifically, eye activity demonstrates less horizontal eye movement, decreased blink amplitude, and increased blink duration with decreased wakefulness (Pivik, 2000).

Specific to the analyses of interest in the current study, spectral power analyses have been used to examine neural activation across time while performing various sustained attention tasks (e.g., Loo et al., 2009), including simulated driving tasks (e.g., Boyle, Tippin, Paul, & Rizzo, 2008). Although there are multiple bands within the EEG, theta (i.e., brain waves at 4 to 8 Hz) and alpha (i.e., brain waves at 8 to 12 Hz) markers have been demonstrated to be consistently related to drowsiness, early stages of sleep,
and sustained attention performance (Oken et al., 2006). Specifically, decreased alertness is typically associated with increased alpha wave activity when the individual’s eyes are open (e.g., during a vigilance task) and decreased alpha wave activity when the individual’s eyes are closed (e.g., early stages of sleep; Oken et al., 2006). Meanwhile, increased theta wave activity is typically associated with increased drowsiness across both situations (Oken et al., 2006). Hence, when measuring sustained attention performance in a sleep deprived person, one may expect increased alpha and theta activity across time, demonstrating increased sleepiness and/or poorer vigilance. The attenuation of alpha activity however, may be expected with the corresponding increase in theta activity when eyes begin to close due to early through Stage 1 sleep as the task progresses. Across various studies conducted by Makeig and colleagues, within-subject correlation between increases in theta activity was consistently demonstrated while participants performed a vigilance task, indicating increasing drowsiness with task progression (Makeig & Inlow, 1993; Makeig & Jung, 1995; Makeig & Jung, 1996). These findings are further bolstered by those found from naturalistic studies, in which progressive slowing of the EEG occurs (i.e., increase in theta power, with a corresponding decrease in alpha power) as the sleep deprived individual falls asleep (e.g., Torsvall & Akerstedt, 1988).

Both EEG and EOG data were recorded using an MP100 System (Biopac, Inc) interfaced with a Dell Optiplex computer running AcqKnowledge v 4.1 with a sampling rate of 500 samples per second. EEG100 amplifiers from Biopac, Inc were used to amplify the EEG signal, and the data was stored to the hard drive of the Dell Optiplex.
Two of the 20 Ag/AgCl surface electrodes that were embedded in an electrode cap (ElectroCap, Eaton, OH) in the International 10/20 system (Klem et al., 1999) were referenced to the right earlobe. Specifically, a 2-channel monopolar montage was recorded from a frontal scalp site (i.e., Fz) and a posterior scalp site (i.e., Pz), referenced at A2, and grounded at A1 (Klem et al., 1999). All EEG electrode sites were prepped with abrasive pads, PDI electrode prep pads (i.e., pads containing 70% alcohol with pumice), and Nuprep EEG skin prep gel. EOG was also recorded to monitor eye movement artifacts and to allow for offline artifact rejection. EOG electrode sites were prepped with abrasive pads, and PDI electrode prep pads. Surface Ag-AgCl electrodes were attached to the sites using disposable self-adhesive electrode collars and electrode gel. Specifically, the electrodes were placed above and below the left eye, and at the left and right outer canthus. For both EEG and EOG, impedance of less than 30 kΩ was ensured, and a 60-Hz notch data filter was employed to minimize the 60-cycle interference, while gain settings were set at 10000K and 2000K, respectively.
Appendix B1: Informed Consent

Ohio University Consent to Participate in a Research Study
Title of Research: The Effect of Sleep on Attention and Other Cognitive Skills
Researchers: Huey Mei Ng & Julie A. Suhr, Ph.D.
Department: Psychology

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form. You should receive a copy of this document to take with you.

Explanation of Study
Purpose of the research: The purpose of this research is to examine how an individual’s sleep habits influences performance on attention and other cognitive skills.

Procedures to be followed: To be eligible to participate, you must:
- be between the ages of 18 and 23
- not currently experiencing sleep difficulties (like sleep apnea, restless legs syndrome, narcolepsy, sleep-walking, sleep-talking, bed-wetting, and night terrors)
- not be experiencing nightmares more than 4 times per week
- not be drinking more than five alcoholic drinks, four or more days per week
- not be using drugs more than twice a month
- not be smoking more than 15 cigarettes per day
- have no history of ADHD
- have no significant neurological history
- not be taking any medications that affect sleep
- and be generally in good health

If you choose to participate, you will be attending two sessions, at least one week apart, and completing sleep diaries over a week.

Orientation Session
During this session, if you choose to participate, you will complete some questionnaires, and engage in two cognitive tasks. You will also be provided with sleep diaries to take with you to complete at home, once before bed and once upon awakening. You will be asked to bring these back with you to the second study session. We will also provide instructions on how to prepare for the next session.

Sleep Diaries
Over the span of a week prior to your scheduled study session, you will be asked to complete a sleep diary for 7 days, once before bed and once upon awakening. You will also be asked to call to the laboratory to leave 4 pieces of information from your sleep diaries in the morning.
Study Session
In preparation for the study session, you should not have taken any medications that affect sleep, such as antihistamines (e.g., Benadryl) or antidepressants (e.g., Celexa). We also ask that you wake-up by 10 AM on the day of the study, refrain from drinking caffeine and smoking 5 hours prior to the session, and drinking alcohol and ingesting drugs 24 hours prior to the study session. If you choose to participate in this session, electro-encephalogram (EEG; a measure of brain waves) and electro-oculogram (EOG; a measure of eye movement) measures will be recorded during parts of the experiment. When you arrive for the session, we will collect the sleep diaries that you completed and brought with you. You will then be asked to complete some questionnaires, after which we will place two 4-mm silver electrodes above and below your left eye, and two 4-mm silver electrodes lateral of your left and right eye. Then, an electrode cap will be placed on your head. After electrode placements, you will engage in three cognitive tasks, followed by a last set of questionnaires.

