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Chronotype preference, partial sleep deprivation, and executive functions performance throughout the wake-cycle

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CHRONOTYPE PREFERENCE, PARTIAL SLEEP DEPRIVATION, AND EXECUTIVE FUNCTIONS PERFORMANCE THROUGHOUT THE WAKE-CYCLE

By

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ABSTRACT

Sleep is vital to survival and well-being. Adequate sleep, which is conceptualized in terms of quantity and quality, is positively related to a number of cognitive functions. In terms of length, it has been recommended that individuals in late adolescence and adulthood should receive no less than eight hours of sleep. Negative effects on higher-order mental processes have been found in states of sleep deprivation. Individuals who experience total sleep deprivation show decrements in performance on tasks of executive function (i.e. sustained attention, planning, and decision making). However, the effects of partial sleep deprivation on executive functions has not been fully examined and is under-studied in the scientific literature. Furthermore, research surrounding chronotype (morning or evening preference) suggests that time of day impacts performance on cognitive tasks. The literature is incomplete regarding the effects of partial sleep deprivation and chronotype preference on executive function. The aim of the current study is to examine these variables.

One hundred-five college students recruited from a university set in the Southern United States participated in this study. Sleep quality, which was assessed using the Pittsburgh Sleep Quality Index, the Sleep Hygiene Scale, and the Adult Sleep-Wake Scale, Chronotype, as assessed by the Morningness-Evenininingness Scale, and executive functions, as measured by the Sustained Attention to Response Task (SART) and the Tower of London Task (TOL) were used in this study. Self-report, paper-based measurements concerning sleep quality and morningness/eveningness preference were administered once, at the initial assessment period, and executive function performance was measured at three task administration times throughout the testing day. Group differences were assessed using MANOVA's, with between-subject analyses (ANOVA's) being conducted on the separate outcome variables to elucidate sleep group and chronotype preferences differences. Results indicated a significant interaction between sleep quality and morningness/eveningness preference, with good sleep quality students performing better on executive function tasks during their preferred time of day.

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CHAPTER 1

Introduction

Sleep is necessary to sustain life and enhance well-being (McCoy & Strecker, 2011). A number of theories have been postulated regarding the purpose of sleep (Dewan, 1968; Hirshkowitz, Moore, & Minhoto, 1997; Hodgson, 1991; Meddis, 1977; Oswald, 1987; Webb, 1975), however, no definitive conclusion has been reached concerning its function. Even so, the benefits of sleep have been well documented. Such benefits include enhanced memory functioning, learning, and decision making abilities are performed more efficiently when adequate sleep has been achieved (Gais & Born, 2004; Gilbert & Weaver, 2010; Harrison & Horne, 2000a; Harrison & Horne, 2000b, Pilcher & Walters, 1997; Smith & Lapp, 1991).

Recommendations from health professionals are for between 7 to 9 hours of sleep per night (National Sleep Foundation, 2006). This interval allows individuals to cycle through the various stages of sleep, in an alternating pattern between REM (rapid eye movement) and NREM (non-rapid eye movement) sleep (Hirshkowitz et al., 1997). NREM sleep is further broken down into three stages: stage 1, stage 2, and stage 3 (Hirshkowitz et al., 1997). This pattern repeats itself every 90 to 120 minutes (Hirshkowitz et al., 1997). Sleep is under the regulation of the autonomic nervous system and, more specifically, by the hypothalamus (Hirshkowitz et al., 1997). The function of sleep, at least to some degree, is to establish a balance or homeostasis (Hirshkowitz et al., 1997). Circadian rhythm, or the biological clock that "regulates physiological activity and behavior," is thought to be seated in the suprachiasmatic nucleus (Hirshkowitz et al., 1997, p. 27). Circadian rhythms are included in the homeostatic processes of the autonomic nervous system and coordinate the balance between wake and sleep states (Hirshkowtiz et al., 1997).

Two aspects of sleep that are uncorrelated, yet important in terms of well-being, are sleep length and sleep quality (Meijer, Habekothe, & Van Den Wittenboer, 2000). Sleep length refers to the time spent in bed and encompasses the period of sleep from going to bed until awakening (Meijer et al., 2000). Sleep quality encompasses the criteria of early sleep onset, few sleep interruptions, and fewer early awakenings (Meijer et al., 1999). Better sleep quality is associated with feeling rested after waking up and higher achievement motivation (Meijer et al., 2000; Reid & Baker, 2013). When assessing sleep, both sleep quality and sleep length need to be examined to determine sleep health (Okubo et al., 2014).

A number of benefits have been ascribed to good sleep. Cognitive functions, which mostly rely on frontal lobe activation (Luria, 1966; Smith & Jonides, 1999; Teuber, 1972), are sensitive to sleep quality and length (Jung, Ronda, Czeisler, & Wright, 2011; Lo et al., 2012). Reaction time to stimuli is quicker in individuals who have had adequate sleep (Jung et al., 2011). This finding is particularly pertinent to driving situations, but could be generalized to other situations, such as in athletic games and military operations. Quality sleep has also been identified as a significant predictor of emotional and psychological well-being. Adams and Kisler (2013) found improved mood ratings after participants completed a subjective measurement of depressive symptoms. Finally, memory functions are enhanced after a good night's sleep (Wagner, Hallschmid, Rasch, & Born, 2006). Wilhelm et al. (2011) found that procedural and declarative memories are consolidated much more effectively after quality sleep, which enhances the later recall of the information.

Just as adequate sleep promotes a number of benefits, inadequate sleep correlates or causes a number of negative consequences. Sleep deprivation has been found to be negatively related to abdominal obesity, hypertension, glucose intolerance, and dyslipidemia, (Jarrin, McGrath, & Drake, 2013; Okubo et al., 2014). Reaction times increase as the amount of sleep deprivation increases. Lapses in attention are also greater in sleep deprived individuals compared to healthy sleepers. This is particularly troubling because attention is necessary for other cognitive functions to be performed (Jung et al., 2011; Killgore, 2010). Higher order mental abilities, such as sustained attention, planning, and decision making are also negatively affected by loss of sleep (Kobbeltvedt, Brun, & Laberg, 2005; Koslowsky & Babkoff, 1992; Lo et al., 2012; Nilsson et al., 2005).

Partial sleep deprivation, which has been conceptualized as getting two to three hours less than the recommended amount of sleep per night (sleep length< six hours; Brown, Buboltz, & Soper, 2006; McCoy & Strecker, 2011; National Sleep Foundation, 2006), is a chronic problem among modern societies. This construct is distinct from total sleep deprivation, which is oftentimes defined as a case of sleep reduction where an individual is awake for prolonged period of time, usually for more than 24 hours (Daviaux, Mignardot, Cornu, & Deschamps, 2014). College students are a population that is particularly vulnerable to inadequate sleep (Breslau, Roth, Rosenthal, & Andreski, 1997; Buboltz, Brown, & Soper, 2001; Tsui & Wing, 2009). It is well established that a number of students suffer from diagnosable disorders, and the vast majority do not get enough sleep at night. Receiving less than seven hours of sleep has been correlated to less than optimal levels of attention and cognitive functioning (Wright et al., 2006) and to a number of behavioral problems in college students, especially absenteeism and poorer academic performance (Tsui & Wing, 2009).

Research regarding chronotype (individual differences in preference and peak activation in functioning at different times of the daily cycle; Tankova, Adan, & Buela-Casal, 1994) is salient in predicting efficacy of task execution. Individuals with a morning-oriented chronotype perform better on tasks that are administered during the hours immediately following waking-up (Tankova et al., 1994). Conversely, evening-type individuals perform tasks more effectively during the later stages of the wake-cycle (Tankova et al., 1994). Various characteristics have been attributed to circadian typology. Studies have found that morning-type preference is related to higher academic performance (Guthrie, Ash, & Bendapudi, 1995; Tankova et al., 1994). Better academic performance interacts with the time of day in which classes were held (Guthrie et al., 1995). When tasks are worked on or accomplished during peak activation times, the results are more likely to be more favorable.

Higher order cognitive processes, in particular those aimed at navigating novel situations and attaining set goals, are commonly referred to as executive functions (Miller & Cohen, 2001; Miyake et al., 2000; Xu et al., 2013). Executive functions have neural correlates to areas of the prefrontal cortex. Sustained attention and focus activate the anterior cingulate cortex (Laird et al., 2005; Miller & Cohen, 2001; Smith & Jonides,

1999) and the prefrontal cortex (Smith & Jonides, 1999). Planning and decision making are functions based in the workings of the orbitofrontal cortex (OFC; Lovstad et al., 2012) and the dorsolateral prefrontal cortex (Cazalis et al., 2003). Research shows that the prefrontal cortex is susceptible to diminished functioning under conditions of sleep deprivation. These findings denote potential severe impairments, as there is a need to focus on tasks and make decisions on a daily basis. Faults in executive functions due to sleep deprivation could be precursors to accidents, failures, and missed opportunities.

Statement of the Problem

A number of studies have been conducted concerning the effects of total sleep deprivation on higher order mental functions (Diekelmann, Landolt, Lahl, Born, & Wagner, 2008; Martella, Casagrande, & Lupianez, 2011; Qi et al., 2010), with the preponderance of data suggesting that the prefrontal cortex, and the mental capacities that are performed by it, is particularly susceptible to impairment due to prolonged wakefulness. However, some mixed results have arisen concerning the effects of total sleep deprivation and cognitive functioning, with some findings suggesting no significant differences exist between totally sleep deprived individuals and healthy sleepers on a number of executive function tasks (Pace-Schott et al., 2009; Tucker, Whitney, Belenky, Hinson, & Van Dongen, 2010). The research surrounding total sleep deprivation on cognitive deficits has yielded useful results; however, this type of sleep loss is much less frequent than that of persistent partial sleep deprivation (Goel, Rao, Durmer, & Dinges, 2009).

Partial sleep deprivation is a wide-spread problem in modern societies (Meerlo & Roman, 2006). College students frequently experience a number of sleep problems, and it has been estimated that between 27% of these students have a diagnosable sleep disorder (Gaultney, 2010). A vast majority of college students report occasional sleep disruptions (88%) and nearly three quarters report not getting enough sleep (Buboltz et al., 2001). Furthermore, 60% classify themselves as being poor sleepers (Lund, Reider, Whiting, & Prichard, 2010). Such statistics are astounding because sleep researchers have found that individuals who get at least seven hours of sleep per night are much more likely to perform at optimum levels on cognitive tasks compared to those who get inadequate sleep (Sternberg et al., 2013). Researchers have gone on to suggest that, for adolescents, anything under 9 hours of sleep is partial sleep deprivation (George & Davis, 2013). Although the recommendation for sleep length consistently points to getting at least seven hours of sleep per night, it is clear that the overwhelming majority of students do not. Insufficient sleep negatively effects cognitive functioning and, in suite, academic performance (Gilbert & Weaver, 2010; Kelly, Kelly, & Clanton, 2001; Tsui & Wing, 2009).

Recent paradigm shifts in assessing the ramifications of sleep deprivation on higher-order cognitive processes have focused on the time of day and circadian rhythm phase. Few studies have examined the influences of partial sleep deprivation and time of day (circadian phase) on these cognitive processes (Lo et al., 2012). Individual differences have also been observed regarding the susceptibility of decreased executive functioning due to sleep loss (Lo et al., 2012). This finding suggests that certain markers, including dispositional traits and attitudes could might mediate the relationship between sleep and cognitive functioning.

Circadian rhythm and time of day are other variables implicated in executive function performance (Bratzke, Rolke, Steinborn, & Ulrich, 2007; Lara, Madrid, & Correa, 2014; Manly, Lewis, Robertson, Watson, & Datta, 2002; Valdez, Ramirez, & Garcia, 2012). Results from these studies suggest that performance during the optimal time of day and circadian rhythm phase is significantly better compared to suboptimal times. The effect of sleep deprivation on cognitive performance tasks is mediated by circadian rhythm timing (Reichert et al., 2014). Williamson and Friswell (2011) found an interaction effect between sleep deprivation and time of day on reaction time and vigilance tasks. Bratzke et al. (2009) corroborated these findings, noting increased reactions times and error rates in sleep deprived individuals who were tested at non-optimal times of their circadian rhythms. However, a literature search including partial sleep deprivation, chronotype, and executive function yielded few results, indicating that the investigation of this combination of variables is lacking.

The dearth of research surrounding partial sleep deprivation, chronotype preference, and executive functions is perplexing given the high incident rate of inadequate sleep among college students. The purpose of the present study is to use a quasi-experimental approach in determining the effects of partial sleep deprivation and chronotype preference on executive functioning. More research is needed to clearly tease apart the impact that sleep and morningness/eveningness attitudes have on high level cognitive processes. This study will contribute to the sleep literature and will provide new insights into the relationships among this research project's variables.

Justification

There is little research on the effects of partial sleep deprivation and circadian typology on executive function (Lo et al., 2012). Expanded knowledge in this area would be beneficial because partial sleep deprivation is rampant in our society, especially in college students. Better understanding of the potential consequence of chronic inadequate sleep on mental functioning would be useful for university campuses to raise awareness regarding the importance of healthy sleep. Additionally, knowing the impact of morningness/eveningness preference and partial sleep deprivation on higher cognitive functions could have a profound impact on the choices that students make concerning their class schedules and the times that they devote to studying. In other real world settings, such as occupational sites, employers could potentially enhance production and efficiency by making scheduling changes that support the optimal functioning of their employees.

Literature Review

Sleep

According to Fordham (1988), sleep can be defined in two ways: first, as a discrete state in and of itself, and second, as being part of a continuous cycle of varying levels of consciousness. Sleep is one of only a handful of functions that is required to sustain life (Gregory, Xie, & Mengel, 2004; Hirshkowitz, Moore, & Minhoto, 1997) and that is essential for well-being and the facilitation of a number of cognitive abilities (George & Davis, 2013; McCoy & Strecher, 2011). Animal research studies have shown that animals deprived of sleep for long enough will die (Rechtschaffen, Bergmann, Everson, Kushida, & Gilliland, 1989), and this finding could very likely be generalized to humans (Hirshkowitz et al., 1997). Individuals who do not get adequate and consistent sleep at night have higher mortality rates than those who do (Garfinkel, 1985; Hirshkowitz et al., 1997; Kripke, Simons, Garfinkel, & Hammond, 1979; Wingard & Berkman, 1983). Sleep deprived people are also at greater risk of developing illnesses and disease (George & Davis, 2013). Excessive sleepiness can have severe negative consequences and potentially be life-threatening (Hirshkowitz et al., 1997). Sleep is a vital process for health and well-being because the brain requires it to function properly (Hirschkowitz et al., 1997). Despite all of the research surrounding sleep, there is still a lack of understanding as to how it affects health.

Theories of sleep. Sleep has three basic characteristics: (a) it is a brain process, (b) it is an active process, and (c) it is comprised of multiple processes (Hirschkowitz et al., 1997). Sleep is not a passive event, void of neuronal activity, but rather an active event with electroencephalography (EEG) studies showing electrical activity in the brain during sleep. A number of theories and hypotheses have been posited to explain and describe the survival function of sleep. One is the *restorative theory*, because of the restorative influence that it evokes on physical, emotional, and psychological well-being (Hirschkowitz et al., 1997; National Sleep Foundation, 2006; Taub & Berger, 1973). The neuronal workings of sleep have also been theorized to neutralize accumulated neurotoxins, synthesize new neurotransmitters, and distribute such chemicals to the various areas of the brain (Drucker-Colin, 1979; Hartman, 1973; Kleitman, 1963). Research has shown that during sleep there is increased tissue synthesis, cell division, and growth hormone production and release (Hirshkowitz et al., 1997). According to this theory, the process of sleep promotes health and well-being by bolstering immune system functioning and by regulating hormones, namely ghrelin and leptin, which monitor and manage feelings of hunger and fullness in order to avoid overeating and unnecessary weight gain (National Sleep Foundation, 2006).

The *adaptive theory* of sleep suggests that sleep has a survival function because different species have varying sleep-wake cycles which help it to survive in its own biological niche (Hirshkowitz et al., 1997; Meddis, 1977; Webb, 1975). Animals that do not have acute night vision are likely to have increased odds at surviving if they become immobile during the night time (Hirshkowitz et al., 1997). Sleep then is an adaptation that enhances survival by allowing an animal to increase its odds of staying alive by minimizing activities during dangerous periods of the 24-hour day cycle. The *energy conservation theory* highlights the decreased metabolic state that occurs during the sleep cycle (Hirshkowitz et al., 1997). Animals, including humans, with higher metabolic rates sleep longer than those with slower metabolic functioning (Zeplin & Rechtschaffen, 1974). By sleeping for longer periods of time, energy may be conserved in order to enhance functioning during the daytime hours. However, the energy conserved during the sleep cycle has shown to largely be insufficient (Hirshkowitz et al., 1997). Dewan (1968) proposed the *programming-reprogramming hypothesis* to describe the function of sleep. During sleep states, information is processed and the consolidation of memories occurs or the dumping of the information takes place (Hirshkowitz et al., 1997). Rapid eye movement (REM) stage of sleep appears to serve memory and intellectual processes (Hirshkowitz et al., 1997). In a study conducted by Smith and Lapp (1991), which supports this theory, investigations found that adults who were undergoing intense learning spent more time in REM sleep at night. Furthermore, babies during early development sleep twice as much as adults, and it is theorized that they are constantly undergoing neuronal programming (Hirshkowitz et al., 1997).

The *restitution theory* of sleep highlights the counterbalancing processes of catabolism (the breaking down of molecules to release energy) and anabolism (the construction of molecules which requires energy; Adam & Oswald, 1984). The activities during wakefulness promote catabolism while sleep enhances anabolism (Adam & Oswald, 1984). Catabolism occurs due to the effect of stressors on the body, which cause cortisol, glucagon, and catecholamines to be released, which then inhibit the release of anabolic hormones, such as insulin and testosterone (Adam & Oswald, 1984). Sleep inhibits the release of catabolic agents and stimulates the production of proteins and growth hormones that serve anabolic purposes (Adam & Oswald, 1984). However, arguments against this theory include the lack of protein synthesis during sleep (Dorociak, 1990), and the cell growth, which requires synthesis of proteins and the presence of insulin, is hampered because there is not a major influx of available insulin during the early phases of sleep (Gribbin, 1990).

The *humoral theory* of sleep suggests that throughout the wake cycle a chemical toxin that promotes tiredness and sleepiness builds up which ultimately brings on the sleep-cycle (Hodgson, 1991). During the sleep phase, this 'hypnotoxin' is eradicated from the body which then induces wakefulness (Hodgson, 1991). Turpin (1986) lends some support to this theory by identifying endogenous chemicals and other hormones, such as peptides, prostaglandins, and melatonin, that show a progressive build-up throughout the day leading to an induction of sleepiness. However, Canavan (1986) argues that there is insufficient evidence for this theory.

Sleep phases and physiology. The sleep cycle, which consists of four (previously five) stages, is cycled through in a systematic fashion (Hirshkowitz et al., 1997; Izac, 2006). These stages can be categorized by the presence of eye movements in REM or lack of such movements in non-rapid eye movement (NREM) sleep, and the cycling of these phases occurs roughly every 90 – 120 minute (George & Davis, 2013; Hirshkowitz et al., 1997; Hodgson, 1991; Izac, 2006). Most of the slow wave sleep (stages 1 through 3) mostly occurs during the first third of the night, whereas REM sleep makes up most of the second half of the sleep cycle (Hirshkowitz et al., 1997). Sleep begins by progressing through the stages of NREM sleep, followed by REM sleep. As the time spent asleep increases, more time is spent in REM sleep (Hirshkowitz et al., 1997). These global stages can be broken down further into REM sleep and stages 1 through 3, with stages 1 through 3 constituting NREM sleep. On average, young adults will spend 2 -5% of the sleep cycle in Stage 1 (~ 24 minutes), 45-55% in Stages 2-3 (~ 240 minutes), 3-8% in Stage 3 (~ 108 minutes), and 20-25% of the night in REM sleep (~ 108 minutes; Hirshkowtiz, Moore, Hamilton, Rando, & Karacan, 1992; Izac, 2006; National Sleep Foundation, 2006; Williams, Karacan, & Hursch, 1974). Newborns spend nearly 50% of their sleep cycle in REM sleep, and infant REM sleep is different from that in adults in terms of EEG and eye-movement characteristics (Izac, 2006).

NREM sleep is broken down into three to four stages. Stage 1 is scored when mixed-frequency and low-voltage brain-wave activity is present and when rapid-eye movements are not present. Theta waves are present during this stage of sleep and are an indication of sleepiness/drowsiness (Izac, 2006). However, slow eye movements (SEMs) can also be present. This is the lightest phase of sleep, and an individual is easily brought back to wakefulness during this stage (George & Davis, 2013). This is considered the transition sleep between wakefulness and sleep (George & Davis, 2013). Stage 2 sleep can be identified by the presence of sleep spindles, which are waveform eruptions (Hirshkowitz et al., 1997; Hodgson, 1991; Izac, 2006). These spindles suggest that different sleep-related brain processes are taking place compared to other stages. Sleep spindles can follow K complex waves, which are high-voltage waveforms (Hirshkowitz et al., 1997; Izac, 2006). Finally, Stages 3 and 4 are characterized by the presence of delta waves, which is the slowest wavelength of brain EEG activity. These waveforms are synchronized, as different areas of the brain produce delta waves in an orderly fashion. The brain activity during Stages 3 and 4 is commonly referred as slow-wave sleep (SWS) and deep sleep. SWS is characterized by high voltage and low frequency delta waves (Simor & Horvath, 2013). This stage of sleep is most restorative, refreshing, and indispensable (Simor & Horvath, 2013). Since 2007, Stages 3 and 4 have been combined and are now conceptualized as the third stage of NREM sleep (George & Davis, 2013). During these later stages of sleep, hormonal changes occur within the body, including a release of growth hormone (Hodgson, 1991). Once the last stage of sleep is completed, sleepers will begin to cycle back through the stages, until REM sleep is reached (Hodgson, 1991).

Sleep stages can be characterized according to sleep-related brain electrical workings, including electroencephalographic (brain-wave), electrooculographic (eye movement), and submental electromyographic (chin muscle) events (George & Davis, 2013; Hirshkowitz et al., 1997; Hodgson, 1991). According to Hirshkowitz et al. (1997), REM sleep is characterized by quick eye movements and mixed-frequency brain-wave activity. During this stage of sleep, there is a reduction in muscle tone and paralysis of postural muscles and twitches of distal flexor muscles are apparent (Izac, 2006). Voluntary muscle control is lost during REM sleep. This phase of sleep is regulated by the sympathetic nervous system, as heart rate and respiration rates tend to be quicker and more irregular (George & Davis, 2013). Additionally, in REM sleep, the wave activity must be void of delta waves and sleep spindles, but theta waves can be present. The first REM period generally occurs after the first 70 to 100 minutes of sleep (Izac, 2006). Research has found that animals, including humans, who have immature nervous systems spend more time in REM sleep during the night than do the mature adults of the same species (Izac, 2006).

Developmental changes in sleep patterns. Sleeping patterns and behaviors change throughout the life span. Hirshkowtiz et al. (1997) describe a number of characteristics and modifications in the sleep-cycle from childhood into older adulthood. Among them, infants sleep nearly twice as much as adults and spend roughly 50% of the in-sleep time in REM sleep. The amount of time in REM sleep steadily declines until adolescence and levels off at around 20-25% of the sleep cycle in adulthood. As humans age, total sleep time declines, with sleep fragmentation (wakefulness interspersed with sleep) occurring more frequently. The amount of time spent in SWS also declines and can disappear altogether in older individuals (Hirshkowitz et al., 1992; Miles & Dement, 1980; Roffwarg, Muzio, & Dement, 1966; Williams et al., 1974). The authors also found that sleep differences between the sexes is minimal during adolescence, but aging can exaggerate sleep-cycle differences between men and women.

Sleep Quality. A good night's sleep includes two dimensions: sleep quality and sleep length (Meijer et al., 2000). Although both dimensions are contained in the conceptualization of good sleep, these two constructs are uncorrelated (Todderdell, Reynolds, Parkinson, & Briner, 1994). Sleep length is also referred to as the time spent in bed, or the "period of sleep until awakening in the morning" (Meijer et al., 2000, p. 145). Sleep quality includes the sleep characteristics of early sleep onset, few interruptions during the sleep cycle, and fewer early awakenings (Meijer et al., 2000). Good quality sleep is important for physical, emotional, and psychological well-being (Buboltz et al., 2009). Sleep quality is one variable that significantly predicts engagements in other healthy behaviors and academic success in college work (Trockel, Barnes, & Egget, 2000). However, college students are particularly susceptible to poor sleep quality (Buboltz et al., 2001; Buboltz et al., 2009; Gaultney, 2010; Lund et al., 2010). College students not only get insufficient sleep, but they also have false perceptions regarding their sleep length and quality (Buboltz et al., 2009).

A number of reasons have been proposed to explain the causes of poor sleep quality in college students. Adams and Kisler (2013) found negative relationships between technology use and sleep quality in a college student sample. Their results indicate that technology use increases sleep latency and causes disruptions during the sleep cycle. Buboltz et al. (2009) suggest that supplements to increase energy due to sleepiness and insufficient sleep also affects sleep quality. Psychological states, including depressive and anxiety symptoms, also have adverse impacts on sleep quality (Adams & Kisler, 2013). Trockel et al. (2000) suggest that sleep quality and habits account for most variance in academic performance compared to other health-related variables. Sleep quality is important for success in a number of areas of life. In the following sections, the beneficial effects of quality sleep and the detrimental effects of poor sleep quality will be discussed in length.

Quality sleep benefits. Not only do important functions related to physical, emotional, and psychological health get a boost, but cognitive processes are also heavily influenced by sleep (National Sleep Foundation, 2006). Sleep length and sleep quality are critical for cognitive abilities such as memory, learning, and decision making (Gilbert & Weaver, 2010; Harrison & Horne, 2000a; Harrison & Horne, 2000b; Mednick, Nakayama & Stickgold, 2003; Pilcher & Walters, 1997; Smith & Lapp, 1991). For example, Rauchs et al. (2011) found that regular sleepers remembered more target items and forgot more non-target items than individuals who had been sleep deprived. It has been suggested that strong hippocampal activation during encoding signals for the neural network to replay the learned sequence during the subsequent sleep period. Furthermore, these researchers found that stimuli, whether it is to be remembered or forgotten, are processed differently by those who have had adequate sleep compared to those who are sleep deprived. Sleep appears to bind elements that constitute a memory and consolidate it to a higher level. The binding and consolidating processes likely occur due to the increased hippocampal activation and the establishment of the memory traces in other neocortical areas. Neocortical activation, including the anterior cingulated cortex and temporal, parietal, and occipital areas, is much more prominent in those who get regular and sufficient sleep (Rauchs et al., 2011). To achieve optimal cognitive functioning, it is important for individuals to get quality and sufficient sleep.

Sleep is a central process in the consolidation of memory traces (Gais & Born, 2004; Maquet, 2001; Stickgold, 2005). Wagner et al. (2006) found that sleep plays a particularly salient role in the consolidation of emotionally laden experiences and memories. They found that participants who slept within three hours of being exposed to emotionally loaded stimuli, had greater learning and recall of the event later on. Sleep promotes the longevity of memory traces and establishes life-long memory of emotional experiences (Wagner et al., 2006). Wilhelm et al., (2011) found that sleep promotes the consolidation of both declarative and procedural memories that will be expected to be recalled at a later time. Stage 3, or SWS, is the stage where the consolidation of declarative memories occurs (Chen et al., 2014). Interestingly, in this study, subjects who were not informed about the later necessity to retrieve the learned information and were able to sleep before the retest period, showed greater retrieval capability compared to those who were not able to sleep before the retest trial. In addition to re-energizing self-regulatory processes, adequate sleep and sleep quality mitigate the effects of stress and strain (Barber, Munz, Bagsby, & Powell, 2009). Through the process of sleep, physiological and psychological functions and abilities are recharged and more effective coping mechanisms may be employed.

Adverse consequences of poor quality sleep. Just as physiological and psychological functioning is optimal with adequate sleep, insufficient and poor sleep quality can have disastrous effects on these aspects. Chen et al. (2014) found that insomniacs have impaired working memory capacities and suggest that consolidation of declarative memories may also be impacted by sleep quality. Memories concerning facts and events are essential in completing tests and assignments in academic settings.

Deficits in this memory process are likely to manifest as lower test scores and grades. College students also report decreases in energy and motivation levels as sleep quality decreases (Reid & Baker, 2013).

General health and quality of life are correlated to sleep quality (Kato, 2014). Metabolic syndrome, which consists of abdominal obesity, hypertension, glucose intolerance, and dyslipidemia, is negatively related to sleep quality (Okubo et al., 2014). Poor sleep quality is also a risk factor in the cause and maintenance of obesity in children (Jarrin et al., 2013). Researchers examined the sleep length and quality in school-aged children and found that sleep during the school week was negatively correlated to greater waist and hip circumferences, body-mass indexes, and percent body fat (Jarrin et al., 2013). Gao et al. (2014) found a strong inverse relationship between sleep quality and depression in a sample of adults with other health issues. They concluded that poor sleep quality and depressive features have an interaction effect on other health concerns, such as Bronchiectasis.

Tkachenko et al. (2014) administered the Personality Assessment Inventory (PAI) and an open-ended sleep quality questionnaire to 49 adults. Their results show that sleep quality was negatively related to the somatic complaints, anxiety, and depression clinical scales. Ramsawh, Stein, Belik, Jacobi, and Sareen (2009) conclude that anxiety disorders are commonly associated to sleep disturbances and that individuals with an anxiety disorder who are poor sleepers report lower life satisfaction and increased disabilities. Chen, Burley, and Gotlib (2012) compared adolescent females with either a family history of depression with peers who had no history of familial depression on subjective sleep quality. They found that females whose mothers had depression reported lower sleep quality than their counterparts. Sleep quality is likely a risk-factor for the development of depression in individuals who may have a predisposition for the disorder. Lower levels of SWS and higher levels of REM sleep may exacerbate the affective symptoms, including depressive features, associated with borderline personality disorder (BPD; Simor & Horvath, 2013). Abnormal slow wave activity was also inversely related to impulsive behaviors in individuals with BPD and antisocial personality disorder (APD; Simor & Horvath, 2013).

A study that examined the relationship among sleep quality, sleep length, divided attention, and memory in typically developing children found that poor sleep quality was related to poorer scores on divided attention and response inhibition tasks (Vriend et al., 2012). Lenne, Triggs, and Redman (1998) found that drivers who were sleep deprived for up to 36 hours were significantly less able to attend to stimuli, had increased reaction times, and were inhibited in their ability to maintain a steady position in their lane. Deficits in attention due to poor sleep quality and length likely inhibit other cognitive tasks that require vigilance and focus. Harrison and Horne (2000a) found that short-term sleep deprivation impairs decision-making abilities, especially in times of crisis, in novel situations, in revising plans, and in stressful environments. Attention is requisite for many daily tasks to be completed effectively and in a safe manner.

Poor sleep quality negatively impacts a number of aspects in life, including physical and psychological health. Inadequate sleep is not only a culprit or causal factor in some of the development of some disorders, but as previously noted, it exacerbates symptoms and increases risks for predisposed individuals. The potential risks surrounding inadequate attention due to poor sleep quality, and the effects these have on higher mental processes, denotes a greater need to understand the relationship between these variables.

Circadian rhythm. A circadian rhythm is defined as, "… the periodicity in physiological (e.g., body temperature and blood pressure) and psychological (e.g., mood) variables" (Guthrie et al., 1995, p.186). The circadian-rhythm cycle is 24 hours; however, during this period of time there appears to be fluctuations in these variables and times when a person feels that his or her physical and psychological functioning is the most optimal (Guthrie et al., 1995). Physiological processes, such as temperature regulation, sleep drive, and alertness follow daily rhythms that tend to reach their lowest point between midnight and dawn and another low in the early afternoon (Czeisler et al., 1980; Monk, 1987; Williamson & Friswell, 2011). Sleep and wakefulness periods occur reliably throughout the nearly 24-hour cycle and tend to coincide with solar and dark phases (Maire, Reichert, & Schmidt, 2013). The most common pattern follows roughly 16 hours of alertness with increasing sleepiness as wakefulness is prolonged into dark phases (Maire et al., 2013).

Circadian rhythms are regulated by the suprachiasmatic nucleus (Durmer & Dinges, 2005), which has been dubbed the 'circadian master clock', and which lies in the anterior portion of the hypothalamus (Maire et al., 2013). Two processes are implicated in the unfolding of the circadian rhythm: the circadian process and the homeostatic process (Maire et al., 2013; Durmer & Dinges, 2005). Circadian processes promote sleep and wakefulness and are regulated by endogenous factors (i.e. melatonin and body temperature; Maire et al. 2013). This process is reset daily by the light-dark cycle. Homeostatic processes promote the propensity to sleep relative to the prior history of the sleep-wake cycle (Maire et al., 2013). The homeostatic process maintains a running count of time spent awake and time spent asleep, and as the time in wakefulness increases, the propensity to sleep also surges. Homeostatic drive decreases during sleep, and will promote the ensuing wakeful state (Durmer & Dinges, 2005). When the homeostatic drive to sleep reaches a certain threshold, sleep will be induced, and when it decreases below another threshold, wakefulness follows (Durmer & Dinges). The homeostatic process appears to be related to the accumulation of the sleep debt, as sleep deprivation elevates the homeostatic motive (Doran, Van Dongen, & Dinges, 2001).

Most human functions, including the sleep/wake cycle and executive function performance, follow an established circadian cycle that includes a peak of activity, usually during the late afternoon period, and a low-point or floor during the night time (Bonnefond, Rohmer, Hoeft, Muzet, & Tassi, 2003). Throughout the circadian rhythm, as wake time increases, alertness decreases and performance is hindered (Williamson & Friswell, 2011). During times of sleep restriction, homeostatic processes rise and cognitive performance begins to slump (Jiang et al., 2011). Bonnefond and colleagues (2003) found that time of day affected (improved) reaction time on simple, visual discrimination tasks, but showed no effect on more complex tasks. One potential reason for this finding may be based on the Yerkes-Dodson Theory (1908), which suggests that a task, depending on its complexity, requires a specific level of arousal for optimal performance to be achieved. Therefore, complex tasks require less arousal, because the combination of high complexity and high arousal would result in overexcitement and overstimulation. On the other hand, less complex tasks need high arousal in order to avert the effects of boredom or monotony (Bonnefond et al., 2003). It is conceivable, then, that the higher-order Descending Subtraction Test employed by Bonnefond and colleagues was hardly influenced by time of day because less arousal was needed to attend to and complete the task.

The interaction between circadian time and sleep deprivation significantly affects performance on a number of cognitive measures (Williamson & Friswell, 2011). Participants who had total sleep deprivation for 28 hours showed deficits on performance tasks such as tracking, reaction time, vigilance, and logical reasoning (Williamson & Friswell, 2011). Interestingly, however, was the finding that the deleterious effects of sleep deprivation were only statistically significant when the time of testing coincided with a trough in circadian function, which highlights an interacting influence between circadian timing and sleep deprivation (Williamson & Friswell, 2011).

Chronotype Preference

Chronotype is an individual characteristic and preference for a time of day in which an individual feels that he or she is at his or her "best" (Guthrie et al., 1995; Randler, Baumann, & Horzum, 2014; Werner, LeBourgeois, Geiger, & Jenni, 2009). These characteristics are also known as morningness-eveningness preferences (Werner et al., 2009). Some individuals prefer to go to bed early and wake up early (morning-type or "lark"), whereas others prefer to stay awake late into the evening and wake up later (evening-type or "owl"; Adan et al., 2012; Cavallera, Boari, Giudici, & Ortolano, 2011; Killgore, 2007; Selvi, Gulfec, Agargun, & Besiroglu, 2007; Werner et al., 2009). Although these preferences are trait-like in nature, Di Milia and Bhole (2009) and Caci, Deschaux, Adan and Natale (2008) found that the mid-twenties and mid-thirties (respectively) appear to be a time period where chronotypes will become solidified, even to the extreme. Tankova et al. (1994) state that a shift towards morningness occurs in the 50's and that women tend to favor morning-type traits, whereas a larger portion of men espouse the evening-type (Adan & Natale, 2002; Adan et al., 2012). Regardless of gender, as individuals grow older, there is a tendency to go to bed earlier and to wake up earlier (Adan et al., 2012).