Duration of participation: The total time for the orientation is 1 hours, and the total time for the study session is 3 hours.

Risks and Discomforts
There is minimal risk associated with the EEG and EOG assessment procedures. You may experience some discomfort during the placement of the electrode cap and during removal of the 4-mm silver electrodes; the experimenter will use care when placing and removing all electrodes.

Benefits
You will learn about research in sleep and attentional performance as well as existing knowledge regarding associations among these constructs. This research will improve our understanding about sleep and its impact on cognitive performance, specifically that of attentional processes. You will also see how physiological measurement equipment (EEG, EOG) is used in psychological research.

Confidentiality and Records
All information and data collected from you, including completed questionnaires and physiological data, will be identifiable only by a numeric code; no identifying information will be tied to the raw data. All of your information obtained from this research will be kept strictly confidential and maintained in locked files, accessible only to the Principle Investigator. However, if the data resulting from this study are published, members of the scientific community are, in accordance with policies of several government and scientific agencies (including the National Institutes of Health), privy to the computer version of the data. Again, there would be no identifying information in this version of the data and the Primary Investigator will keep the copies of the raw data. Your name will be in no way tied to these data.
**Compensation**
You will be compensated a total of 5 credit hours, if you complete all sections of the study, to fulfill research requirements as part of the Introductory Psychology class or to receive extra credit for other classes offering research credits. Credit for each section is as follows: 1 credit for the 1 hour information session, 1 credit for the return of the sleep diaries, and 3 credits for the 3 hour experiment session. Additionally, you will be paid $10 for the 3 hour experiment session. You will be compensated based on the sections you complete. You may withdraw at any time without penalty.

**Contact Information**
If you have any questions regarding this study, please contact Huey Mei Ng, email: hn260604@ohio.edu, phone number: 590-4952 or Dr. Suhr, email: suhr@ohio.edu, phone number: 593-1091.

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

By signing below, you are agreeing that:
- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions
- known risks to you have been explained to your satisfaction.
- you understand Ohio University has no policy or plan to pay for any injuries you might receive as a result of participating in this research protocol
- you are 18 years of age or older
- your participation in this research is given voluntarily
- you may change your mind and stop participation at any time without penalty or loss of any benefits to which you may otherwise be entitled.

Signature_________________________________________ Date_____

Printed Name__________________________________________
Appendix B2: Health Questionnaire

Please respond to the questions below as accurately as you can. All of your responses are completely confidential and will be identified only by your participant ID number.

1. What is your age? ____

2. Are you currently being treated for rheumatoid arthritis?
   Yes ___________  No ___________

3. Are you currently being treated for asthma?
   Yes ___________  No ___________

4. Are you currently being treated for heart trouble?
   Yes ___________  No ___________

5. Are you currently being treated for high blood pressure?
   Yes ___________  No ___________

6. Are you currently being treated for diabetes?
   Yes ___________  No ___________

7. Are you currently being treated for cancer?
   Yes ___________  No ___________

8. Did you have cancer within the past 5 years?
   Yes ___________  No ___________

9. Do you have thyroid problems?
   Yes ___________  No ___________

10. Are you currently being treated for other chronic physical health concerns not indicated in Questions 2-9?
    Yes ___________  No ___________

11. If yes to Question 14, please indicate physical health concern being treated:
    _____________________________________________________________________

12. Do you drink more than five alcoholic drinks, four or more days per week?
    Yes ___________  No ___________

13. Do you use recreational drugs (e.g., marijuana) more than twice a month?
    Yes ___________  No ___________
14. Do you smoke more than 15 cigarettes a day?
Yes ___________  No ___________

15. Do you have frequent nightmares (i.e., more than 4 times a week)?
Yes ___________  No ___________

16. Are you currently diagnosed with narcolepsy?
Yes ___________  No ___________

17. Are you currently sleep-walking and/or sleep-talking?
Yes ___________  No ___________

18. Are you currently experiencing bed-wetting, during sleep?
Yes ___________  No ___________

19. Are you currently experiencing night terrors (i.e., experience of extreme terror and temporary inability to awaken that is usually not a result of a bad dream, and accompanied by screaming or confusion)?
Yes ___________  No ___________

20. To the best of your knowledge, have you ever been diagnosed with any neurological illnesses (e.g., seizures, brain tumor, stroke)?
Yes ___________  No ___________

21. Have you ever experienced a head injury resulting in loss of consciousness for > 30 minutes?
Yes ___________  No ___________

22. Have you ever been diagnosed with Attention Deficit Disorder (ADD) or Attention Deficit/ Hyperactivity Disorder (ADHD)?
Yes ___________  No ___________

23. Are you currently being treated for depression?
Yes ___________  No ___________

24. Are you currently being treated for bipolar disorder?
Yes ___________  No ___________

25. Are you currently being treated for other chronic mental health concerns not indicated in Questions 19-20?
Yes ___________  No ___________

26. If yes to Question 21, please indicate mental health concern being treated:
________________________________________________________________________
27. Are you currently taking any prescribed medications that affect sleep or sleepiness (e.g., antihistamines and antidepressants)?
   Yes ___________  No ___________

28. Please list all medications you are currently taking on a daily basis:

________________________________________________________________________
Appendix B3: Berlin Questionnaire

Instructions: Please respond to the questions below as accurately as you can. All of your responses are completely confidential and will be identified only by your participant ID number. As with all of the information we will collect today, your name and identity will not in any way be tied to your responses. Please answer all questions.