Chronotype could be considered a personality trait because of its stability and because it relates to individual differences and preferences (Randler et al., 2014). Matthews (1988) postulates that the development of morningness/eveningness preference is partially through exogenous factors, indicating that personality traits interact with cognitive and social influences which in turn influence the setting of circadian rhythms. Randler and colleagues (2014) found that conscientiousness shows the strongest correlation to chronotype, with morning individuals being more conscientious than their evening counterparts. Furthermore, behavioral activation system (BAS) drives were higher in morning individuals, with morning types found to be more proactive than evening people. However, extraversion correlated more highly with evening preference. It has also been suggested that evening-types are less emotionally stable and also score higher on subjective ratings of sensation-seeking, impulsiveness, invincibility, and risk-taking (Cavallera et al., 2011; Killgore, 2007).

Morning and evening preferences also correlate with mood. In healthy subjects, sleep deprived morning individuals reported a worsening of depressive symptoms, whereas evening types did not experience this exacerbation of depressive features (Selvi et al., 2007). Sleep deprivation in morning chronotypes also led to increased tiredness and decreased activity levels, but evening types actually reported increased mood and less anger/hostility as the wake-cycle progressed (Selvi et al., 2007).

Guthrie et al. (1995) found that chronotype influences academic performance, especially in early morning classes. Students enrolling in morning classes who have an evening preference perform more poorly in their academic functioning compared to morning types. Two potential reasons for these negative impacts were provided by Guthrie and colleagues, who suggested that evening-type students may have increased levels of absenteeism in morning classes and that these late-studying night owls may experience sleep deprivation because of their late bedtimes and the need to wake up early for class. Valdez et al. (2012) indicate that chronotype explains some of the variance in people's performance on attention, working memory, and executive function tasks. These authors also indicate that sleep deprivation could also confound the execution of such tasks.

Morning or evening preference is related to both personality and performance measures. Recently, research examined the effect of morningness-eveningness preference on cognitive abilities. Results are mixed with some findings suggesting that chronotype may not uniformly affect cognitive functions (Cavallera et al., 2011), whereas others have found that cognitive processes can be influenced by the time of day when tests are administered (Bennet, Petros, Johnson, & Ferraro, 2008). Bennet et al. (2008) examined the difference between morningness and eveningngess on executive functions and found that performance on the Wisconsin Card Sorting Task decreased throughout the day for morning-type individuals. Both aspects of this task, cognitive flexibility, which is calculated as the proportion of perseverative errors to total responses, and efficiency, which is the rate of correct answers to errors, decreased in larks who took this test in the afternoon. However, the evening-type individuals improved in this task as they were tested later in the day. There were no significant differences on digit span tasks, verbal fluency, or continuous performance tests (CPT) between the chronotypes. Bennet et al. (2008) suggest that stronger effects of chronotype on CPT may be found if tasks were of longer length. Finally, these authors suggested that future research in this area should use three testing times in order to maximize the observation of the effects of time-of-day on executive functions.

Individuals who are able to perform a task during their preferred time of day execute them more effectively. Hahn et al. (2012) found that participants perform much better on executive function tasks when the assessments are administered during their preferred time of the day. Reaction times of psychomotor vigilance tasks showed a synchrony between time of day and participants' circadian typology (Schmidt, Peigneux, Cajochen, & Collette, 2012). On the Stroop task, when administered during non-optimal times of the day, participants struggled to inhibit the dominant response on the incongruent items (Schmidt et al., 2012). Lara et al. (2014) examined the relationship between chronotype and inhibitory abilities in college students. After administering the Sustained Attention to Response Task (SART) to the participants, researchers found that decrements in inhibitory performance were exacerbated during non-optimal testing times. In morning-type individuals, there was a linear decrement on the SART during the evening administration, whereas the evening-types showed linear decrements throughout the morning administration. Lara et al. (2014) recommend that chronotype should be considered in research that aims to study executive function performance.

The current study aims to build off of Lara et al. (2014) and Lo et al. (2012) recommendations to include an analysis of chronotype of executive functioning. Three testing times will be used to assess for performance differences on these higher order processes throughout the wake-cycle. Including chronotype in this study will further elucidate the effect that this characteristic has on a number of executive control processes.

Partial Sleep Deprivation

Inadequate sleep has been characterized as getting less than two to three hours of the recommended amount of sleep per night (< six hours; Brown et al., 2006; McCoy & Strecker, 2011; National Sleep Foundation, 2006). George and Davis (2013) suggest that adolescents need roughly 9 hours of sleep per night and that anything under this amount is sleep deprivation. Sleep deprivation, synonymous with inadequate sleep, adversely influences performance in social, academic, and physical realms (Brown et al., 2006; Gilbert & Weaver, 2010). Deficits in higher-order mental processes, such as attention, decision making, learning, and memory show deficits following disrupted sleep (McCoy & Strecker, 2011). Furthermore, a chronic pattern of sleep deprivation creates a sleep debt (Hirshkowitz et al., 1997). If adequate sleep is not achieved soon after, physical and psychological troubles can occur (National Sleep Foundation, 2006). Lo et al. (2012) found that limiting sleep to 6 hours a night can initiate and exacerbate a sleep debt. The benefits of quality and length of sleep continue to be expounded. Whereas adequate sleep promotes health and well-being, sleep deprivation can undermine multiple facets of human functioning.

Adequate sleep is frequently categorized as getting approximately eight to nine hours of sleep each night (National Sleep Foundation, 2006). In adolescents and college students the recommended length of sleep has been set closer to nine hours per night (Carskadon, 2002; Forquer, Camden, Gabriau, & Johnson, 2008). However, recent research by Sternberg et al. (2013) suggests that seven hours of sleep is enough to sustain healthy functioning. Sternberg and colleagues analyzed a sample of 36,140,947 individuals that were administered assessments that correlated sleep quality with cognitive abilities. Their results showed that individuals who slept for seven hours performed optimally on matching, memory, and math calculation tasks. Of interest is the finding that after more than seven hours of sleep performance began to decrease.

College students, however, are exceptionally prone to partial sleep deprivation due to the activities associated with their way of life (Breslau et al., 1997). The academic life style (i.e. social events and academic rigors) restricts the amount of nocturnal sleep college students are able to get (Breslau et al., 1997). A study examining sleep length and hygiene in 1007 college students found that sleep length during the week was 6.7 hours (±1.2) and 7.4 hours on the weekend (±1.4; Breslau et al., 1997). Sleep quality, more so than sleep quantity, has been implicated in health and well-being (Brown et al., 2006). The consistency of sleep/wake cycles affects overall sleep quality (Barber et al., 2009; Forquer et al., 2008; Lee, Wuertz, Rogers, & Chen, 2013; Taub & Berger, 1973). Consistent sleep patterns fall under sleep hygiene practices, which can be defined as behaviors that promote improved quantity and quality of sleep (Brick, Seely, & Palermo, 2010; Stepanski & Wyatt, 2003). Imbedded in sleep hygiene is the notion that consistent bedtime patterns and schedules are important aspects related to sleep quality (Brick et al., 2010, Taub & Berger, 1973). Taub and Berger (1973) found that inconsistencies in sleep hygiene practices, specifically in relation to sleep and wake times, are likely to lead to sleep deficits and deprivations. Their research found that behavioral and subjective performance is optimal only when consistent circadian rhythms are achieved.

Research conducted on sleep hygiene has found that poor sleep hygiene practices negatively impact the quality of sleep (Stepanski & Wyatt, 2003). It has been found that a majority of college students do not have sufficient knowledge about healthy sleep practices (Knowlden, Sharma, & Bernard, 2012). However, even sufficient knowledge is not enough to promote the practice of healthy sleep hygiene (Brown, Buboltz, & Soper, 2002; Tsai & Li, 2004). Certain sleep practices, such as maintaining a regular bedtime and waking hour promotes sleep quality (Stepanski & Wyatt, 2003). However, college students have inconsistent bedtime and waking routines (Breslau et al., 1997; Brown et al., 2002; Buboltz et al., 2001; Knowlden et al., 2012). In a study by Knowlden et al. (2012), they demonstrated that an increase in sleep hygiene predicted higher sleep quality in college students. Other sleep hygiene practices that promote sleep quality are avoiding daytime naps, abstaining from caffeine in the evening, eliminating excessive alcohol consumption in the evening, not going to bed hungry, and maintaining a regular exercise routine (Stepanski & Wyatt, 2003).

College students employ poor sleep habits and practices (Gilbert & Weaver, 2010), which, in turn, leads to poor sleep quality (Knowlden et al., 2012). Such practices include varying times of falling asleep and waking up (Tsui & Wing, 2009). When bed times and wake-up times are varied throughout the week, Delayed Phase Sleep Disorder can develop. According to the National Sleep Foundation (2006), Delayed Phase Sleep

Disorder is, "an inability to fall asleep at a desired, conventional clock time and awaken at a socially acceptable morning time" (National Sleep Foundation, 2006). This sleeping disorder is problematic because it alters circadian rhythms, which can severely impair both physical and psychological functioning (National Sleep Foundation, 2006). Tsui and Wing (2009) found that sleep deprived students, on average, would sleep over an hour and a half longer on weekends to make up for lost sleep during the week. They also found that 72.7 percent of their sample identified themselves as being sleep deprived. This rate of college sleep disturbance has been replicated in other studies of sleep deprivation in college students (Buboltz et al., 2001; Gilbert & Weaver, 2010). One reason suggested for the variation in sleeping patterns between the weekdays and weekends was the early start times of classes during the week. Students who had early morning classes (i.e., those that started at or before 8:30 a.m.) were more likely to be tardy or absent (Tsui & Wing, 2009). Early morning lectures also predicted sleep deprivation, the accumulation of a sleep debt, and poor sleep quality (Tsui & Wing, 2009).

Tsui and Wing (2009), in addition to highly variable sleep patterns and sleep deprivation, found that such sleep practices in college students are likely to lead to an unhealthy lifestyle. Namely, they found that students who do not get adequate sleep are fatigued during the daytime, which is likely to affect their academic performance. As academic performance decreases, students are more likely to experience heightened levels of stress, which in turn will reduce the length and quality of sleep (Tsui & Wing, 2009). This finding is particularly troubling because it elucidates the lengths that students will go through in order to attempt to maintain or improve their performance in academics. However, by further increasing their sleep debt and lowering the quality of their sleep, the students' performance is likely to continue in a downward spiral.

In another research project on college student sleep practices and quality, Buboltz et al. (2001) found a number of specific difficulties that students have while sleeping. Some of the common sleep disruptions that befall university students are the inability to fall asleep within the first 30 minutes of laying down, being tired upon waking up, and having to wake up too early. These researchers also concluded that such sleep difficulties may stem from certain environmental and other pressures. According to Tsui and Wing (2009), sleep deprivation is highly correlated to increased studying efforts. Students, in an attempt to maintain high marks and performance in academics, often stay up later and rise earlier in order to maximize study time. However, research on this topic demonstrates that such efforts have a negative effect on learning and overall grade point average (GPA; Gilbert & Weaver, 2010). The pressure for students to perform well at the college level may lead to greater and more chronic sleep disruptions, which is likely to impair performances on required tasks.

In a study examining the relationship between sleep quality and performance, the latter conceptualized as GPA, Gilbert and Weaver (2010) found that lower sleep quality is associated with poorer academic performance. Some of the variance between sleep quality and academic performance is accounted for by course incompletion (Gilbert & Weaver, 2010). This result explicates one of the findings of Tsui and Wing (2009) that highlighted the relationship between sleep deprivation and tardiness and absenteeism from class. It appears that inadequate sleep leads to an incompletion of work, which affects school performance and GPA. Once again, as Tsui and Wing (2009) pointed out, these events are likely to lead to a downward cycle where sleep quality and GPA continue to drop in a reciprocal manner. Kelly et al. (2001) corroborated these results and found that long sleepers, or those that received more than 8 hours of sleep per night, reported higher GPA's compared to short sleepers or students who slept fewer than 6 hours per night. These findings replicate those of Lack (1986), who found that sleep difficulties were negatively correlated to academic performance. However, most of the tests of academic performance were conducted in the morning, which potentially could have been affected by chronotype.

Adding to the downward cycle of sleep deprivation and diminished performance is the presence of mood disorders. In a study by Taub and Berger (1973), college students who experienced poor sleep quality and length were more likely to manifest symptoms of depression versus students who regularly got sufficient sleep. Moreover, students demonstrated more anger and frustration when their sleep cycles were varied and inconsistent. With low frustration tolerance, and an exacerbation of depressive symptoms such as anhedonia, avolition, and decreased energy, it becomes clearer how students experience lower levels of achievement and are less able to complete courses and course work. Gomes, Tavares, and de Azevedo (2011), found that students who had failed courses during the school year were more likely to have experienced sleep deprivation and disruptions. These researchers also found that complaints of depression, tension, and fatigue increased in students who had experienced insufficient sleep. Insufficient sleep, which is a frequency of not enough sleep, is an important factor in determining academic success (Gomes et al., 2011). Poor sleep quality takes a detrimental toll on students' physical and psychological well-being, on their ability to perform at optimal levels in academics, and on their ability to find pleasure in extracurricular and other daily activities (Goodin, McGuire, & Smith, 2010).

Interpersonal functioning also relates to sleep length and quality. Kahn-Greene, Lipizzi, Conrad, Kamimori, and Killgore (2006) found that sleep deprivation gives rise to a lower frustration tolerance and increased expression of aggressiveness. These authors concluded that individuals who are sleep deprived are less likely to accept blame, to make restitution or amends for wrongdoings, and are more likely to make unconventional responses to frustrating circumstances. More frequent expressions of irritability are also observed in those who have been sleep deprived (Orzel-Gryglewska, 2010). Ratings of neuroticism also increase following one night of sleep deprivation, and locus of control is also significantly impacted (Blagrove & Akehurst, 2001). In examining the relationship between sociability, states of optimism, and partial sleep deprivation, individuals who got less than 6 hours of sleep are less likely to be sociable and be less optimistic (Haack & Mullington, 2005). Those who received between seven to eight hours of sleep reported more optimism and life satisfaction (Haack & Mullington, 2005). Insufficient sleep can significantly lower psychosocial functioning. However, such changes in mood and interpersonal functioning are transient and can be returned to a baseline level after a single 12-hour recovery period (Haack & Mullington, 2005).

Although the effects of sleep loss on interpersonal functioning and mood are well examined and established, Talamini, Bringmann, de Boer, and Hofman (2013) emphasize that this is a reciprocal relationship, and that emotional distress can alter the electrophysiology of sleep. Researchers found that there is an increase in time spent in SWS and a flattening of time spent in REM sleep in individuals who experience emotionally laden events. Talamini et al. (2013) suggest that the alterations in the sleep electrophysiology of emotionally distressed individuals is a regulating function that protects against the continuation of the emotional disruption.

Certain demographic variables related to college students predict sleep quality (Goodin et al., 2010). The interaction effect between ethnicity and socioeconomic status (SES) is found to be a significant predictor of sufficient sleep (Goodin et al., 2010). These researchers found that certain ethnic minorities, and those from lower SES backgrounds, are more likely to experience poor sleep quality. Potential reasons for this interaction effect are the detrimental sequelae of discrimination and increased perception of stress and chronic sympathetic nervous system activation (Goodin et al., 2010). Choy (2001) found that students who came from economically disadvantaged homes were more likely to hold some form of employment while completing college course work. Employment, compounded with class work, tends to decrease the consistency of sleep rhythms. Thus, students who work and attend classes may sacrifice sleep time to complete homework and fulfill job responsibilities.

College students are frequently exposed to stressful events and situations (Lee et al., 2013). Goodin et al. (2010) note that stress, as a consequence of discrimination, negatively impacts sleep. Lee et al. (2013) examined the effects of perceived stress and sleep quality in female students. Their results show that perceived levels of stress were positively correlated to daytime sleepiness, depressive symptoms, fatigue severity, total night sleep time, and other physical symptoms. Furthermore, decreased nocturnal sleep positively correlated with depressive symptoms and fatigue severity during wakeful hours. Poor sleepers had higher levels of perceived stress (Tsai & Li, 2004). Female college students report higher rates of stress and lower sleep quality compared to their male counterparts (Tsai & Li, 2004). Other research has documented differences between genders in sleep quality. Buboltz et al. (2001) found that women were more likely to experience sleep difficulties than men. Lee et al. (2013) also found that female college students were likely to get less than seven hours of sleep per night. This partial sleep deprivation is likely to add to their sleep debt, which negatively affects numerous areas of functioning. Finally, these researchers found that during the work week, female college students were more likely to have varied sleep practices and schedules. These inconsistencies disrupt circadian rhythms and further exacerbate sleep issues (Lee et al., 2013).

In order to curb poor sleep quality, interventions promoting healthy sleep hygiene practices can be effective in improving sleep quality (Brown et al., 2002; Stepanski & Wyatt, 2003). However, simple psychoeducational measures to enhance sleep hygiene knowledge has not been found to be sufficient enough to bring about behavioral changes (Brown et al., 2002). Furthermore, some sleep hygiene behaviors in college students have been found to be particularly resistant to change. Brown et al. (2002) found that practices, such as reducing worry and limiting outside distractions, are particularly difficult for college students to modify. Unhealthy sleep hygiene practices and poor sleep quality can potentially have severe negative consequences for students (Gaultney, 2010).

Executive Function

Executive function can be defined as "control systems that implement different behavioral strategies in response to both internal and external cues" (Kolb & Wishaw, 2009, p. 433). These control systems aim to monitor and regulate behaviors and thoughts in order to reach or achieve desired goals (Miller & Cohen, 2001; Miyake et al., 2000; Valdez, Ramirez, & Garcia, 2012; Xu et al., 2013). Lezak, Howieson, and Loring (2004) conceptualize executive functions as "capacities that enable a person to engage successfully in independent, purposive, self-serving behavior" (p. 35). Specifically, executive functions include initiation, planning, hypothesis generation, cognitive flexibility, decision making, self-regulation, judgment, feedback utilization, and self-perception (Spreen & Strauss, 1998), judgment, working memory, shifting set (Cheung, Mitsis, & Halperin, 2004), verbal reasoning, problem-solving, planning, sequencing, sustained attention, resistance to interference, multitasking, and the ability to deal with novelty (Chan, Shum, & Toulopoulou, 2008).