1. What is your current height (inches)? ____________

2. What is your current weight (lbs)? ____________

3. Has your weight changed?
   _____ Increased
   _____ Decreased
   _____ No change

4. Do you snore?
   _____ Yes
   _____ No
   _____ Do not know

   If you chose “Yes” for question 4 please answer questions 5-8. If not, please go to question 9 (next page).

5. How loud do you snore?
   _____ Loud as breathing
   _____ Loud as talking
   _____ Louder than talking
   _____ Very loud

6. How often do you snore?
   _____ Almost every day
   _____ 3-4 times/week
   _____ 1-2 times/week
   _____ 1-2 times/month
   _____ Never/almost never

7. Does your snoring bother other people?
   _____ Yes
   _____ No
8. How often have your breathing pauses been noticed?
   ______ Almost every day
   ______ 3-4 times/week
   ______ 1-2 times/week
   ______ 1-2 times/month
   ______ Never/almost never

9. Are you tired after sleeping?
   ______ Almost every day
   ______ 3-4 times/week
   ______ 1-2 times/week
   ______ 1-2 times/month
   ______ Never/almost never

10. Are you tired during waketime?
    ______ Almost every day
    ______ 3-4 times/week
    ______ 1-2 times/week
    ______ 1-2 times/month
    ______ Never/almost never

11. Have you ever fallen asleep while driving?
    ______ Yes
        ______ No

12. Do you have high blood pressure?
    ______ Yes
        ______ No
        ______ Do not know
Appendix B4: International Restless Legs Syndrome Screening Criteria

_Instructions:_ Please respond to the questions below as accurately as you can. All of your responses are completely confidential and will be identified only by your participant ID number. As with all of the information we will collect today, your name and identity will not in any way be tied to your responses. Please answer all questions.

1. Do you have unpleasant leg sensations (like crawling, paraesthesia, or pain) combined with motor restlessness and an urge to move?
   Yes ___________  No ___________

2. If yes to question 1, do these symptoms occur ≥ 5 times/month?
   Yes ___________  No ___________

3. If yes to question 1, do these symptoms occur only at rest and does moving improve them?
   Yes ___________  No ___________

4. If yes to question 1, are these symptoms worse in the evening/night compared with the morning?
   Yes ___________  No ___________
### Appendix B5: Pittsburgh Sleep Quality Index

*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**, when have you usually gone to bed (what time)? ________ PM/AM
2. During the **past month**, how long *(in minutes)* has it taken you to fall asleep each night? ________
3. During the **past month**, when have you usually gotten up in the morning (what time)? ________ PM/AM
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 spend in bed) ________
5. For this next question, please put a check in the box that best describes how you have slept in the past month

<table>
<thead>
<tr>
<th>During the past month, how often have you had trouble sleeping because you...</th>
<th>Not during the past month</th>
<th>Less than once a week</th>
<th>Once or twice a week</th>
<th>Three or more times a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cannot get to sleep within 30 minutes</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>b. Wake up in the middle of the night or early morning</td>
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<td></td>
<td></td>
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<tr>
<td>c. Have to get up to use the bathroom</td>
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<td></td>
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</tr>
<tr>
<td>d. Cannot breathe comfortably</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Cough or snore loudly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Feel too cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>g. Feel too hot</td>
<td></td>
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<td></td>
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<tr>
<td>h. Have bad dreams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Have pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j. Other reason(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** If in 5j, you indicated other reason(s), **please describe:**

__________________________________________________________________
For Questions 6-8, please put a check in the box that best describes how you have slept in the past month

<table>
<thead>
<tr>
<th>During the past month...</th>
<th>Not during the past month</th>
<th>Less than once a week</th>
<th>Once or twice a week</th>
<th>Three or more times a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. …how often have you taken medicine (prescribed or “over the counter”) to help you sleep?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. …how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. …how much of a problem has it been for you to keep up enthusiasm to get things done?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. During the past month, how would you rate your sleep quality overall?
   Very good _____  Fairly good _______  Fairly bad _______
   Very bad ______
**Appendix B6: Epsworth Sleepiness Scale**

How likely would you 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 the things recently, try to work out how they would have affected you. Please circle your response using the following scale to choose the most appropriate number for each situation:

0 = would **never** doze  
1 = **slight** chance of dozing  
2 = **moderate** chance of dozing  
3 = **high** chance of dozing

<table>
<thead>
<tr>
<th>Situation</th>
<th>Chance of Dozing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
</tr>
<tr>
<td>Sitting and reading</td>
<td>0</td>
</tr>
<tr>
<td>Watching TV</td>
<td>0</td>
</tr>
<tr>
<td>Sitting inactive, in a public place (e.g., theater or meeting)</td>
<td>0</td>
</tr>
<tr>
<td>As a passenger in a car for an hour without a break</td>
<td>0</td>
</tr>
<tr>
<td>Lying down to rest in the afternoon when circumstances permit</td>
<td>0</td>
</tr>
<tr>
<td>Sitting and talking to someone</td>
<td>0</td>
</tr>
<tr>
<td>Sitting quietly after a lunch without alcohol</td>
<td>0</td>
</tr>
<tr>
<td>In a car, while stopped for a few minutes in traffic</td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix B7: Morningness-Eveningness Questionnaire

Instructions: Please read each question carefully and answer all questions in numerical order. Each question should be answered independently of others. Do NOT go back and check your answers. All questions have a selection of answers. For each question place a cross for ONE answer only. Some questions have a scale instead of a selection of answers. Place a cross at the appropriate point along the scale. Please answer each question as honestly as possible. All of your responses are completely confidential and will be identified only by your participant ID number.