Executive functions take on a managerial role for neurobehaviors, such as selective attention, self-regulation, and coordinating and integrating information (Spencer-Smith & Anderson, 2009). These capabilities are necessary for adaptive and efficient functioning in daily activities (Alexander & Stuss, 2000; Anderson, 2002) and social interactions (Huizinga & Smidts, 2011). These mental capabilities allow for flexibility in thinking and play an important role for the adaptations of everyday living (Huizinga & Smidts, 2011; Lovstad et al., 2012). The executive function of self-regulation has been found to mediate the relationship between socially antagonistic attitudes and behaviors (Wenner, Bianchi, Figueredo, Rushton, & Jacobs, 2013).

The prefrontal cortex (PFC) is the area in the brain considered to be the seat of executive function (Luria, 1966; Smith & Jonides, 1999; Spencer-Smith & Anderson, 2009; Teuber, 1972). However, integrating the whole brain is essential for the execution of efficient and adaptive executive functions (Spencer-Smith & Anderson, 2009). In the scientific literature, the terms PFC and executive function are used interchangeably, denoting the strong connection between these functions and this area of the brain (Yuan & Raz, 2014). Functional neuroimaging techniques have confirmed this link, elucidating the association between the prefrontal cortex, specifically the rostral and dorsal portions of this brain area, and executive functions (Albert & Steinberg, 2011; Yuan & Raz, 2014). However, certain higher-order processes show greater activation in the lateral part of the PFC (Yuan & Raz, 2014). Evidence shows the activation of the anterior cingulate cortex and the inferior parietal lobule (Buchsbaum, Greer, Chang, & Berman, 2005) during the Wisconsin card-sorting task, which includes the functions of selective-attention, behavioral inhibition, working memory, and goal-directed behavior (Miller & Cohen, 2001). In a meta-analysis by Laird et al. (2005), the inferior frontal gyrus and the anterior cingulate cortex were shown to be active when participants performed the Stroop task, which requires similar executive controls to those of the Wisconsin card-sorting task (Miller & Cohen, 2001). In another meta-analysis conducted by Yuan and Raz (2014), in healthy adults, larger prefrontal cortices were indicative of better performance on executive function tasks.

Different executive functions activate various areas of the prefrontal cortex. Core executive functions, such as working memory, inhibition, and task switching, have been thought to be centralized in the lateral prefrontal cortex (LPFC; Lovstad et al., 2012). In working memory manipulations and object retrieval tasks, the right dorsolateral prefrontal cortex becomes highly activated (Diamond & Goldman-Rakic, 1989; Jolles, Kleibeuker, Rombouts, & Crone, 2011). The ventrolateral prefrontal cortex becomes more engaged as load increases and in conditions of information manipulation (Jolles et al., 2011). The orbitofrontal cortex (OFC) is associated with self-regulation, emotional-regulation, and decision making (Lovstad et al., 2012).

Development of Executive Functions. The development of the PFC and executive functions are highly correlated (Shing, Lindenberger, Diamond, Li, & Davidson, 2010; Xu et al., 2013), and different executive functions mature at varying times (Spencer-Smith & Anderson, 2009). This distinction in the emergence of executive functions is largely determined by the maturation of the underlying brain structures that serve as the primary location for specific abilities (Spencer-Smith & Anderson, 2009). The prefrontal cortex increases in white matter, or the myelination of axons, between the ages of four and 20 (Giedd et al., 1999). Meanwhile, cortical grey matter develops in a nonlinear fashion, with a peak in grey matter in the frontal lobe occurring around the age of 12, followed by a decrease during post-adolescence (Giedd at al., 1999). Shaw et al., (2008), in a cross-sectional study that included neuroimaging scans of individuals aged 3.5 to 33 years, found that lateral frontal cortical development and thickness followed a cubic trajectory, with an increase in childhood, a decrease during adolescence, and a stabilization of thickness in adulthood. Shing et al. (2010), found that the facets of executive function are not well differentiated in children younger than seven years of age. These researchers hypothesize that functional capacities of the PFC in younger children are characterized by a lack of differentiation in the neural basis for executive function and that functional changes give way to more focal activation as the child matures. These functional maturation processes also begin to operate in a much more efficient manner (Shing et al., 2010). In a confirmatory factor analysis study, Xu et al. (2013), replicated these findings of the interrelated development between the PFC and executive functions.

Their research yielded a single factor conceptualized as 'executive functions' in children from seven to 12 years of age, but a three factor structure emerged in adolescents aged 13 and older. The three factor model included the capacities of updating working memory (UWM), inhibition, and shifting (Xu et al., 2013). The differences in factor structure elucidates the correlation between PFC development and the fine-tuning of executive functions. During late childhood and early adolescence, around the age of 12, the PFC undergoes significant structural and functional changes (Xu et al., 2013), in particular greater specificity and localization of executive functions in the PFC.

van der Ven, Kroesbergen, Boom, and Leseman (2013) attempted to replicate the three-factor model of executive functions. They found that a two factor model, consisting of updating and a combination of shifting and inhibition, was the most accurate solution in children with a mean age of 6.5 years. This finding suggests that executive functions may not be as differentiated in young children as they are in adults. Lee et al. (2012) found that a two factor model constituting of updating and a combination of inhibiting/switching was a better model fit for children aged six when compared to a three factor model. Huizinga and Smidts (2011) also found that a two factor model that best describes the executive functions in children and young adolescents. According to these researchers, the two common factors in their study were the Behavior Regulation Index and the Metacognition Index. Young children, whose PFC is still undergoing maturation, have shown less distinction and delineation in brain activity between tasks targeting specific executive controls. These findings suggest an ongoing progression of executive functions capabilities as children move through childhood and into adolescence and adulthood.

Development of various components of the prefrontal cortex occurs at different ages and follows distinct developmental trajectories (Gogtay et al., 2004; Mills, Lalonde, Clasen, Giedd, & Blakemore, 2014). In a neuroimaging study examining the cytoarchitecture of the prefrontal cortex, Shaw et al. (2008) concluded that areas within the frontal cortex follow cubic, quadratic, and linear developmental trajectories. The area of the anterior orbitofrontal cortex follows a cubic developmental trajectory, with an increase of cortical thickness until nine years of age, followed by a decline during adolescence, and then a stabilization into adulthood (Mills et al., 2014; Shaw et al., 2008). The posterior section of this area follows a quadratic trajectory, with an increase and climax of cortical thickness around 17 years of age, followed by a decrease until 25 years of age (Shaw et al., 2008). These authors also found similar developmental trajectories in the posterior and anterior areas of the medial frontal cortex. Shaw et al. (2008) further hypothesize that the increase in children's planning, working memory, and cognitive functioning coincides with the development of the frontal cortex. In corroboration of this hypothesis, Fatzer and Roebers (2012) found that performance on tests that measure executive functioning abilities increased in young children as they grew from age six until age nine. Performance on executive functions tasks continues to increase from childhood through adolescence (Huizinga & Smidts, 2011; Jolles et al., 2011).

The loss of (maturation) gray matter (GM) in the brain (Gogtay et al., 2004), which consists of the neuronal cell bodies, follows the trajectories described by Shaw et al. (2008). Within the frontal cortex, GM loss occurs first in the precentral gyrus and progresses linearly to the more anterior areas, with the prefrontal cortex maturing last

(Gogtay et al., 2004). This finding suggests that areas associated with higher-order processes, including executive functions, mature after lower-order sensorimotor regions (Gogtay et al., 2004). Within the prefrontal cortex, the left side appears to mature earlier than the right side, but this finding correlates to the handedness of the subjects involved (Gogtay et al., 2004). Differences in GM volume between the sexes have also been discovered. Grey matter trajectory heights were different for males and females, with females having smaller surface areas than males (Mills et al., 2014). However, no statistically significant differences in cortical thickness was found between the sexes (Mills et al., 2014).

Sex differences at different developmental stages have been found on performance measures of executive functions. In planning and mental look-ahead tasks, such as the Tower of London, young girls between the ages of four and five showed better performance than boys of the same age (Unterrainer et al., 2013). Even though the young males included in this study lagged behind a year to their female counterparts, by age six, performance differences disappeared. Discrepancies between males and females on executive function tasks have also been found in adolescence, with females scoring higher than males (Huizinga & Smidts, 2011).

Planning and Decision Making. According to Lezak et al. (2004), planning is "the identification and organization of the steps and elements… needed to carry out an intention to achieve a goal" (p. 614). Response planning is a confluence of processes that guide an individual towards successful goal directed behaviors (Asato, Sweeney, & Luna, 2006) and necessitates the use of other executive functions, such as mental manipulation capacity of working memory, organization, sustained attention on the task at hand, and inhibition (Asato et al., 2006; Baker et al., 1996; Owen, Doyon, Petrides, & Evans, 1996). The complexity of the cognitive behavior planning process requires the activation of multiple brain areas (Cazalis et al., 2003). Neuroimaging studies have found that planning tasks recruit the dorsolateral prefrontal cortex (DLPFC), with heightened activity in the left side in more complex tasks (Cazalis et al., 2003). Planning tasks activate the ventromedial prefrontal cortex (Killgore, Balkin, & Wesensten, 2006).

The development of planning capacities follows a similar development trajectory as other cognitive processes and is associated with the maturation of the prefrontal area of the brain (Asato et al., 2006). Improvements in planning efficiency and accuracy continue to occur between childhood and adolescence (Asato et al., 2006). Discrepancies between children and late adolescent performances on planning tasks is particularly evident as the complexity of the response planning increases. Asato et al. (2006) suggest that this performance gap may be based more upon mature individuals' abilities to invest appropriate amounts of time in order to plan and execute behaviors adequately.

Boghi et al. (2006) examined planning differences between the sexes using neuroimaging techniques. They found that, for the most part, neuronal activity was similar between the genders on planning tasks, with activation occurring in the prefrontal, parietal, and occipital cortical areas. However, some subtle differences emerged, denoting distinct recruitment and processing within the neuronal network for both genders. As task difficulty increased, females showed greater activation in the left precentral and bilateral middle frontal gyrus, whereas males showed greater activation in the precuneus.

Sustained attention. Attention and inhibition are executive function capacities (Bertrand, Marchand, Postuma, & Gagnon, 2013; Chan, Shum, & Toulopoulou, 2008; Smith & Jonides, 1999). Sustained attention, which is also referred to as vigilance, is the "continuous allocation of processing resources for detecting an important event" (McCoy & Strecker, 2011 p. 566). Divided attention is the ability to effectively and efficiently allocate attentional resources in situations where various stimuli must be monitored (McCoy & Strecker, 2011). In tasks that require sustained attention to target stimuli and inhibition of habitual response, such as the Stroop task, the anterior cingulate cortex becomes active (Laird et al., 2005; Miller & Cohen, 2001; Smith & Jonides, 1999). Additionally, it has been hypothesized that the PFC is also activated during the resolution of cognitive conflict as means of directing attention earlier in the processing sequence (Smith & Jonides, 1999).

Attention, and its filtering processes, is essential for information processing. Not only does attention facilitate the processing of incoming stimuli, but it is also a source of preference formation (Janiszewski, Kuo, & Tavasolli, 2012). In other words, attentional resources act as filters to allow only preferred stimuli to enter conscious awareness, leading to additional processing (Greenwald & Leavitt, 1984; Janiszewski et al., 2012). According to Greenwald and Leavitt (1984) attention is a multilayered process that devotes greater capacities to information as it makes its way through lower to higher levels of awareness. Preattention is the first level mentioned and requires few cognitive capacities (Greenwald & Leavitt, 1984). It is likely that this level of processing takes place on the fringe of conscious awareness. The second level of attention, according to Greenwald and Leavitt (1984), is focal attention, and at this level, the incoming information is analyzed for the source of the message and coded into some category. The third level produces comprehension of the information, which requires consumes greater attentional resources. The fourth, and final phase of attentional resources in information processing, is that of elaboration. At this point, attentional resources are devoted to expounding upon the presented message and forming connections with previously acquired information. Without adequate focus, or devotion of attentional resources, a stimulus dies out in early phases of processing, and further action upon the message is not conducted.

Janiszewski et al. (2012) demonstrated that attention plays an important role in selection processes. Their research showed that unattended items are less likely to be selected in future settings, whereas items that attracted attention were more likely to be attended to and picked later. Williams, Pouget, Boucher, and Woodman (2013) found that when attention was not fixated on an object, that object did not have a vivid enough representation stored in memory to make it eligible for later recollection. Additionally, visual-spatial attention aids in memory recall (Williams et at., 2013). The authors propose that fixating on the locations of previously presented targets decreased the likelihood that distracting information will affect memory and recall. Furthermore, attention acts to minimize distracters and to improve cognitive functions such as memory and decision making (Janiszewski et al., 2012; Williams et at., 2013).

Being able to pay attention and concentrate during classes is of particular importance to college students. Vigilance is perhaps the most sensitive executive function to sleep deprivation. Decrements in sustained attention can be evident after long periods of testing, even in the absence of sleep disruptions (McCoy & Strecker, 2011).

According to Pilcher, Geldhauser, Beeco, and Lindquist (2013), a number of cognitive capacities suffer when sleep deprivation occurs. These researchers found that sustained attention and memory functions showed decrements in performance after periods of partial sleep deprivation. These deficits were mostly related to working memory. Sleep deprivation has been found to increase the frequency of lapses in attention and reduces vigilance in performance tasks (Geiger-Brown et al., 2012). In addition, reaction times to stimuli are also increased (Fafrowicz et al., 2010; Graw, Krauchi, Knoblauch, Wirz-Justice, & Cajochen, 2003; Scott, McNaughton, & Polman, 2006). Fafrowicz et al. (2010), found that individuals tend to make more errors of omission when sleep deprived. Such errors stem from lapses in attention and focus. In another study of lapses in attention and error rates, Sadeh, Dan, and Bar-Haim (2011) found that tasks assigned later in the wake cycle after sleep deprivation yielded a higher frequency of omission errors. Sleep deprivation produces multiple cognitive deficits and decrements in performance across a number of tasks. Such shortfalls in reaction time, memory, and attention have potential negative and undesirable consequences in many areas of everyday life.

One potential mechanism for deficits in attention is decreased arousal (Blagrove, Alexander, & Horne, 1995). According to Blagrove et al. (1995), poor sleep quality decreases arousal, which in turn affects attention. These researchers also found that subjects with poor sleep reported greater levels of distractibility. Heightened distractibility and decreased levels of arousal negatively impact vigilance and concentration, which provide some insight into the frequency of omission errors after periods of partial or full sleep deprivation. Just as lapses in attention can cause such errors (Fafrowicz et al., 2010; Sadeh et al., 2011), being distracted by non-target stimuli, decreased arousal and/or ability to focus are also likely to account for variance between inadequate sleep and error rates.

Sleep Deprivation and Executive Function

Complex cognitive processing requires alertness and sustained attention (Jung et al., 2011; Killgore, 2010). Sleep plays an important role in sustaining baseline functioning, including basic alertness and emotional regulation, whereas a lack of sleep results in sleepiness, dampened mood, and physical exhaustion (Killgore, 2010). Vigilance and cognitive performance show steep declines if the normal period of 16-hour wakefulness is prolonged until near the end of the biological night (Maire et al., 2013). Total sleep deprivation can disrupt cognitive functions, including executive functions (Harrison & Horne, 2000a, 2000b). The PFC is particularly susceptible to the effects of sleep deprivation (Tucker et al., 2010)

A proposed mechanism for the decrements in executive functioning due to sleep loss is the involvement of the frontal lobe during the execution of these tasks (Harrison & Horne, 2000a). Glucose metabolism rates in the frontal lobe decrease during sleep deprivation periods (Thomas et al., 2000). Reduced metabolic activity is positively correlated with diminished executive functioning (Hsieh, Cheng, & Tsai, 2007). However, total sleep deprivation is not requisite for observable decrements in cognitive functioning (Killgore, 2010). Belenky et al. (2003) tested participants on psychomotor vigilance tasks and found that individuals who had mild to moderate partial sleep deprivation (between five and seven hours of sleep) initially showed declines in performance, and, after a few days, performance stabilized at lower-than-baseline levels.

Individuals who had been exposed to severe partial sleep deprivation (less than three hours of sleep per night) showed steady declines with no stabilization of performance. Sleep deprivation not only slows reaction times but also increases error rates (both omission and commission errors), and it negatively affects the time-on-task effect (Lim & Dinges, 2008; Williamson & Friswell, 2011).

Sustained attention on both auditory and visual tasks is adversely affected by total sleep deprivation (40 hours; Jung et al., 2011). Sleep deprivation increases response time and attentional lapses (Jung et al., 2011). The effects of total sleep loss on sustained attention and goal-directed behaviors suggests that sleep deprivation impairs the control networks of the brain, which likely include sensory and motor pathways (Drummond, Anderson, Straus, Vogel, & Perez, 2005) and the forebrain arousal systems (Jung et al., 2011).

Sleep-deprived individuals show signs of cognitive slowing during planning and decision-making tasks (Kobbeltvedt et al., 2005; Koslowsky & Babkoff, 1992; Nilsson et al., 2005). Lackluster performance on planning tasks following total sleep loss occur even when reaction time and working memory seem unaffected (Nilsson et al., 2005). Furthermore, sleep deprivation leads to less favorable judgments surrounding, and more pessimistic attitudes towards, decisions made (Kobbeltvedt et al., 2005). Circadian timing, which is the process that enhances the sleep drive as the duration of wakefulness increases, significantly affects planning performance and performance times in sleep deprived individuals (Blatter, Opwis, Munch, Wirz-Justice, & Cajochen, 2005). However, the negative effects are most pronounced in more complex tasks. Planning performance declines as soon as the duration of wakefulness exceeded the normal daily amount (16 hours; Blatter et al., 2005).