1. Considering only your own “feeling best” rhythm, at what time would you get up if you were entirely free to plan your day?

2. Considering only your own “feeling best” rhythm, at what time would you go to bed if you were entirely free to plan your evening?

3. If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by an alarm clock?

4. Assuming adequate environmental conditions, how easy do you find getting up in the mornings?

5. How alert do you feel during the first half hour after having woken in the mornings?

6. How is your appetite during the first half-hour after having woken in the mornings?
7. During the first half-hour after having woken in the morning, how tired do you feel?  

- Very tired
- Fairly tired
- Fairly refreshed
- Very refreshed

8. When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?  

- Seldom or never later
- Less than one hour later
- 1 to 2 hours later
- More than two hours later

9. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 7:00 – 8:00 AM. Bearing in mind nothing else but your own “feeling best” rhythm, how do you think you would perform?  

- Would be on good form
- Would be on reasonable form
- Would find it difficult
- Would find it very difficult

10. At what time in the evening do you feel tired and as a result in need of sleep?  

<table>
<thead>
<tr>
<th>Time</th>
<th>Tiredness Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 PM</td>
<td>Not at all tired</td>
</tr>
<tr>
<td>9 PM</td>
<td>A little tired</td>
</tr>
<tr>
<td>10 PM</td>
<td>Fairly tired</td>
</tr>
<tr>
<td>11 PM</td>
<td>Very tired</td>
</tr>
</tbody>
</table>

11. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own “feeling best” rhythm which ONE of the four testing times would you choose?  

- 8:00 – 10:00 AM
- 11:00 AM – 1:00 PM
- 3:00 – 5:00 PM
- 7:00 – 9:00 PM

12. If you went to bed at 11:00 PM at what level of tiredness would you be?  

- Not at all tired
- A little tired
- Fairly tired
- Very tired

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following events are you most likely to experience?  

- Will wake up at usual time and will NOT fall asleep
- Will wake up at usual time and will doze thereafter
- Will wake up at usual time but will fall asleep again
- Will NOT wake up until later than usual
14. One night you have to remain awake between 4:00 – 6:00 AM in order to carry out a night watch. You have no commitments the next day. Which ONE of the following alternatives will suit you best?

- Would NOT go to bed until watch was over
- Would take a nap before and sleep after
- Would take a good sleep before and nap after
- Would take ALL sleep before watch

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own “feeling best” rhythm which ONE of the following times would you choose?

- 8:00 – 10:00 AM
- 11:00 – 1:00 AM
- 3:00 – 5:00 PM
- 7:00 – 9:00 PM

16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10:00 – 11:00 PM. Bearing in mind nothing else but your own “feeling best” rhythm how well do you think you would perform?

- Would be on good form
- Would be on reasonable form
- Would find it difficult
- Would find it very difficult

17. Suppose that you can choose your own work hours. Assume that you worked a FIVE hour day (including breaks) and that your job was interesting and paid by results. Which FIVE CONSECUTIVE HOURS would you select?

18. At what time of the day do you think that you reach your “feeling best” peak?

19. One hears about “morning” and “evening” types of people. Which ONE of these types do you consider yourself to be?

- Definitely a “morning” type
- Rather more a “morning” than an “evening” type
- Rather more an “evening” than a “morning” type
- Definitely an “evening” type
Appendix B8: Sample Sleep Diary

DAY 1

Date/Day:

**Bedtime diary**

How many planned naps did you take today? __________
How long (total time) did you spend napping today (minutes)? __________
How many times did you accidentally fall asleep today (unplanned naps)? __________
How long (total time) was your unplanned nap(s) (minutes)? ________________

Have you had any caffeinated beverages today?
Yes ________ No ________
If yes, please indicate the number of drinks (cups) for each type:
Coffee : __________
Tea : __________
Soda : __________

Have you had any alcoholic beverages today?
Yes ________ No ________
If yes, please indicate the number of drinks for each type:
Beer : __________
Liquor : __________

Have you had any cigarettes today?
Yes ________ No ________
If yes, please indicate the number of cigarettes: _____

**Morning diary**

**What time did you get into bed? ____________ AM/PM

** What time did you wake up? ____________ AM/PM

**How long did it take you to fall asleep last night (minutes)? ____________

How many times do you remember waking up last night? ____________

**How long (total time) were you awake when you woke up last night (minutes)?
______________

Please rate your sleep quality:

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Very poor          Very good

[Please relate the four pieces of information as indicated by ** from the morning diary during your daily phone call to 740-590-4952]
Appendix B9: Personal Demographics Questionnaire

Please respond to the questions below as accurately as you can. All of your responses are completely confidential and will be identified only by your participant ID number. As with all of the information we will collect today, your name and identity will not in any way be tied to your responses.

1. Are you Hispanic or Latino?:
   Yes______  No_____

2. Which of the following would you say is your race? (Please mark all that apply):
   ______ White
   ______ Black or African American
   ______ Asian
   ______ Native Hawaiian or other Pacific Islander
   ______ American Indian, Alaska Native
   ______ Other: Please specify: ________________________________________________
   ______ Don’t know/Not sure

   If you chose more than one option above, please answer question 2a. If not, please go to question 3.

2a. Which of these groups would you say best represents your race? (Please mark only one response):
   ______ White
   ______ Black or African American
   ______ Asian
   ______ Native Hawaiian or other Pacific Islander
   ______ American Indian, Alaska Native
   ______ Other: Please specify: ________________________________________________
   ______ Don’t know/Not sure

3. What time did you wake-up today?
   ___:___ am/pm

4. When was the last time you had anything to eat? Please indicate the time and date:
   ___:___ am/pm ..... date: _____________________

5. When was the last time you had any alcohol? Please indicate the time and date:
   ___:___ am/pm ..... date: _____________________

6. When was the last time you consumed any drugs (i.e., medications, recreational)? Please indicate the time and date:
   ___:___ am/pm ..... date: _____________________
   what consumed: ________________________
7. Have you had any caffeinated beverages (i.e., coffee, tea, soda) today?
   Yes_______   No________
   If Yes, what time did you consume your last caffeinated beverage?
   ___:___ am/pm

8. Have you had any cigarettes today? Yes_______   No________
   If Yes, what time did you last smoke?
   ___:___ am/pm
Appendix B10: Adult Sleep-Wake Scale

*Instructions*: The following statements relate to your sleep habits in general. Your answer should be one that is most representative or reflective of your sleep patterns. Please answer all questions by placing a check in the box that best describes your sleep patterns.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Never</th>
<th>Once in a while</th>
<th>Sometimes</th>
<th>Quite often</th>
<th>Frequently, but not always</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. After waking up during the night, I drift back off to sleep easily.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. After waking up during the night, I roll over and go right back to sleep.</td>
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<td></td>
<td></td>
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<tr>
<td>3. After waking up during the night, I have a hard time going back to sleep.</td>
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<td></td>
</tr>
<tr>
<td>4. How long does it usually take you to go back to sleep after waking during the night?</td>
<td>&lt; 5 min</td>
<td>5 to 10 min</td>
<td>10 to 15 min</td>
<td>15 to 20 min</td>
<td>20 to 30 min</td>
<td>&gt; 30 min</td>
</tr>
<tr>
<td>5. After waking up during the night, I am calm and relaxed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6. In general, I find it difficult to get out of the bed in the morning.</td>
<td></td>
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</tr>
<tr>
<td>7. In general, I am slow-to-start in the morning.</td>
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<tr>
<td>8. In the morning, I wake up and feel ready to get up for the day.</td>
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<tr>
<td>9. In the morning, I wake up and just can’t get going.</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Statement</td>
<td>Never</td>
<td>Once in a while</td>
<td>Sometimes</td>
<td>Quite often</td>
<td>Frequently, but not always</td>
<td>Always</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>10. In the morning, I wake up rested and alert.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11. In general, I “put off” or delay going to bed.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. How long do you usually “put off” or delay going to bed?</td>
<td>&lt; 15 min</td>
<td>15 to 30 min</td>
<td>30 to 45 min</td>
<td>45 to 60 min</td>
<td>60 to 90 min</td>
<td>&gt; 90 min</td>
</tr>
<tr>
<td>13. In general, it is very hard for me to go to bed on time.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14. When it’s time to go to bed, I want to stay up and do other things (e.g., read, work, or watch TV).</td>
<td></td>
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</tr>
<tr>
<td>15. In general, I have to make myself go to bed.</td>
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</tr>
<tr>
<td>16. After I fall asleep, but during the night, I awaken more than once.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. How often do you usually wake up during the night.</td>
<td>Never</td>
<td>Once</td>
<td>Twice</td>
<td>Three times</td>
<td>Four times</td>
<td>&gt; four times</td>
</tr>
<tr>
<td>18. After I fall asleep, but during the night, I toss and turn in bed.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>19. In general, I sleep without arousals or awakenings.</td>
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</tr>
<tr>
<td>20. After I fall asleep, but during the night, I am very restless.</td>
<td></td>
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</tr>
<tr>
<td>21. In general, I try to make myself go to sleep.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Statement Table

<table>
<thead>
<tr>
<th>Statement</th>
<th>Never</th>
<th>Once in a while</th>
<th>Sometimes</th>
<th>Quite often</th>
<th>Frequently, but not always</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. When I am in bed and it is time to fall asleep, I am not sleepy.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>23. In general, I fall asleep quickly.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>24. How long does it usually take you to fall asleep after lights out?</td>
<td>&lt; 15 min</td>
<td>15 to 30 min</td>
<td>30 to 45 min</td>
<td>45 to 60 min</td>
<td>60 to 90 min</td>
<td>&gt; 90 min</td>
</tr>
<tr>
<td>25. When I am in bed and it is time to fall asleep, I am unable to settle down.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Appendix B11: Positive and Negative Affect Scale

This scale consists of a number of different words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. **Indicate to what extent you feel this way RIGHT NOW.** Use the following scale to record your answers.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>very slightly or not at all</td>
<td>a little</td>
<td>moderately</td>
<td>quite a bit</td>
<td>extremely</td>
<td></td>
</tr>
</tbody>
</table>

_____ interested

_____ distressed

_____ excited

_____ upset

_____ strong

_____ guilty

_____ scared

_____ hostile

_____ enthusiastic

_____ proud

_____ irritable

_____ alert

_____ ashamed

_____ inspired

_____ nervous

_____ determined

_____ attentive

_____ jittery

_____ active

_____ afraid

Appendix B12: Visual Analogue Scale

How sleepy do you feel?
Sleepy __________________________ Alert

How tired do you feel?
Tired __________________________ Energetic
Appendix B13: Psychomotor Vigilance Task Instructions

For the current study, the instruction will be as follows: “You are about to engage in a task that involves attending to stimuli on a screen. It will take approximately 10 minutes. Please pay attention to the ‘X’ in the center of the screen in front of you. Hit space bar as quickly as possible when you see this box (image of the box will be shown to participants on the screen). Please do not hit the space bar until you see the box. Let’s try a few for practice.”