Lucassen et al., (2014) examined the effects of partial sleep deprivation on executive functioning in obese individuals. These authors conceptualized partial sleep deprivation as less than 6.5 hours of sleep per night. Sleep deprived individuals showed significant deficits in executive functions, as measured by the Wechsler Abbreviated Intelligence Scale (WASI), Rey Complex Figure Test, California Verbal Learning Test (CVLT – II), Grooved Pegboard (GPeg), Wisconsin Card Sort (WCST), Trail Making Test (TMT), Verbal Fluency Test (FAS), and the Iowa Gambling Task. The sample was then retested after a remedial period of improved sleep quality and executive function deficits were partially ameliorated. Sleep quality, according to this study, appears to be a significant factor of optimal executive functioning. The test battery included was fairly comprehensive, but a test was not included that specifically targeted planning and decision making.

Attention may underlie behavioral diminishment in sleep deprived people (Blatter et al., 2005). Attention is required for the proper execution of a behavior and, especially in complex tasks, performance is non-optimal if attention is disrupted or dysfunctional (Blatter et al., 2005). In sleep deprived shift workers, increasingly difficult or complex tasks are completed less efficiently and with lower accuracy (Bonnefond et al., 2003; Lythe, Williams, Anderson, Libri, & Mehta, 2012). One explanation for these reductions in performance is that higher-order tasks require higher attention and memory loads (Bonnefond et al., 2003). Brain activation during working memory tasks include the fronto-parietal network (Lythe et al., 2012). The VLPFC, in rested wakeful states, is activated during working memory tests, but in sleep deprived individuals this area fails to engage no matter the difficulty of the measure (Lythe et al., 2012).

Partial sleep deprivation negatively affects alertness and sustained attention. Lo et al. (2012) examined the effects of partial sleep deprivation and circadian rhythmicity on cognitive processes. Their results suggest that alertness and attention are impacted in a much greater degree than executive functions. These authors hypothesized that the circadian rhythms mediate this effect, as executive functions are minimally impacted depending on the time of day in which the test is administered. Performance on tasks that are given during work maintenance zones (evening times) are more resistant to errors than are those that are presented during morning hours when the brain is more susceptible to the effects of sleep loss (Lo et al., 2012). Bratzke, Steinborn, Rolke, and Ulrich (2012) found discrepant results, with their longitudinal sample demonstrating insignificant differences on the Stroop Task and on a Psychomotor Vigilance Task throughout a continuous 40-hour state of wakefulness. Such differences are likely due to tasks and the associated constructs that were administered.

The association between task complexity and partial sleep deprivation was assessed by Jiang et al. (2011). Adolescents and young adults who experienced partial sleep deprivation over a five-day period and subsequently were asked to perform a working memory tasks had impaired functioning. These authors note another interesting finding: Young adults reported an earlier and significantly higher subjective sleepiness score than did the adolescent group. In working memory tasks, both total sleep deprivation and partial sleep deprivation adversely impact sustained attention (Drummond et al., 2005). However, it has been postulated that sufficient executive functioning can be maintained up to four days of partial sleep deprivation (Drummond et al., 2005). As reported in numerous studies, adolescents and young adults chronically exhibit poor sleep hygiene, as indicated by varying sleep and wake times between weekdays and weekends (Brown et al., 2002; Buboltz et al., 2001; Knowlden et al., 2012). As consecutive days of partial sleep deprivation rise, the important executive functions, such as planning, decision making, and sustained attention are likely to show increased dysfunction.

Decision-making is impaired after significant periods of sleep deprivation. Ratcliff and Van Dongen (2009) found that participants who had been in a state of continuous wakefulness for 62 hours were impaired on a two-choice numerosity discrimination task (decision making task), and that they adopted more conservative decision criteria. These authors suggest that the more conservative approach in decision making stems from a need to compensate for less efficient processing of visual stimuli. Individuals who are sleep deprived also have a tendency to make more random responses (Ratcliff & Van Dongen, 2009). In an assessment of partial sleep deprivation and cognitive performance, Neu et al. (2011) found lower performance on a symbol span test and on a finger tapping test. These deficits due to partial sleep deprivation, in this case less than five hours of sleep, indicate disruptions in sustained attention, visual scanning, response time, and motor speed. Sleep deprivation, either total or partial, has detrimental effects on various cognitive processes, including executive functions. Such deficits are likely based in the neurobiology of the brain, as the PFC is susceptible to lack of sleep more than other areas (Tucker et al., 2010).

Poor planning and decision making is found in individuals who have been sleep deprived for 49 hours (Killgore et al., 2006). Planning and decision making strategies become more disadvantageous as sleep deprivation increases (Killgore et al., 2006). A potential explanation is that sleep deprived individuals may be less able to weigh short-term gains against greater long-term costs (Killgore et al., 2006). Such changes in decision-making indicates a short-sightedness and exhibits a preference for smaller, short-term gains over delayed, yet greater rewards (Killgore, Grugle, & Balkin, 2012). The decreased blood-flow to the prefrontal cortex during sleep deprivation (Thomas et al., 2000) inhibits the proper functioning of this area, which in turns leads to deficits in executive functions, such as planning and decision-making.

Impulsivity and disinhibition increase as the amount of time in wakefulness increases (Anderson & Platten, 2011). Disinhibition towards negative stimuli is more pronounced in individuals who have been deprived of sleep for 36 hours (Anderson & Platten, 2011). Individuals who have experienced severe sleep loss are increasingly inept at inhibiting inappropriate responses and are quicker to make rash, incorrect or maladaptive decisions (Anderson & Platten, 2011). Adequate planning and carrying-out decisions made are necessary skills in vocational and academic realms. Individuals who are sleep deprived are more likely to not plan ahead and to be short-sighted (over-focus on immediate rewards) in the decisions that they make. Such inadequacies are likely to have significant impacts on educational and occupational pursuits.

Results surrounding sleep deprivation and executive functioning have been mixed (Tucker et al., 2010). In one study, participants were subjected to 51 hours of total sleep deprivation and their performance was then measured on a number of executive and non-executive tasks (Tucker et al., 2010). In this controlled experiment, overall performance on a modified Sternberg task showed significant impairments, but the deterioration was most prominent in the non-executive functions (i.e., reaction time). However, even reaction times can be related to goal directed behaviors (Jung et al., 2011) and are therefore likely grounded in executive processes. Working memory scanning efficiency remained intact during the study. Furthermore, these authors found improvements, which were above those found in the control group, in the sleep deprived group on a verbal fluency task. These findings suggest that individuals in sleep deprived conditions may rely more heavily on executive functions, summoning greater effortful control and inhibition of habitual responses. Reaction times were slower, but error rates remained low, denoting increased recruitment of executive processes. In another study conducted by Hsieh and colleagues (2007), no differences in reaction time and response accuracy were found between states of regular sleep and sleep deprivation. However, when stimuli were dissimilar from targets, longer error correction times were noted in sleep deprived individuals. The authors suggest that during error correction tasks the frontal lobe must correct inappropriate responses to incongruent stimuli and that deficits in frontal lobe functioning due to sleep deprivation are a probable mechanism for this finding.

Executive functions can be affected by sleep loss, yet executive processes appear to differ in their susceptibility to it (Bratzke at al., 2009). Task-switching, which is considered a fundamental executive function (Miyake et al., 2000), becomes less efficient after total sleep deprivation (Bratzke et al., 2009). Switch-costs increase as the amount of time of sleep deprivation rises. This finding suggests that the ability to multi-task, or selectively attend to different stimuli, takes greater effort and is less efficient after sleep loss.

The literature on sleep deprivation and executive functions show some discrepancy, but a number of studies indicate that deficits in these higher-order processes occur after significant sleep deprivation (≥36 hours). Greater recognition in sleep deprivation studies has been given to chronotype preferences, which has afforded more insight into the relationship between these variables. However, a review of the literature on partial sleep deprivation and executive functioning elucidates a dearth of findings on these constructs. Additionally, recommendations from many authors include the need to use more than two testing times throughout the day to best assess the effects of morningness-eveningness traits. From an ecological validity standpoint, examining the impact of partial sleep deprivation on executive functions would be more generalizable to real-life situations, including academic performance and occupational functioning. Accordingly, the aim of this study is to assess the impact of partial sleep deprivation and chronotype on executive functioning. Based on the preceding, the following hypotheses will be tested in the research on a sample of young adults.

Hypotheses

Hypothesis 1a. Students who have poor sleep quality will score significantly lower when compared to students who get quality sleep on planning and decision making, as measured by the Tower of London task, across three testing times throughout the day.

Hypothesis 1b. Students who have poor sleep quality will score significantly lower when compared to students who get good quality sleep on a sustained attention task, as measured by the Sustained Attention to Response Task, across three testing times throughout the day.

Hypothesis 2a. Morning-type students will score significantly better on a planning and decision-making task, as measured by the Tower of London, in the morning compared to individuals who identify as evening-type.

Hypothesis 2b. Morning-type students will score significantly better on a sustained attention task, as measured by the Sustained Attention to Response Task, in the morning compared to individuals who identify as evening-type.

Hypothesis 3a. Evening-type students will score significantly better on a planning and decision-making task, as measured by the Tower of London, in the evening compared to individuals who identify as morning-type.

Hypothesis 3b. Evening-type individuals will score significantly better on a sustained attention task, as measured by the Sustained Attention to Response Task, in the evening compared to individuals who identify as morning-type.

Hypothesis 4a. Chronotype preference and sleep quality will have an interaction effect on planning and decision-making, as measured by the Tower of London task, throughout the wake-cycle.

Hypothesis 4b. Chronotype preference and sleep quality will have an interaction effect on sustained attention, as measured by the Sustained Attention to Response Task, throughout the wake-cycle.

CHAPTER 2

Method

Participants

One hundred and five undergraduate students in introductory psychology courses at a southern university completed a paper-based survey assessing sleep quality and morningness/eveningness preference, in addition to two computerized executive function tasks. The mean age for the sample was 20.7 years, a standard deviation of 5.8, with a range from 18 to 68. Sixty-one percent of the sample was female (n = 64). Diversity was noted in the sample, with 81% identifying as Caucasian, 13.3% as African American, 2.9% as Latino, 1.9% as Asian, and 1% as other. Furthermore, with undergraduate classes being the focus of recruiting efforts, 40% of the sample were freshman students, 29.5% were sophomores, 20% were juniors, 7.6% were seniors, and 2.9% did not denote a year classification.

Instruments

A sociodemographic questionnaire, developed by the researcher, was included in the survey packet. This survey included questions regarding the participants age, race, gender, year in school, high school (GPA), current (GPA), household income, desired level of education, and current employment status. Participants were also asked to report the time they went to bed the previous night and the time they woke up in the morning.

On the sociodemographic questionnaire, participants recorded their usual bed time and wake time.

Pittsburgh Sleep Quality Index. The Pittsburgh Sleep Quality Index (PSQI), developed by Buysse, Reynolds, Monk, Berman, and Kupfer (1989), is a self-report measure that assesses overall sleep quality and some of its various components. It consists of 19 items, from which 7 component scores can derived. Examples of questions are: "During the past month, when have you usually gone to bed at night" (Subjective sleep quality) and "During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity" (daytime dysfunction; Buysse et al., 1989). Investigation into the understandability of the items included in the PSQI have shown that questions are simple, easy to understand, and easy to respond to (Buysse et al., 1989). Open-ended questions are included, which request normal bed time, how many minutes it takes the examinee to fall asleep, normal wake time, and total number of hours slept per night. Items five through nine have responses that are rated from 0 (not during the past month) to 3 (three or more times per week). The component scores that are calculated from the PSQI are identified as subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component score is weighted on a 0 to 3 scale. These seven component scores are then totaled into a global score with a range of 0 to 21, with higher scores indicating a higher frequency of sleep dysregulation. Scores greater than 5 are considered indicative of sleep disturbances and poor sleep quality (Buysse et al., 1989; Pilcher, Ginter, & Sadowsky, 1997). Additionally, a score greater than 5 signifies that the individual has sleep difficulties in at least two of the measured components (Buysse et al., 1989; Pilcher et al., 1997).

The PSQI has sound psychometric properties. Cronbach's alpha is 0.83, showing good internal consistency and that each component score factors into an overall construct of sleep quality (Buysse et al., 1989). Habitual sleep efficacy and subjective sleep quality were found to correlate significantly with global score ($r = 0.76$ for each), whereas the weakest correlation for the global score was found for sleep disturbances ($r = 0.35$; Buysse et al., 1989). The average correlation coefficient between the global sleep quality score and the components was 0.58 (Buysse et al., 1989). The PSQI has also demonstrated high test-retest reliability with scores relatively stable across testing times (Buysse et al., 1989). This measure has also demonstrated effectiveness in discriminating between "good" sleepers and "poor" sleepers which denotes excellent validity (Buysse et al., 1989).

The Adult Sleep-Wake Scale. The Adult Sleep-Wake Scale (ADSWS) is another measure of overall sleep quality (Fortunato, Lebourgeois, & Harsh, 2008). This measure consists of 25 items, which are rated along a 6-point Likert-type scale. For all but five items, the following scale anchors were used: 1 (*never*) to 6 (*always*; Fortunato et al., 2008). The other five items, are also rated along a 6-point Likert-type scale and the anchors range from 1 (< 15 min) to 6 (> 90 min; Fortunato et al., 2008). Examples of items include, "After waking up during the night, I roll over and go right back to sleep" and "How long does it usually take you to go back to sleep after waking during the night" (Fortunato et al., 2008).

Fortunato and colleagues (2008) found that the ADSWS promotes a 5-factor structure, with the five dimensions identified as Going to Bed, Falling Asleep, Maintaining Sleep, Reinitiating Sleep, and Retuning to Wakefulness. Each subscale consists of five items (Fortunato et al., 2008). These five factors were also found to explain a significant portion of the variance, between 69% and 73%, as it relates to sleep quality (Fortunato et al., 2008). Fortunato et al. (2008) demonstrated that the 5-factor model of the ADSWS has adequate internal reliability, as the Cronbach's alphas for the subscales were found to be .89 (Going to bed), .88 (Falling Asleep), .87 (Maintaining Sleep), .93 (Reinitiating Sleep), and .86 (Returning to Wakefulness). Test-retest reliability ranged from 0.67 to 0.82, which denotes satisfactory consistency across administration times. Furthermore, the ADSWS is useful in distinguishing poorer sleep quality in individuals who experience work related stress and strain, as well as other clinical conditions such as depression, compared to those who experience greater positive affect (Fortunato et al., 2008).

Morningness-Eveningness Questionnaire. The Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976) is a self-report survey that includes 19 items relating to preferred times to wake-up and go to bed and optimal times of physical and mental performance and alertness (Selvi et al., 2007). This assessment tool is commonly used to measure morningness and eveningness attitudes (Cavallera et al., 2011). The MEQ yields scores that range from 16 to 86, with higher scores suggesting a morning preference (Bennett et al., 2008; Killgore, 2007; Selvi et al., 2007). A cut-off of 59 and above denotes a morning chronotype and a score of 41 or below suggests an evening preference (Bennett et al., 2008; Selvi et al., 2007). Alternative cutoff scores were suggested by Taillard, Philip, Chastang, and Bioulac (2004), with evening types scoring under 53 and morning types scoring above a 64, with those scoring in-between these cutoffs being classified as "neither type". However, Killgore (2007) suggests a cut-off score of 54 adequately identifies morning and evening types. This will be the cut-off score used in the current study. The Morningness-Eveningness Questionnaire is a self-report measure has been found to effectively measure chronotype (Bennett et al., 2008).

Sustained Attention to Response Task. The Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) is a computerized task that is a widely used tool to assess failures in sustained attention or vigilance (Smilek, Carriere, & Cheyne, 2011). This test of attention has ecological validity, as it relates to real-world problems of vigilance (Smilek et al., 2011). A distinguished feature of the SART is that it develops a habitual response pattern by requiring that the automatic response set be the "default" condition (Smilek et al., 2011). This requires continuous responding from the participant (Cheyne, Carriere, & Smilek, 2006). During the task, a series of numbers (1 through 9) is presented to the participant and he or she is asked to respond to the series, or withhold a response if a NOGO digit appears (the appearance of an infrequent critical digit; Cheyne et al., 2006; Smilek et al., 2011). Responses are made by pressing a key whenever the presented digit is not the infrequent critical digit (Cheyne et al., 2006). This approach to measuring sustained attention is intended to assess for transient lapses in attention (Cheyne et al., 2006). The SART takes roughly four and a half minutes to complete (Robertson et al., 1997). Digits are presented for 250 msec (Robertson et al., 1997) followed by a masking period which allows for the making or inhibiting of a response. The period of time from one digit appearance to the next is roughly 1150 msec (Robertson et al., 1997).

Individuals who report greater difficulties in maintaining attention perform more poorly on the SART (Robertson et al., 1997). This test has excellent face validity (Cheyne et al., 2006) and test-retest reliability (Robertson et al., 1997; Smilek et al., 2011). During the SART, faster reaction times are related to lapses in attention because quicker responses are indicative of habitual responses (Cheyne et al., 2006). The SART correlates with other measures of attention (i.e. the attention-related cognitive errors scale [ARCES] and the Mindful Attention Awareness Scale [MAAS]; Cheyne et al., 2006). Errors of commission and omission are also recorded (Cheyne et al., 2006) and these will be used as outcome variables for the current study.

Tower of London. The Tower of London (TOL) is a performance-based instrument (MacAllister et al., 2012) that measures various aspects of executive functions (Albert & Steinberg, 2011; Cazalis et al., 2003; Fimbel, Lauzon, & Rainville, 2009; MacAllister et al., 2012; Rainville, Lepage, Gauthier, Kergoat, & Belleville, 2012). Neuroimaging studies have found that the TOL activates the DLPFC, with greater activation occurring on the left side (Cazalis et al., 2003). Originally, the TOL was created to assess the degree of deficits in planning in patients with frontal lobe injury (Fimbel et al., 2009; Shallice, 1982). The TOL is now frequently employed as a task that measures planning or problem-solving strategies (Rainville et al., 2012). Other research projects have generalized the usefulness of the TOL and its assessment of planning by using it to measure other executive functions, including goal-directed behavior (Lezak et al., 2004), inhibitory processes (Rainville et al., 2002), and working memory performance (Baker et al., 1996). The TOL also provides a timed aspect for the trials and can therefore be used to measure processing speed and efficiency in solving novel problems (MacAllister et al., 2012).