At the end of practice trials, they will be told, “We shall start the task now. Remember, press the space bar as fast as possible when you see the image of the box. You may begin the task by hitting the space bar when you are ready.”

Appendix B14: Continuous Performance Test Instructions

For the current study, the instruction will be as follows: “You are about to take part in a task that involves attending to stimuli on a screen. It will take approximately 24 minutes. On each trial, you will see one of two stimuli on the screen. Each will be a white square with a black square inside it. On some trials, this inner square will be near to the top of the white square; on other trials it will be near the bottom. When the square is on the top, it is a target (image of the target will be shown to participants on the screen). During the task, you should press the space bar whenever you see the target stimulus. When the square is on the bottom, it is not a target (image of the non-target will be shown to participants on the screen). During the task you should not press the space bar when the non-target is displayed. During the duration of the task, you will see a series of targets and non-targets. Press the space bar as quickly as you can whenever you see a target (top square – image of target will be shown again). Do nothing when you see a non-target (bottom square – image of non-target will be shown again). The task lasts approximately 24 minutes, so you need to concentrate on the task in order to perform well. You will now have 16 practice trials.”

At the end of practice trials, they will be told, “Remember press the space bar as quickly as you can whenever you see a target (top square – image of target will be shown again). Do nothing when you see a non-target (bottom square – image of non-target will be shown again). You may begin the task by hitting the space bar when you are ready.”

Appendix B15: Mock Lecture Task Instructions

For the current study, the instruction will be as follows: “You are about to engage in a mock lecture about traumatic brain injury. It will take approximately 26 minutes. You will have an opportunity to earn up to $5 based on your performance on a short multiple choice quiz at the end of the lecture. First the 10 questions will be shown to you on the screen. Then, you will be shown the lecture on traumatic brain injury, after which the short quiz will be provided to you on paper. Please press the space bar when you are ready to begin.”
Appendix B16: Multiple Choice Questions

1. What are the three types of movements that the eye makes?
   A) Concave, convex, context
   B) Vertical, horizontal, diagonal
   C) Vergence, saccadic, and pursuit
   D) Accomodation, constriction, dilation

2. What is myopic (a problem with vision) also referred to as?
   A) Clearsighted
   B) Farsighted
   C) Narrowsighted
   D) Nearsighted

3. What is presbyopia (a problem with vision)?
   A) Reduced near vision ability caused by aging
   B) Periodic, searing pain in the eye
   C) Abnormal curvature on the cornea
   D) Inability to see in the dark

4. What faulty receptor results in color blindness?
   A) Rods
   B) Ganglions
   C) Cones
   D) Optic nerve

5. What colors do individuals with tritanopia see?
   A) See the world in yellow and blue
   B) See the world in greens and reds
   C) See the world in pink and yellow
   D) See the world in purple and pink

6. What results from the destruction of photoreceptors?
   A) Eye is unable to take photos
   B) Progressive loss of peripheral vision
   C) Inability to see certain colors
   D) Progressive loss of central vision

7. What is the most common form of juvenile (occurring at an earlier age) macular degeneration?
   A) Astigmatism
   B) Stargardt disease
   C) Deuteronomia
   D) Cataract
8. What are some ways early cataract can be improved?
   A) Surgery
   B) Stay in the dark and avoid daylight
   C) New glasses, brighter lighting, anti-glare sunglasses
   D) Contact lenses

9. What does glaucoma result from?
   A) Group of diseases that destroys/damages optic nerve
   B) An accident that results in a coma
   C) Inability of eye to accommodate
   D) Lack of an optic nerve

10. What will happen if glaucoma is left untreated?
    A) Loss of central vision
    B) Loss of color vision
    C) Loss of peripheral vision
    D) Loss of day and night vision
Appendix B17: Debriefing Form

First, we want to thank you for participating in this study. We greatly appreciate your time and willingness to participate. We have categorized participants as either a “good” or “poor” sleepers, based on their reported sleep habits and sleep quality in order to examine how sleep factors into your cognitive abilities while awake. Specifically, we are trying to determine if having poor sleep habits results in attentional difficulties that further translates to the activities of daily life for a college student, such as paying attention and taking notes during class. Prior studies have found that performance on attention tasks does decline for individuals deprived and restricted of sleep as demonstrated by slower reaction times, increased lapsing and more errors made on tasks. There is no research to date examining the impact of such attentional difficulties on daily activities for college students. Hence, we are trying to determine if these attentional difficulties do in fact impact classroom note-taking abilities. Additionally, college students have been found to attribute attentional difficulties as indicative of attention-deficit/hyperactive disorder (ADHD). Given the overlap in attentional difficulties between sleep loss and ADHD, we are also examining the relationship between reported sleep habits and ADHD symptoms.

Also, we would like to provide you with resources should you feel uneasy or bothered by any aspects of the study in any way after you leave the study, including your responses to questions or information you have learned about sleep and attentional performance. If you would like to talk with someone, we encourage you to contact either one of the following offices:

Psychology and Social Work Clinic
Porter 002
593-0902

Counseling and Psychological Services
Hudson 337
593-1616

Thank you again for all of your help. If you have any questions after you leave, do not hesitate to call any of the contacts on your informed consent form.
Appendix C

Supplemental Analyses: Tables 5 to 11

Table 5.

**Correlation Matrix of Three ADSWS Subscales and Total Score with Cognitive Performance Measures, when BDI and BAI are Controlled for.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>PVT-RT &lt;small&gt;(n = 61)&lt;/small&gt;</th>
<th>PVT-LPS &lt;small&gt;(n = 62)&lt;/small&gt;</th>
<th>PVT-AC &lt;small&gt;(n = 59)&lt;/small&gt;</th>
<th>TOVA-AC &lt;small&gt;(n = 62)&lt;/small&gt;</th>
<th>TOVA-RT &lt;small&gt;(n = 62)&lt;/small&gt;</th>
<th>TOVA-OM &lt;small&gt;(n = 65)&lt;/small&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSWS:MW</td>
<td>.032</td>
<td>.035</td>
<td>.036</td>
<td>.010</td>
<td>.062</td>
<td>.175</td>
</tr>
<tr>
<td>ADSWS:BSH</td>
<td>.238</td>
<td>.267*</td>
<td>- .158</td>
<td>-.083</td>
<td>.229</td>
<td>.104</td>
</tr>
<tr>
<td>ADSWS:SI</td>
<td>.082</td>
<td>.066</td>
<td>-.130</td>
<td>-.113</td>
<td>.075</td>
<td>.139</td>
</tr>
<tr>
<td>ADSWS:TS</td>
<td>.135</td>
<td>.132</td>
<td>- .183</td>
<td>- .146</td>
<td>.076</td>
<td>.139</td>
</tr>
</tbody>
</table>

*Note. AC = accuracy; ADSWS = Adult Sleep-Wake Scale; BSH = bedtime sleep habits; LPS = lapses; MW = morning wakefulness; NA = nighttime awakenings; OM = errors of omission; PVT = Psychomotor Vigilance Task; RT = reaction time; SI = sleep initiation; TOVA = Test of Variables of Attention; TS = total score; * = p < .05*

Table 6.

**Correlation Matrix of Three ADSWS Subscales and Total Score with EEG Measures during the Mock Lecture Task, when BDI and BAI are Controlled for.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>EEG-BFT &lt;small&gt;(n = 45)&lt;/small&gt;</th>
<th>EEG-BPA &lt;small&gt;(n = 45)&lt;/small&gt;</th>
<th>EEG-BPT &lt;small&gt;(n = 45)&lt;/small&gt;</th>
<th>EEG-MFT &lt;small&gt;(n = 45)&lt;/small&gt;</th>
<th>EEG-MPA &lt;small&gt;(n = 45)&lt;/small&gt;</th>
<th>EEG-MPT &lt;small&gt;(n = 45)&lt;/small&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSWS:MW</td>
<td>.160</td>
<td>-.187</td>
<td>-.200</td>
<td>-.072</td>
<td>-.143</td>
<td>-.190</td>
</tr>
<tr>
<td>ADSWS:BSH</td>
<td>.192</td>
<td>-.006</td>
<td>-.031</td>
<td>-.066</td>
<td>-.086</td>
<td>-.120</td>
</tr>
<tr>
<td>ADSWS:SI</td>
<td>.153</td>
<td>-.289*</td>
<td>-.275</td>
<td>-.088</td>
<td>-.315*</td>
<td>-.304*</td>
</tr>
<tr>
<td>ADSWS:TS</td>
<td>.222</td>
<td>-.254</td>
<td>-.230</td>
<td>-.077</td>
<td>-.230</td>
<td>-.219</td>
</tr>
</tbody>
</table>

*Note. ADSWS = Adult Sleep-Wake Scale; BFT = baseline Fz theta; BSH = bedtime sleep habits; BPA = baseline Pz alpha; BPT = baseline Pz theta; EEG = electroencephalograph; MFT = mock lecture Fz theta; MPA = mock lecture Pz alpha; MPT = mock lecture Pz theta; MW = morning wakefulness; SI = sleep initiation; TS = total score; * = p < .05*
Table 7.

Correlation Matrix of Sleep Duration the Night Before, State Alertness, and Negative State Mood with Cognitive Performance Measures.

<table>
<thead>
<tr>
<th>Variables</th>
<th>PVT-RT</th>
<th>PVT-LPS</th>
<th>PVT-AC</th>
<th>TOVA-AC</th>
<th>TOVA-RT</th>
<th>TOVA-OM</th>
</tr>
</thead>
<tbody>
<tr>
<td>D7-TST (n)</td>
<td>.228</td>
<td>.166</td>
<td>-.171</td>
<td>-.058</td>
<td>.154</td>
<td>.073</td>
</tr>
<tr>
<td>(65)</td>
<td></td>
<td></td>
<td></td>
<td>(66)</td>
<td>(66)</td>
<td>(59)</td>
</tr>
<tr>
<td>VAS: Alert (n)</td>
<td>.029</td>
<td>.049</td>
<td>.021</td>
<td>.078</td>
<td>.005</td>
<td>-.070</td>
</tr>
<tr>
<td>(65)</td>
<td></td>
<td></td>
<td></td>
<td>(66)</td>
<td>(66)</td>
<td>(59)</td>
</tr>
<tr>
<td>PANAS: negative (n)</td>
<td><strong>.055</strong></td>
<td><strong>.218</strong></td>
<td>-.052</td>
<td>-.018</td>
<td>.318**</td>
<td>.125</td>
</tr>
<tr>
<td>(61)</td>
<td>(62)</td>
<td>(59)</td>
<td>(62)</td>
<td>(62)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. D7-TST = night before total sleep time; AC = accuracy; LPS = lapses; OM = errors of omission; PANAS = Positive and Negative Affect Schedule; PVT = Psychomotor Vigilance Task; RT = reaction time; TOVA = Test of Variables of Attention; VAS = Visual Analogue Scale; r values when BDI and BAI are controlled for are in boldface; ** = p < .01

Table 8.