The TOL has shown clinical validity and reliability (MacAllister et al., 2012; Rainville et al., 2012). An advantage of using the TOL in assessing executive functions is that it is a non-verbal task that does not necessitate complex verbal abilities; as long as the participant can understand the verbal/written instructions then TOL is an appropriate assessment tool (Rainville et al., 2012). It has been postulated that the TOL has been used in the most informative research which assesses planning, problem-solving, and goal-oriented behaviors (Albert & Steinberg, 2011). This instrument distinguishes behaviors associated with mild cognitive impairments (MCI), showing a lack of self-monitoring, and more rule-breaking behaviors in those with MCI (Rainville et al., 2012). The TOL has been found to detect deficits in executive functions better than self-report measures, such as the Behavioral Rating Inventory of Executive Functions (MacAllister et al., 2012).

The TOL is a variation of the Tower of Hanoi (Rainville et al., 2012) and was developed by Shallice (1982). In the original TOL, participants were presented with a test instrument that contained three rods and three differently colored balls in variable arrangements, with the objective of matching another test instrument that consisted of a goal-state (Albert & Steinberg, 2011; Shallice, 1982). In this study, a computerized-based version will be used. In it, the participant is shown a goal instrument and a game instrument, each showing a distinct distribution of the three differently colored balls. The subject is instructed to move the balls on the game instrument to match the configuration of the balls on the goal instrument. Furthermore, the participant is asked to match the game set to the goal set in as few of moves as possible. On the computerized version, the balls are selected, dragged, and dropped by clicking and moving the mouse. The TOL consists of five sets of four problems, beginning with problems that can be solved in as few of three moves and ending in problems that require a minimum of seven moves. A global score, with a maximum of 36, is calculated based on the number of moves that a subject makes in order to replicate the model design. A higher score, or the closer the subject's score approaches 36, reflects a correct replication with fewer moves required. The time to complete the task is also measured. The global, or performance score, and the time needed to complete the task will be outcome variables for the current study.

Procedure

Participants for this study were university students and were able to give informed consent. After approval from the Institutional Review Board (IRB), participants were recruited through in-class presentations of the study. Class presentations were approved by and coordinated with the instructor and included a brief description of the nature of the study. Some of the course instructors offered extra credit for those that participated in the study, in addition to an alternative extra credit opportunity for those that did not participate. The paper-based survey, which consisted of the sociodemographic questionnaire, the Pittsburgh Sleep Quality Index, the Adult Sleep/Wake Scale, the Sleep Hygiene Index, and the Morningness/Eveningness Questionnaire took approximately 20 minutes to complete. The computerized sustained attention (SART) and planning and decision making (TOL) tasks required another 15 minutes of the participant's time at each assessment period throughout the day.

Students who volunteered during a class announcement were provided a schedule with available days and the required task administration times to select the day that best fit into their schedules. Testing days were conducted on Tuesdays, Thursdays, and Fridays throughout the week. Participants were required to complete the computerized assessments at three different times throughout the day on the day that they elected to participate in the study. Times at which sustained attention and planning and decision-making tasks were administered were between 0700 - 0800, 1200 - 1300, and 1600 - 1700 hours, or morning, midday, and evening, respectively. On their selected day, participants were presented with the informed consent document and were given time to read through the form. No penalties or adverse consequences were applied to those who withdraw from the study at any time during the recruitment or administration process. Once informed consent was given, the participant began the study by filling out the survey packet that included the demographic questionnaire, the Pittsburgh Sleep Quality Index, the Adult Sleep/Wake Scale, the Sleep Hygiene Index, and the Morningness/Eveningness Questionnaire. After the completion of the survey packet, participants were instructed to log onto a computer and were provided instructions on the projector screen in the lab for opening and completing the SART and TOL. Once the initial trial was completed, the participants were reminded via verbal instruction to return to the lab and complete the executive function tasks at the two other assessment times during that day.

Analyses

Hypothesis 1a: A MANOVA was conducted in order to compare students who had poor sleep quality and high sleep quality on an executive function task (TOL) that measured planning and decision making at three testing times throughout the day.

Hypothesis 1b: A MANOVA was conducted in order to compare students who had poor sleep quality and high sleep quality on a sustained attention task (SART) at three testing times throughout the day.

Hypothesis 2a: A MANOVA was conducted in order to compare morning-type and evening-type students on an executive function task (TOL) that measured planning and decision making abilities during a morning time administration.

Hypothesis 2b: A MANOVA was conducted in order to compare morning-type and evening-type individuals on a sustained attention task (SART) during a morning time administration.

Hypothesis 3a: A MANOVA was conducted in order to compare morning-type and evening-type students on an executive function task (TOL) that measured planning and decision making abilities during an evening time administration.

Hypothesis 3b: A MANOVA was conducted in order to compare morning-type and evening-type students on a sustained attention task (SART) during an evening time administration.

Hypothesis 4a: A MANOVA was conducted to compare students on sleep quality and chronotype preference on an executive function task (TOL) that measured planning and decision making during three testing times throughout the wake cycle.

Hypothesis 4b: A MANOVA was conducted to compare students on sleep quality and chronotype preference on a sustained attention task during three testing times throughout the wake cycle.

CHAPTER 3

Results

Data were de-identified and an ID number was assigned to participants in order to maintain participant confidentiality and connect the results on the survey packet to the outcomes of the TOL and SART. Data was screened for missing values. Cases that had more than 10% of data missing ($n = 5$), were not included in the final analyses. Cases with other missing data appeared to be randomly distributed, so a mean substitution method was used to include such data in the analysis. According to Tabachnick and Fidell (1983), using mean substitution is an appropriate method to handle random missing data. It is further suggested that using demographic variable(s) to calculate means is one method to increase the appropriateness and suitability of the mean substitution to the sample. This recommendation was adhered to, and in the current sample gender, was the demographic variable used to calculate variable means and the corresponding mean was inserted into missing data points for the TOL. The PSQI was scored and global scores were used as a measure of sleep quality according to the guidelines of Buysse et al. (1989). The cutoff score of 5 was used to delineate good sleepers from poor sleepers. The number of students identified as good quality sleepers ($n = 51$) was roughly equal to those identified as poor quality sleepers ($n = 46$). Part of the equation in determining sleep quality includes the subscale of sleep duration, which is an assessment of partial sleep deprivation. In the current sample, 48 students (49.5%) indicated that they slept at least seven hours per night, 33 (34.0%) indicated that they slept between six and seven hours per night, 11 (11.3%) indicated that they slept between five and six hours per night, and five (5.2%) indicated that they slept less than five hours per night. The MEQ was totaled, as described by Horne & Ostberg (1976), and the cutoff score of 54 was used to distinguish between morning and evening types (Killgore, 2007). In the current sample, there were significantly more students who identified as evening-types (n = 81) compared to those that identified as morning-types (n = 16). With the data entered into SPSS, and random checks per variable to ensure data was entered properly, exploratory descriptive analyses were conducted to assess for normality, outliers, and the measures of central tendency.

One-way ANOVAs were conducted to determine if there were differences between morning-types and evening-types, and good quality sleepers versus bad quality sleepers, on caffeine consumption throughout the week. Results indicated that there was not a statistically significant difference between the chronotypes on caffeine consumption, $F(1,90) = .101, p = .751$. A statistically non-significant difference was also found between the sleep quality groups on caffeine consumption, $F(1,90) = 2.167, p = .144$.

The TOL outcome variables are a total score and a time for completion of each administration. The following number of values were substituted with gender means due to missing data points on the TOL for overall performance: two for the morning administration (one male and one female), one for the midday administration (male), and one for the evening administration (male). The time to complete each TOL task was also recorded, and the following number of missing data points were substituted with gender mean scores: one for the morning administration (female), one for the midday administration (male), and two for the evening administration (one male and one female).

Differences between the genders on the TOL dependent variables of overall performance and time for each administration were assessed. The assumption of homogeneity of variance was not violated, as indicated by the Levene's statistic. For the morning administration, the variances were equal between the genders on overall score, $F(1,99) = .107, p = .744$ and time, $F(1,99) = .285, p = .595$. On the midday administration, the variances were equal between the genders on overall score, $F(1,99) = 2.074, p = .153$ and time, $F(1,99) = 2.697, p = .104$. Equal variances between the genders on overall score and time for the evening administration, $F(1,99) = 3.357, p = .070$ and $F(1,99) = .164, p = .686$, respectively, were also observed.

TOL outcome variables were assessed for normality. Initial exploratory analyses of the Tower of London performance scores indicated that the assumption of normality was violated, as indicated by the Kolmogorov-Smirnov test and by calculating skewness and kurtosis z-scores using the corresponding statistic and standard error measurement. Exploratory analyses, including measuring Mahalanobis distance, with a critical value of χ^2 at $p < .001$ and $df = 6$, identified three significant outliers. These outliers were omitted from further analyses. The removal of the significant outliers improved the skewness and kurtosis statistics, but the Kolmogorov-Smirnov tests were still significant for the performance score and task time for each administration. On the morning administration of the TOL, $D(101) = .110, p = .004$, and $D(101) = .109, p = .005$ for overall score and time, respectively. For the midday administration, $D(101) = .165, p < .001$, and $D(101) = .143, p < .001$ for overall score and time, respectively. Finally, for the evening administration, $D(101) = .210, p < .001$, and $D(101) = .089, p < .001$, for overall score and time, respectively. Log and square root transformations were completed, but the results did not significantly affect the distribution of scores across the TOL; therefore, un-transformed data was used for the analyses associated with the various hypotheses. MANOVA, and the F statistic, is robust to violations of normality, as long as non-normality is not being influenced by outliers (French, Macedo, Poulsen, Waterson, & Yu, 2008).

The SART yields measurements of errors of commission and omission. For the final analysis, to assess for lapses in attention, the number of errors of commission and omission were used as dependent variables. Mean substitution by gender was the method used in the event of missing data. More missing data was noted on the SART, primarily due to the program not correctly storing participant scores. This was noted immediately after the participant had been administered the task, but in order to avoid changing the protocol, the participant was not allowed to re-take the task during the time of administration when the results failed to store. During the morning administration, there were six incidents of missing data, for both errors of commission and omission. During the midday administration, there were two incidents of missing data on the outcome variables, and during the evening administration, there were six cases where data were missing. In assessing for normality, only the midday administration for both errors of commission and omission violated the assumptions of skewness and kurtosis, $D(101) = .103, p = .011$, and $D(101) = .111, p = .004$ for errors of commission and omission, respectively. Homogeneity of variance was equal between the genders during the morning administration of the SART, $F(1,99) = .155, p = .695$, and $F(1,99) = .487, p = .487$ for errors of commission and omission respectively. For the midday administration, the variance was equal between the genders for errors of commission and omission, $F(1,99) = .537, p = .465$, and $F(1,99) = .201, p = .655$. On the evening administration, the assumption of homogeneity of variance was also met between the genders for both errors of commission and omission, $F(1,99) = .000, p = .982$, and $F(1,99) = .045, p = .832$.

Scatter plots were created to assess linearity. In examining the scatter plots, TOL outcome variables and SART outcome variables showed adequate linearity. Box's statistic was calculated to address the assumption of homoscedasticity. This assumption was violated for the TOL outcome variables and the independent variables of sleep quality and chronotype preference, $F(42,2244.051) = 1.399, p = .047$. Box's statistic for the SART outcome variables and the independent variables of sleep quality and chronotype preference was also significant, $F(42,2244.051) = 2.840, p < .001$. Although violations of assumptions occurred in the data, MANOVA is a statistical test that is robust to violations with ample sample size, such as non-normality, even when group sample sizes are unequal (Mertler & Vannatta, 2010). The current sample size of 97, with 16 being the cell with the smallest sample size (morning-identified individuals) can be considered large enough to ensure robustness to the above mentioned violations.

Data were entered into SPSS and an exploratory descriptive analyses were conducted, as noted above, in order to determine whether or not the basic assumptions of parametric tests were met. Although the assumptions of normality and homogeneity of variance were violated, due to the robustness of MANOVA with sufficient sample size, the following analyses were conducted to test the hypotheses proposed in this study. A correlational analysis was conducted, and a number of significant correlations were found. See Table 1 for results of correlation analysis.

Table 1
Correlational analysis results

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. PSQI														
2.MEQ	-.177													
3.TOL1	.111	.119												
4.TOL2	**.204***	-.031	**.313****											
5. TOL3	-.036	-.094	**.307****	**.335****										
6.TOLTM 1	-.027	.062	**-.333****	-.079	.037									
7. TOLTM2	.030	.124	-.033	**-.253***	.075	**.448****								
8. TOLTM 3	**.228***	-.006	-.065	.037	**-.232***	**.364****	**.509****							
9. SARTCOM1	.024	-.021	-.077	-.011	-.026	-.024	-.062	**-.170**						
10. SARTOM1	-.046	.073	.086	-.018	.078	.074	**.204***	.180	**-.869****					
11. SARTCOM2	.078	-.133	-.161	-.086	**-.266****	-.123	-.185	-.155	**.506****	**-.549****				
12. SARTOM2	-.074	.191	.057	-.071	-.051	.096	.143	**.225***	**-.528****	**.481****	**-.750****			
13. SARTCOM3	.049	.047	-.098	.042	**-.269****	-.035	-.121	-.106	**.439****	**-.484****	**.676****	**-.508****		
14. SARTOM3	0.13	.000	.114	-.069	.143	.030	.136	.132	**-.449****	**.498****	**-.590****	**.563**	**-.826****	

Note: * $p < .05$., ** $p < .01$.
PSQI (Pittsburgh Sleep Quality Index)
MEQ (Monrningness/Eveningness Questionnaire)
TOL1,2,3 (TOL performance score at morning, midday, and evening times, respectively)
TOLTM1,2,3 (TOL completion times at morning, midday, and evening times, respectively)
SARTCOM1,2,3 (Errors of commission at morning, midday, and evening, respectively)
SARTOM1,2,3 (Errors of omission at morning, midday, and evening, respectively)

Hypothesis 1a

Hypothesis 1a stated that students who have poor sleep quality would score significantly lower compared to students who get good quality sleep on planning and decision making tasks, as measured by the Tower of London task, during three testing times throughout the day. A MANOVA was conducted to determine the effect of sleep quality on planning and decision-making as measured by the TOL total score and time of completion for each administration throughout the wake-cycle. Box's statistic was significant, $F(21,32439.89) = 2.053$, $p = .003$, indicating that the assumption of heteroscedasticity was violated. Due to the violation of normality assumptions, Pillai's Trace, which is considered to be the most powerful and robust *F* statistic (Carey, 1998), was used to interpret the results. The main effect of sleep quality (Pillai's Trace) $F(6,90) = 1.971$, $p = .078$, multivariate $\eta^2 = .116$, indicates a non-significant effect on the combined outcome variables of the TOL.

An examination of the between-subject effects revealed with greater specificity the nature of the effect of sleep quality on planning and decision-making abilities. The difference between good quality sleepers and poor quality sleepers on the performance score during the morning session was non-significant, $F(1,95) = .947$, $p = .333$, $\eta^2 = .010$. A significant difference was observed between good sleepers and poor sleepers on the TOL performance score during the mid-day administration, $F(1,95) = 6.788$, $p = .011$, $\eta^2 = .067$. The difference between students with good sleep quality and poor sleep quality on the TOL performance score was non-significant during the evening, $F(1,95) = .040$, $p = .842$, $\eta^2 = .000$. No statistically significant difference was noted between good quality sleepers and poor sleepers on the time to complete the TOL in the morning, $F(1,95) =$

.140, p = .709, η^2 = .001. A statistically non-significant difference between students with good sleep quality and poor sleep quality was found between these groups on the time required to complete the TOL during the mid-day administration, $F(1,95) = .801$, p = .373, η^2 = .008. The final comparison between good sleep quality and poor sleep quality on the time needed to complete the TOL, which occurred during the evening, was non-significant, $F(1,95) = 1.725$, $p = .192$, $\eta^2 = .018$. Table 2 presents the group means and standard deviations for sleep quality and TOL outcome variables. This hypothesis was partially supported; poor sleepers during the mid-day administration performed significantly better than their good sleep counterparts.

Table 2

MANOVA means, standard deviations, and N values for sleep quality groups on TOL

	Mean	*SD*	*N*
TOL1 Good sleep	30.21	3.56	51
Bad sleep	30.89	3.34	46
Total	30.53	3.46	97
TOL2 Good sleep	30.94	3.82	51
Bad sleep	32.66	2.46	46
Total	31.76	3.35	97
TOL3 Good sleep	33.41	2.30	51
Bad sleep	33.31	2.81	46
Total	33.36	2.54	97
TOLTM1 Good sleep	449722.52	115083.39	51
Bad sleep	460184.78	159045.34	46
Total	454684.00	137050.42	97
TOLTM2 Good sleep	315111.90	81729.95	51
Bad sleep	331875.27	102470.51	46
Total	323061.54	92042.50	97
TOLTM 3 Good sleep	268959.18	52664.64	51
Bad sleep	286761.14	79357.45	46
Total	277401.34	66905.95	97

TOL1,2,3 (TOL performance score at morning, midday, and evening times, respectively)
TOLTM1,2,3 (TOL completion times at morning, midday, and evening times, respectively)

Hypothesis 1b

Hypothesis 1b stated that students who have poor sleep quality would score significantly worse compared to students who get good quality sleep on a sustained attention task, as measured by the SART, during three testing times throughout the day. A MANOVA was conducted to determine the effect of sleep quality on sustained attention. Box's statistic was significant, $F(21,32439.894) = 2.326, p = .001$, which indicates a violation of the assumption of heteroscedasticity. Due to the violation of normality assumptions, Pillai's Trace was the statistic used to interpret the results. The main effect of sleep quality (Pillai's Trace) $F(6,90) = .601, p = .729$, multivariate $\eta^2 = .039$, indicates that sleep quality does not have a significant effect on sustained attention throughout the wake-cycle. This hypothesis was not substantiated; analyses indicate that students who have poor sleep quality did not commit significantly more errors of commission and omission compared to those who report good quality sleep. Examination of the between-subject analyses did not yield any statistically significant differences between sleep groups and sustained attention throughout the wake-cycle. Table 3 presents the group means and standard deviations for sleep quality and SART outcome variables.