Correlation Matrix of EEG Measures during the Mock Lecture Task.

<table>
<thead>
<tr>
<th>Variables</th>
<th>EEG-BFT</th>
<th>EEG-BPA</th>
<th>EEG-BPT</th>
<th>EEG-MFT</th>
<th>EEG-MPA</th>
<th>EEG-MPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>D7-TST (n =49)</td>
<td>.002</td>
<td>-.118</td>
<td>-.089</td>
<td>.037</td>
<td>-.201</td>
<td>-.146</td>
</tr>
<tr>
<td>VAS: Alert (n =49)</td>
<td>-.220</td>
<td>-.228</td>
<td>-.249</td>
<td>-.338*</td>
<td>-.257</td>
<td>-.297*</td>
</tr>
<tr>
<td>PANAS: negative (n =45)</td>
<td><strong>.068</strong></td>
<td><strong>.111</strong></td>
<td><strong>.063</strong></td>
<td><strong>.042</strong></td>
<td><strong>.022</strong></td>
<td><strong>.036</strong></td>
</tr>
</tbody>
</table>

Note. D7-TST = night before total sleep time; BFT = baseline Fz theta; BPA = baseline Pz alpha; BPT = baseline Pz theta; EEG = electroencephalograph; MFT = mock lecture Fz theta; MPA = mock lecture Pz alpha; MPT = mock lecture Pz theta; PANAS = Positive and Negative Affect Schedule; VAS = Visual Analogue Scale; r values when BDI and BAI are controlled for are in boldface; * = p < .05
Table 9.

**Correlation Matrix of Standard Deviation of Sleep Duration Over the Week with Cognitive Performance Measures as well as EEG Measures during the Mock Lecture Task, when Sleep Duration Over the Week is Controlled for.**

<table>
<thead>
<tr>
<th></th>
<th>Cognitive Performance (n)</th>
<th>Mock Lecture Task (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation</td>
<td>PVT-RT</td>
<td>PVT-LPS</td>
</tr>
<tr>
<td>of sleep</td>
<td>.279*</td>
<td>.276*</td>
</tr>
</tbody>
</table>

*Note. AC = Accuracy; BFT = baseline Fz theta; BPA = baseline Pz alpha; BPT = baseline Pz theta; EEG = electroencephalograph; LPS = lapses; MFT = mock lecture Fz theta; MPA = mock lecture Pz alpha; MPT = mock lecture Pz theta; OM = errors of omission; PVT = Psychomotor Vigilance Task; RT = reaction time; TOVA = Test of Variables of Attention; * = p < .05

Table 10.

**Correlation Matrix of the CAARS Inattention and Memory Problems as well as DSM-IV Inattentive Symptoms Subscales with Cognitive Performance Measures, when BDI and BAI are controlled for.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>PVT-RT</th>
<th>PVT-LPS</th>
<th>PVT-AC</th>
<th>TOVA-AC</th>
<th>TOVA-RT</th>
<th>TOVA-OM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAARS: I/MP (n)</td>
<td>-.261*</td>
<td>-.117</td>
<td>.225</td>
<td>-.003</td>
<td>-.161</td>
<td>-.079</td>
</tr>
<tr>
<td>CAARS: IS (n)</td>
<td>-.160</td>
<td>-.035</td>
<td>.139</td>
<td>-.039</td>
<td>-.160</td>
<td>.009</td>
</tr>
</tbody>
</table>

*Note. AC = accuracy; CAARS = Conners’ Adult ADHD Rating Scale; CM = errors of commission; DSM-IV IS = Diagnostic and Statistical Manual of Mental Disorders 4th edition Inattentive Symptoms; I/MP = inattention/memory problems; LPS = lapses; OM = errors of omission; PVT = Psychomotor Vigilance Task; RT = reaction time; * = p < .05
Table 11.

Means and Standard Deviations of Dependent Variables Used in Exploratory Analyses.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSWS: SRI</td>
<td>20.82</td>
<td>3.76</td>
<td>BDI-II-score</td>
<td>4.31</td>
<td>3.50</td>
</tr>
<tr>
<td>ADSWS: MW</td>
<td>14.72</td>
<td>4.56</td>
<td>BAI-score</td>
<td>3.46</td>
<td>3.55</td>
</tr>
<tr>
<td>ADSWS: BSH</td>
<td>16.31</td>
<td>4.95</td>
<td>VAS-alert</td>
<td>67.60</td>
<td>19.69</td>
</tr>
<tr>
<td>ADSWS: SI</td>
<td>19.57</td>
<td>3.13</td>
<td>PANAS-negative</td>
<td>12.31</td>
<td>0.30</td>
</tr>
<tr>
<td>ADSWS: TS</td>
<td>90.81</td>
<td>12.90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. ADSWS = Adult Sleep-Wake Scale; BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory – Version II; BSH = bedtime sleep habits; MW = morning wakefulness; PANAS = Positive and Negative Affect Schedule; SI = sleep initiation; SRI = sleep re-initiation; TS = total score; VAS = Visual Analogue Scale; * = p < .05