Table 3

MANOVA means, standard deviations, and N values for sleep quality groups on SART

	Mean	*SD*	*N*
EoC1 Good sleep	11.14	6.12	51
Bad sleep	12.08	5.96	46
Total	11.58	6.03	97
EoO1 Good sleep	15.42	5.67	51
Bad sleep	14.34	5.16	46
Total	14.91	5.43	97
EoC2 Good sleep	11.10	6.24	51

Bad sleep	13.07	6.02	46
Total	12.03	6.19	97
EoO2 Good sleep	15.88	5.62	51
Bad sleep	13.84	7.01	46
Total	14.91	6.37	97
EoC3 Good sleep	11.28	6.88	51
Bad sleep	13.12	6.45	46
Total	12.15	6.71	97
EoO 3 Good sleep	14.47	6.55	51
Bad sleep	13.32	6.07	46
Total	13.92	6.32	97

EoC1,2,3 (Errors of commission at morning, midday, and evening, respectively)
EoO1,2,3 (Errors of omission at morning, midday, and evening, respectively)

Hypothesis 2a

Hypothesis 2a stated that morning-type students would score better on a planning and decision-making task, as measured by the TOL, in the morning compared to individuals who identify as evening-types. A MANOVA was conducted to determine the effect of morningness/eveningness on planning and decision making abilities administered during the morning. Box's statistic was non-significant, $F(3,9333.230) = 1.455$, $p = .255$, indicating that homoscedasticity is assumed between morning-types and evening-types. The effect of morningness/eveningness on planning and decision-making during the morning was non-significant (Pillai's Trace), $F(2,94) = 1.605$, $p = .206$, $\eta^2 = .033$, indicating that morning-type individuals did not score significantly different than evening-type individuals on the TOL task. This hypothesis was not substantiated. Examination of the between-subjects results did not yield significant effects between chronotype preference and the TOL. Table 4 presents the means and standard deviations for chronotype preference and TOL outcome variables.

Table 4

MANOVA means, standard deviations, and N values for morningness/eveningness on TOL

	Mean	*SD*	*N*
TOL1 morning-type	31.87	3.56	51
Evening-type	30.89	3.34	46
Total	30.53	3.46	97
TOL2 morning-type	30.94	3.82	51
Evening-type	32.66	2.46	46
Total	31.76	3.35	97
TOL3 morning-type	33.41	2.30	51
Evening-type	33.31	2.81	46
Total	33.36	2.54	97
TOLTM1 morning-type	449722.52	115083.39	51
Evening-type	460184.78	159045.34	46
Total	454684.00	137050.42	97
TOLTM2 morning-type	315111.90	81729.95	51
Evening-type	331875.27	102470.51	46
Total	323061.54	92042.50	97
TOLTM 3 morning-type	268959.18	52664.64	51
Evening-type	286761.14	79357.45	46
Total	277401.34	66905.95	97

Hypothesis 2b

Hypothesis 2b stated that morning-type students would score significantly better on a sustained attention task, as measured by the Sustained Attention to Response Task, in the morning compared to individuals identified as evening-type. A MANOVA was conducted to determine the effect of morningness/eveningness preference on sustained attention during a morning administration of the SART. Box's *M* statistic was non-significant, $F(3,9333.230) = 1.091, p = .351$. The effect of morningness/eveningness preference on sustained attention in the morning was non-significant (Pillai's Trace), $F(2,94) = .848, p = .432, \eta^2 = .018$. The effect of chronotype on errors of commission, $F(1,93) = .068, p = .794, \eta^2 = .001$, was non-significant, indicating that morning type individuals did not commit fewer errors of commission compared to evening-types during the morning administration of the SART. The effect of chronotype on errors of omission was also non-significant, $F(1,93) = .429, p = .514, \eta^2 = .005$. This result indicates that students who identify as morning-type do not commit fewer errors of omission than to their evening counterparts. Table 5 presents the means and standard deviations for chronotype preference and SART errors of commission and omission during a morning administration.

Table 5

MANOVA means, standard deviations, and N values for morningness/eveningness on SART

	Mean	*SD*	*N*
EoC1 Morning	11.19	4.30	16
Evening	11.77	6.22	85
Total	11.68	5.95	101
EoO1 Morning	16.00	4.18	16
Evening	14.63	5.59	85
Total	14.84	5.39	101
EoC2 Morning	10.00	5.74	16
Evening	12.48	6.14	85
Total	12.09	6.12	101
EoO2 Morning	16.44	6.36	16
Evening	14.49	6.28	85
Total	14.80	6.30	101
EoC3 Morning	11.57	6.66	16
Evening	12.30	6.71	85
Total	12.19	6.67	101
EoO 3 Morning	14.56	6.00	16
Evening	13.72	6.40	85
Total	13.86	6.31	101

EoC1,2,3 (Errors of commission at morning, midday, and evening, respectively)
EoO1,2,3 (Errors of omission at morning, midday, and evening, respectively)

Hypothesis 3a

Hypothesis 3a stated that evening-types would score significantly better on a planning and decision-making task, as measured by the Tower of London, than those who identified as morning-types. A MANOVA was conducted to determine the effect of chronotype on planning and decision-making abilities during an evening task administration. Box's *M* statistic was non-significant, $F(3,9333.230) = .664, p = .574$. The effect of morningness/eveningness on the TOL during the evening was non-significant (Pillai's Trace), $F(2,94) = .051, p = .951, \eta^2 = .001$. as indicated by the global score, $F(1,93) = .111, p = .740, \eta^2 = .001$. Examination of the between-subject analyses also yielded non-significant results between morning-types and evening-types on the TOL performance score and time required to complete the task during the evening task administration. This hypothesis was not supported. Table 6 presents the means and standard deviations for chronotype preference and TOL outcome variables during the evening administration.

Table 6

MANOVA means, standard deviations, and N values for morningness/eveningness on TOL

	Mean	*SD*	*N*
TOL1 morning-type	31.87	3.56	51
Evening-type	30.89	3.34	46
Total	30.53	3.46	97
TOL2 morning-type	30.94	3.82	51
Evening-type	32.66	2.46	46
Total	31.76	3.35	97
TOL3 morning-type	33.41	2.30	51
Evening-type	33.31	2.81	46
Total	33.36	2.54	97
TOLTM1 morning-type	449722.52	115083.39	51
Evening-type	460184.78	159045.34	46
Total	454684.00	137050.42	97
TOLTM2 morning-type	315111.90	81729.95	51
Evening-type	331875.27	102470.51	46
Total	323061.54	92042.50	97
TOLTM 3 morning-type	268959.18	52664.64	51
Evening-type	286761.14	79357.45	46
Total	277401.34	66905.95	97

Hypothesis 3b

Hypothesis 3b stated that evening-types would score significantly better on a sustained attention task, as measured by the Sustained Attention to Response Task, in the evening than those who identified as morning-type. To test this hypothesis, a MANOVA was conducted to determine the effect of chronotype preference on errors of commission and omission. Box's *M* statistic was significant, $F(3,9333.230) = 2.789, p = .039$ indicating that the assumption of hetersoscedasticity was violated. Pillai's Trace was the *F*-statistic used to interpret the results. The results were non-significant, $F(2,94) = .094$, $p = .910$, $\eta^2 = .002$, indicating that evening-types did not differ on sustained attention from morning-types on an afternoon administration of the SART. Examination of between-subject results also yielded non-significant differences between morning-types and evening-types on errors of commission and omission during an evening administration of the SART. Examination of Table 7 presents the means and standard deviations for chronotype preference and SART errors of commission and omission during an evening administration.

Table 7

MANOVA means, standard deviations, and N values for morningness/eveningness on SART

	Mean	*SD*	*N*
EoC1 Morning	11.19	4.30	16
Evening	11.77	6.22	85
Total	11.68	5.95	101
EoO1 Morning	16.00	4.18	16
Evening	14.63	5.59	85
Total	14.84	5.39	101
EoC2 Morning	10.00	5.74	16
Evening	12.48	6.14	85
Total	12.09	6.12	101
EoO2 Morning	16.44	6.36	16

Evening	14.49	6.28	85
Total	14.80	6.30	101
EoC3 Morning	11.57	6.66	16
Evening	12.30	6.71	85
Total	12.19	6.67	101
EoO 3 Morning	14.56	6.00	16
Evening	13.72	6.40	85
Total	13.86	6.31	101

EoC1,2,3 (Errors of commission at morning, midday, and evening, respectively)
EoO1,2,3 (Errors of omission at morning, midday, and evening, respectively)

Hypothesis 4a

Hypothesis 4a stated that chronotype preference and sleep quality would have an interaction effect on planning and decision-making, as measured by the TOL, throughout the wake-cycle. A MANOVA was conducted to assess the interaction between morningness/eveningness preference, sleep quality, and planning and decision making abilities during the three TOL administrations throughout the wake-cycle. The results show a significant interaction, (Pillai's Trace) $F(6,88) = 4.132, p = .001$, multivariate $\eta^2 = .220$. ANOVA's were conducted to elucidate the nature of this interaction. An assessment of the between-subject analyses highlighted a number of significant interactions between chronotype preference, sleep quality, TOL administration times, and TOL outcome variables. Chronotype preference and sleep quality had a significant interaction for the overall score of the TOL during the morning administration, $F(1,93) = 11.080, p = .001, \eta^2 = .106$. Examination of the means for chronotype preference and sleep quality on the TOL global score for the morning administration indicates that morning types, who reported good sleep quality, had the highest mean score (mean = 33.50) and morning types who reported poor sleep quality had the lowest mean score (mean = 29.16). Evening types who reported poor sleep quality had the second highest global mean score during the morning administration of the TOL (mean = 31.15), and evening-types with good sleep quality had a mean score of 29.41. The time required to complete the TOL during the morning did not differ significantly between the sleep quality and chronotype groups, $F(1,93) = .060, p = .807, \eta^2 = .001$.

On the midday administration, significant group differences were noted on the global TOL score, $F(1,93) = 4.990, p = .028, \eta^2 = .051$. Morning-type students with good sleep quality recorded the highest mean score (mean = 33.20), evening-types with poor sleep quality recorded the second highest mean score (mean = 32.83), morning-types with poor sleep quality recorded the third highest mean score (mean = 31.67), and evening-type individuals with good sleep quality had the lowest mean scores (mean = 30.39). Time taken to complete the TOL during the midday administration was significantly different between the chronotype and sleep quality groups, $F(1,93) = 5.069, p = .027, \eta^2 = .052$. In examining the mean times of completion for the groups, morning types with good sleep quality completed the task the fastest (mean = 293703.90), evening types with good sleep quality had the second fastest mean time (mean = 320333.37), evening types with poor sleep quality had the third fastest mean time (mean = 320597.17), and morning types with poor sleep quality had the slowest mean completion time (mean = 408431.50).

The administration of the TOL in the evening further elucidated the interaction between chronotype and sleep quality. A MANOVA indicated a significant interaction on the TOL global score by sleep quality and morningness/eveningness, $F(1,93) = 4.263, p = .042, \eta^2 = .044$. Examination of mean group times on the TOL global score indicate that morning types with good sleep quality had the highest mean score (mean = 34.40), evening types with poor sleep quality had the second highest mean score (mean = 33.53), evening types with good sleep quality had the third highest mean score (mean = 33.17), and morning types with poor sleep quality had the lowest global mean score (mean = 31.83). Comparing the chronotype and sleep quality groups during the evening administration on the time needed to complete the TOL did not yield statistically significant results, $F(1,93) = .137, p = .712, \eta^2 = .001$. Table 8 presents the mean scores and standard deviations of the morningness/eveningness preference and sleep quality interactions on the TOL outcome variables for each task administration throughout the wake-cycle.

Table 8

MANOVA means, standard deviations, and N values for sleep quality, morningness/eveningness on TOL

	Sleep Quality	*MEQ*	*Mean*	*SD*	*N*
TOL1	Good quality	Morning	33.50	2.37	10
		Evening	29.41	3.35	41
		Total	30.21	3.56	51
	Poor quality	Morning	29.16	3.00	6
		Evening	31.15	3.35	40
		Total	30.89	3.34	46
	Total	Morning	31.87	3.33	16
		Evening	30.27	3.44	81
		Total	30.53	3.46	97
TOL2	Good quality	Morning	33.20	3.88	10
		Evening	30.39	3.65	41
		Total	30.94	3.82	51
	Poor quality	Morning	31.67	3.50	6
		Evening	32.83	2.83	40
		Total	32.68	2.46	46
	Total	Morning	32.63	3.70	16
		Evening	31.60	3.27	81
		Total	31.77	3.35	97
TOL3	Good quality	Morning	34.40	1.26	10
		Evening	33.17	2.44	41

		Total	33.41	2.30	51
	Poor quality	Morning	31.83	4.02	6
		Evening	33.53	2.58	40
		Total	33.31	2.81	46
	Total	Morning	33.44	2.83	16
		Evening	33.35	2.50	81
		Total	33.36	2.54	97
TOLTM1	Good quality	Morning	411559.50	73364.93	10
		Evening	458618.01	122042.55	41
		Total	449390.85	115066.93	51
	Poor quality	Morning	435844.50	119781.78	6
		Evening	463835.83	165053.81	40
		Total	460184.78	159045.34	46
	Total	Morning	420.666.38	90329.65	16
		Evening	461194.71	143996.28	81
		Total	454509.62	137049.71	97
TOLTM2	Good quality	Morning	293703.90	80619.55	10
		Evening	320333.37	82126.85	41
		Total	315111.90	81729.95	51
	Poor quality	Morning	408431.50	130642.42	6
		Evening	320597.17	94326.25	40
		Total	332053.82	102479.15	46
	Total	Morning	336726.75	113487.71	16
		Evening	320463.64	87806.21	81
		Total	323146.21	92055.24	97
TOLTM3	Good quality	Morning	261552.50	54426.03	10
		Evening	270765.68	52757.96	41
		Total	268959.18	52664.64	51
	Poor quality	Morning	291018.67	66200.30	6
		Evening	286222.55	81885.75	40
		Total	286848.13	79377.88	46
	Total	Morning	27602.31	58781.00	16
		Evening	278398.70	68709.46	81
		Total	277442.60	66923.16	97

Hypothesis 4b

Hypothesis 4b stated that chronotype preference and sleep quality would have an interaction effect on sustained attention, as measured by the number of errors of commission and omission on the Sustained Attention to Response Task, throughout the wake-cycle. A MANOVA assessed the interaction between chronotype and sleep quality on sustained attention. The results of this analysis indicate a non-significant interaction, (Pillai's Trace) $F(6,88) = .633, p = .704, \eta^2 = .041$. Tests of between-subject effects did not yield any significant interactions between chronotype preference and sleep quality on errors of commission and omission during three administration times of the SART throughout the wake-cycle. During the morning administration, the interaction between chronotype preference and sleep quality on errors of commission and omission was not statistically significant, $F(1,93) = .062, p = .803, \eta^2 = .001$ and $F(1,93) = .050, p = .823, \eta^2 = .001$, respectively. During the midday administration of the SART, there were no statistically significant interactions between morningness/eveningness preference and sleep quality on errors of commission and omission, $F(1,93) = .714, p = .400, \eta^2 = .008$ and $F(1,93) = 1.030, p = .313, \eta^2 = .011$, respectively. Finally, during the evening administration of the SART, there was not a statistically significant interaction between chronotype preference and sleep quality on errors of commission and omission, $F(1,93) = 1.413, p = .238, \eta^2 = .015$ and $F(1,93) = .527, p = .470, \eta^2 = .006$. Table 9 presents the mean scores and standard deviations of the morningness/eveningness preference and sleep quality interactions on the SART outcome variables for each task administration throughout the wake-cycle.

Table 9

MANOVA means, standard deviations, and N values for sleep quality, morningness/eveningness on SART

	Sleep Quality	*MEQ*	*Mean*	*SD*	*N*
EoC1	Good quality	Morning	11.10	4.56	10
		Evening	11.12	6.49	41
		Total	11.12	6.12	51
	Poor quality	Morning	11.33	4.27	6
		Evening	12.21	6.21	40
		Total	12.01	5.96	46
	Total	Morning	11.19	4.31	16
		Evening	11.66	6.34	81
		Total	11.58	6.03	97
EoO1	Good quality	Morning	16.20	4.34	10
		Evening	20.23	30.82	41
		Total	19.44	27.68	51
	Poor quality	Morning	15.67	4.27	6
		Evening	23.88	40.74	40
		Total	22.81	38.05	46
	Total	Morning	16.00	4.18	16
		Evening	22.04	35.88	81
		Total	21.04	32.87	97
EoC2	Good quality	Morning	8.40	4.60	10
		Evening	11.75	6.46	41
		Total	11.10	6.24	51
	Poor quality	Morning	12.67	6.86	6
		Evening	13.11	5.99	40
		Total	13.05	6.03	46
	Total	Morning	10.00	5.74	16
		Evening	12.42	6.23	81
		Total	12.02	6.19	97
EoO2	Good quality	Morning	18.30	5.25	10
		Evening	15.28	5.61	41
		Total	15.88	5.62	51
	Poor quality	Morning	13.33	7.28	6

		Evening	13.93	7.06	40
		Total	13.85	7.01	46
	Total	Morning	16.44	6.36	16
		Evening	14.61	6.36	81
		Total	14.91	6.37	97
EoC3	Good quality	Morning	9.40	6.02	10
		Evening	11.73	7.06	41
		Total	11.28	6.88	51
	Poor quality	Morning	15.17	6.55	6
		Evening	13.11	6.12	40
		Total	13.38	6.14	46
	Total	Morning	11.57	6.66	16
		Evening	12.42	6.61	81
		Total	12.28	6.59	97
EoO3	Good quality	Morning	15.80	6.05	10
		Evening	14.15	6.69	41
		Total	14.47	6.55	51
	Poor quality	Morning	12.50	5.68	6
		Evening	13.44	6.19	40
		Total	13.32	6.07	46
	Total	Morning	14.56	5.95	16
		Evening	13.80	6.41	81
		Total	13.93	6.32	97

CHAPTER 4

Discussion

Sleep quality and chronotype preference are influential constructs that significantly interact and elicit interesting trends in executive functioning throughout the wake-cycle. Individually, however, sleep quality and chronotype preference had few significant effects on planning, decision making, and sustained attention during three test administration times during the day. Although few significant effects were found when assessing these variables individually, the interaction effects and trends found in the current study offer insights and broaden areas for future research. The findings from tests of each hypothesis will be covered below, in addition to the relevant sample demographics, applications of the findings, limitations, and areas for future research.

The majority of participants for the current study sample were female (61%), identified as Caucasian (81%), and were freshman students (40%). The mean age was 20.7 years with a standard deviation of 5.8 and a range from 18 to 68. Sleep quality, as assessed by the PSQI, was indicated to be good by the majority of participants (52.6%), and the vast majority identified as evening types (83.5%). Sleep length, as assessed by the sleep duration subscale of the PSQI indicated that 48 students (49.5%) indicated that they slept at least seven hours per night, 33 (34.0%) indicated that they slept between six and seven hours per night, 11 (11.3%) indicated that they slept between five and six hours per night, and 5 (5.2%) indicated that they slept less than five hours per night.

The variables included in the current study showed a number of significant correlations. Sleep quality was positively correlated to the midday, performance score of the TOL. The global performance scores on the TOL across all three testing times were all positively correlated, suggesting good reliability in these outcome measures. Likewise, the errors of commission and omission, as measured by the SART across the three testing times, were also positively correlated, once again, indicating adequate reliability.

Results indicate that sleep quality and chronotype preference have a significant interaction effect on the executive functions of planning, decision-making, and sustained attention. Morning-types with good sleep quality consistently scored the highest (best) on the TOL and also completed it the fastest. However, evening-types with good sleep quality showed the greatest improvement throughout the wake-cycle. Individually, these constructs did not yield expected or statistically significant effects on executive functions throughout the wake-cycle. Sleep quality had a significant effect on planning and decision-making, but only during the noon time administration. There were no significant effects of sleep quality on sustained attention.

Chronotype preference did not affect planning and decision-making abilities during the morning and evening task administrations. These findings suggest that performance did not differ between the morning-types and evening-types during the morning and evening testing times. Although the differences between these groups were not significant, morning-types had a higher group performance mean than their evening counterparts, but evening-types showed greater improvements throughout the day. Chronotype preference did not have a significant effect on sustained attention throughout the wake cycle. However, morning-types had a lower mean numbers of errors of commission during the morning and evening testing times, whereas evening-types had a lower mean number of errors of omission during these task administration times.

Hypothesis 1a

The first hypothesis proposed that sleep quality would have a statistically significant effect on planning and decision-making abilities throughout the wake-cycle. Based on past research, it was believed that students who had poor sleep quality would score worse on executive functions than students with good sleep quality. Non-significant group differences were found between good quality sleepers and poor quality sleepers on the combined TOL outcome variables, which were the overall performance scores and the time to complete the task per administration, during the morning and evening testing times. These results were inconsistent with prior research. Given the copious research suggesting the effects of sleep quality on cognitive abilities, the current findings could be due to the majority of participants reporting more than six hours of sleep per night, particularly given the positive correlation between sleep length and sleep quality found in this study. An additional consideration given the non-significant results concerns the time required to complete the task. Given the short duration of the test, it is likely that poor quality sleepers were able to compensate and rouse sufficient executive capabilities to complete the task in a manner comparable to their good sleep counterparts.

Examination of group means on these outcome variables highlighted some interesting trends which are ostensibly different from what would be expected given the literature on sleep and executive functioning. Although mean group differences on the TOL performance scores were not significant during the morning and evening administrations, it is interesting to note that students who had good quality sleep had lower mean performance scores in the morning than those who had bad sleep. Only on the evening administration were good sleepers observed to have a higher mean score compared to poor sleepers.

Poor quality sleepers had significantly higher scores than good sleepers during the mid-day task administration. This is a perplexing result, as the underlying hypothesis of a midday task administration was that this time would serve as a baseline measurement. Circadian rhythm could be a potential explanatory source, with poor quality sleepers experiencing an increase in arousal and alertness around midday that may be inherently different from that of good sleepers. Another consideration to take into account regarding this finding would again be chronotype preference, as the majority of the current sample identified as evening-type. Such individuals may begin to feel more awake and alert in comparison to morning-types that may feel a lull in activation as the day progresses. The overall lack of differences in planning and decision-making between good quality sleepers and poor quality sleepers is in contrast to what would be expected given the extensive research that indicates that good sleep quality is related to better executive functioning than to poor quality sleep. However, the relationship between sleep quality and executive functioning becomes more clear when chronotype preference is factored in.

The difference between good quality sleepers and poor quality sleepers on the overall performance score during the midday administration was the only statistically significant finding. This was another perplexing result, given the abundant evidence which suggests that good quality sleepers perform better on cognitive tasks than poor quality sleepers. On closer examination of group means for the midday testing time, it was found that it took poor quality sleepers longer to develop and execute their plans when completing the TOL, whereas students with good sleep quality were observed to complete the TOL quicker, on average, than students with poor sleep quality. However, performance scores during midday showed that poor quality sleepers performed significantly better than good quality sleepers (i.e. developed more accurate plans and carried them out). Poor quality sleepers, if allowed the time to develop plans and a strategy to execute them, perform better than good quality sleepers. Examination of group means on the time to complete the TOL during the morning and evening task times revealed that good sleepers completed the TOL faster, although not significantly faster, than poor quality sleepers. Faster response times have been noted in people who get quality sleep versus those that get poor quality sleep (Jung et al., 2011; Kobbeltvedt et al., 2005). In the current study, students who reported good quality sleep, especially during mid-day, were more efficient in perceiving the stimuli, assessing its features, and carrying out responses. However, poor quality sleepers who took longer to complete the task performed better by making fewer mistakes and achieving higher performance scores.

Hypothesis 1b

A second aim of the current study was to assess the effects of sleep quality on sustained attention. Results from the analysis of sleep quality on errors of commission and omission found no significant differences between the sleep quality groups. Examination of mean scores between the sleep groups uncovered some interesting trends regarding sleep quality and sustained attention. Throughout the wake cycle, good quality sleepers had fewer errors of commission, but more errors of omission, compared to poor quality sleepers. Although these results are non-significant, the lower mean number of errors of commission in the good quality sleep group suggests that good quality sleepers are less reliant on habitual responding (in the case of the SART) and are able in inhibit inappropriate responses. Blagrove et al. (2005) stated that sleep quality influences arousal levels. The current findings may suggest that quality sleepers, who are more fully awake and alert throughout the day, may have more efficient executive controls and may be more capable of inhibiting inappropriate responses. This type of enhanced control is likely a reason as to why good quality sleepers had higher incidents of errors of omission than their poor quality sleep counterparts. The Yerkes-Dodson Theory (1908) may also be implicated in the group mean differences on the sustained attention task. This theory posits that task complexity requires certain levels of arousal to achieve optimal performance, with complex tasks requiring less arousal than simple ones. In the current sample, the lower rate of errors of commission in the good quality sleep group could be related to the higher arousal/alertness of these students and greater executive control capability. The poor quality sleep group, in comparison, being less alert and less able to inhibit the habitual response, committed fewer errors of omission, but responded to non-target stimuli more frequently. Considering real-world applications, students with better sleep quality are likely to do better on assignments and tests, due to their ability to attend better to presented or relevant material. Further, greater executive control and less reliance on habitual responding is necessary for decreasing decision-making errors. Good quality sleep, and its accompanying alertness and increased arousal, is important for individuals who must make decisions throughout the wake cycle. Drivers who get adequate sleep quality may be less likely that than their poor quality sleep counterparts to have lapses in attention or miss relevant environmental stimuli. In a different setting, medical doctors may be less likely to make mistakes that negatively impact the well-being of patients if they get quality sleep; an almost infinite number of scenarios could be generated highlighting the harm that could stem from poor quality sleep and increased rates of errors of commission and omission.

Hypotheses 2a and b

The second purpose of the current study was to examine the effects of chronotype preference on executive functioning. Morningness/eveningness preference did not have a significant effect on planning, decision-making, or sustained attention. No significant differences were noted on these tasks between morning and evening-types, regardless of the time of day in which testing occurred. The results in the current research project are surprising, given that research suggests that chronotype preference influences a number of cognitive abilities, including executive functions (Bennet et al., 2008; Hahn et al., 2012). The non-significant effect could be due to circadian rhythm timing. Executive functioning can fluctuate throughout the circadian period (Zamzow, 2014). Matchock and Mordkoff (2009) found that arousal in both morning and evening types increased from 0800 until 1400, after which the evening peak occurs for evening-types, and a decrease in arousal was noted in morning-types. In the current study, this could be an explanation for the non-significant difference between the chronotypes on planning and decision-making. With arousal and alertness largely congruent throughout the majority of the day, significant executive function differences may not be detectable. Notwithstanding the non-significant results, consideration of chronotype group means on executive functioning tasks highlight some potentially meaningful trends. Morning-types had higher mean performance scores across all three administration times compared to evening types, although such differences were not significant. Although non-significant, it is interesting to note that morning-types completed the TOL faster than evening-types during the morning and evening testing times. One potential reason for the slight differences in group means is the unequal sample sizes, with only 16 students identifying as morning-type and 81 identifying as evening-type. Another potential cause for this finding may be associated with personality characteristics that correlated with the chronotypes. Conscientiousness is highly related to morning-type preferences (Randler et al., 2014). Morning-type preference has also been found to correlate with proactivity, with morning individuals being more behaviorally activated and achievement oriented (Randler et al., 2014). Further, evening-types are more likely to be extroverted and score higher on subjective ratings of impulsivity, and risk-taking (Cavallera et al., 2011; Killgore, 2007; Randler et al., 2014). These personality characteristics may have mediated these results and suggest personality could be examined in conjunction with chronotype preference and executive functioning.

Hypotheses 3a and b

The next hypotheses examined the effect of chronotype preference on sustained attention throughout the wake-cycle, as measured by the number of commission and omission errors on the SART. Results did not yield significant differences between morning-types and evening-types on sustained attention throughout the day. One potential explanation for this non-significant result relates to what has been mentioned above in regard to alertness and its connection to circadian rhythm and optimal functioning times of the day.

Past research has found that inhibition wanes during non-optimal testing times (Lara et al., 2014; Schmidt et al., 2012). The non-significant results from the current project suggest that evening-types had higher rates of errors of commission both during the morning and evening sessions, whereas morning types had a higher group mean for errors of omission during the morning and evening SART administrations. The higher group mean of errors of commission in evening individuals may reflect the tendency of impulsivity in individuals with an evening orientation, especially in considering that the habitual response is to hit the mouse when target stimuli is not present during the SART. Evening-types, who may have a tendency to be more impulsive, are likely to have had difficulties in inhibiting the habitual response on the SART, leading to errors of commission.

Although statistically non-significant, both chronotypes showed mean increases in errors of commission between the morning time administration and the evening administration, whereas errors of omission rates decreased when comparing the morning to the evening test results. In general, these findings may suggest that self-regulation decreased throughout the day, leading to a greater reliance on habitual responding. A decrease in self-regulation abilities, manifested by habitual responding, could be influenced by distinct phenomena relevant to morning or evening preference. Morning-type students with increased errors of commission throughout the wake-cycle may rely on habitual responding due to decreased focus and alertness when the task was administered during a non-optimal time. The evening-types, however, may have had an increase in errors of commission due to a proneness to impulsive responding. These tendencies could be related to the sleep/wake homeostasis drive which is the process that promotes sleepiness as the wake-cycle increases in length. In the evening-time, the drive to sleep may decrease inhibition and self-regulation, thereby increasing errors of commission.

The greatest rate of errors of omission occurred during the midday administration. Students who had an evening preference also had their highest rate of errors of commission, whereas morning-types had their lowest group mean of such errors. This finding may suggest that both chronotypes struggle to maintain attention during the decrease in arousal that generally occurs during the circadian rhythm dip at midday (1300 – 1400; National Sleep Foundation, 2006). In real-world application, it appears that meaningful tasks or appointments be conducted either before or after the occurrence of the midday lull in order to reduce lapses in attention and the mistakes that may stem from them. This may be particularly salient for universities, which could potentially increase student performance by eliminating classes during the midday lull.

Hypothesis 4a

The final hypotheses of this study examines the interaction effects between sleep quality and chronotype preference on planning, decision-making, and sustained attention throughout the wake-cycle. Statistically significant interactions were noted on the planning and decision-making task (TOL) at all three testing times during the wake-cycle. During the morning administration time, morning-types with good sleep quality had the highest overall performance, whereas morning-types with poor sleep quality had the lowest performance. The second highest performance during the morning administration was achieved by evening-types with poor sleep quality, and the third highest performance was by those who identified as evening-type and reported good sleep quality. It is not surprising that morning-types with good sleep quality would perform the best during a morning task administration. Good sleep quality, preferred task-taking time, and higher conscientiousness has been found in morning-types (Randler et al., 2014) are proposed to be contributors to optimal performance. However, it is interesting to note that evening-types with poor sleep quality out-perform morning-types with poor sleep quality and evening-types with good sleep quality. This finding may indicate differences in circadian rhythms that are influenced by chrontoype preference and sleep quality. Further, evening-types with poor sleep quality may engage in compensatory behaviors, such as consuming more caffeine in the morning, more forceful effort, etc.

Morning-types with poor sleep quality had the lowest overall mean score on the TOL during the morning administration. This result may suggest that this group of students is more susceptible to the effects of poor sleep quality. This finding replicates past research that indicated that poor sleep quality negatively affects a number of cognitive functions (Kobbeltvedt et al., 2005; Koslowsky & Babkoff, 1992; Nilsson et al., 2005), and the current results suggest that poor sleep quality decreases an individual's ability to plan and make decisions appropriately. However, it contradicts the finding that people perform optimally when a task is given during their preferred time of day. Given the research findings on chronotype and sleep quality, it could be predicted that evening-types with poor sleep quality would be the group that scores the lowest on a planning and decision-making task administered in the morning. However, these students had the second highest performance mean on the planning and decision-making tasks. This finding is quite distinct from what was expected based on previous research. However, in examining the time needed that it took to complete the TOL, evening-types with poor sleep quality took the longest to complete the task during the morning administration. This group of students exhibited less efficiency in planning and decision-making abilities, but by taking additional time to complete the task they increased their mean score. Morning-types with good sleep quality were the most efficient and also achieved the highest group mean score. Morning-types with poor sleep quality had the second fastest mean completion time, but the lowest overall performance score. Although these students quickly organized and executed their plans, their decisions were not as accurate as those made by students in other chrontoype/sleep quality groups. This impairment in planning and decision making suggests poor sleep quality negatively effects these cognitive abilities, even when the administration was conducted during their optimal time. However, in looking at the evening-type with poor sleep quality group, it appears that, when adequate time is taken before carrying out a decision, accurate choices can be made. Although mean time differences existed between the groups, these differences were not significantly different.

During the midday administration, morning-types with good sleep quality had the highest mean score, followed by evening-types with poor sleep quality, morning-types with poor sleep quality, and evening-types with good sleep quality. Differences in scores and completion times during the midday administration were statistically significantly different. Morning-types with poor sleep quality had the second lowest performance score and the slowest completion time. At this time of day, these students not only struggled, when compared to their peers of other chronotype/sleep quality groups to appropriately develop accurate responses, but it also took them longer to carry out their decisions. The evening-type students with poor sleep quality scored higher and completed the task only slightly slower than their good sleep counterparts, who had the lowest mean performance score during the midday administration.

Initially, it was thought that the midday administration would serve as a baseline period for student groups based on sleep quality and chronotype preference. However, some interesting results occurred. Morning-types with good sleep quality had the highest mean performance score, but it was slightly lower than their morning mean score. Morning-types with poor sleep quality showed the greatest increase in performance score, improving over two points higher than their morning administration mean. A tendency to have more closely related performance mean scores, noted by a slight decrease in the highest mean score (morning-types with good sleep quality) and the biggest increase in group performance score (morning-types with poor sleep quality), may reflect the "midday slump" as it relates to alertness and a neutralizing of morningness and eveningness preference.

Students with a morning preference and good sleep quality had the highest mean score during the evening administration of the planning and decision making task. The consistent high performance of these individuals may support the relationship that has been found between morning-types and the personality characteristics of conscientiousness and proactivity (Randler et al., 2014). Morning-types are less likely to be sleepy throughout the day and perform better at school (Milic et al., 2014). Although evening-types with good sleep quality scored lower than quality sleep morning types and poor quality sleep evening types, these individuals showed the greatest mean improvement across the wake schedule, averaging 29.41 points in the morning and 33.17 in the afternoon. The increase in score, which was greater when compared to the increases in the other group means, suggests that performance is at its peak during the optimal time of the day. This is further supported by examining the time needed to complete the task requiring planning and decision-making functions. Morning preferenced individuals with good sleep quality completed the task the fastest, with evening-types with good sleep quality completing it faster than evening-types with poor sleep quality and morning-types with poor sleep quality. Although the quality sleepers who have an evening preference did not have a mean score quite as high as their poor sleep counterparts, their faster completion time suggests more efficiency in completing the task.

The surprising results of these analyses may also reflect the difficulty that college students have in maintaining consistent sleep-wake cycles and reinforcing their chronotype preference. Given the frequent shifts in class schedules (i.e. every semester or quarter), early classes, late studying times, and social events, chronotype preference may not be as strongly manifested in college student life as it would be in other settings. The demanding and ever-shifting schedules of college students increase their reliance on compensatory behaviors, such as caffeine consumption, with such factors seemingly having an influence on executive functions throughout the wake-cycle.

Hypothesis 4b

The final hypothesis tested for an interaction between of sleep quality and chronotype preference on sustained attention throughout the wake cycle. No significant interactions were noted. No significant group differences may have occurred due to the task taking roughly four and a half minutes to complete; Bennet et al. (2008) also found that brief, sustained attention tasks were not affected by chronotype preference. These researchers suggested that longer sustained attention tasks may be more successful in teasing out performance differences between the chronotypes. Further, circadian rhythm timing and similar levels of arousal between the chronotype groups are likely implicated in these non-significant results. Group means were examined and some interesting trends emerged, although such trends were non-significant. In examining the trends of group means on errors of commission and omission, those with good sleep, independent of chronotype preference, had fewer errors of commission than those with poor sleep during the morning administration. During the morning administration, morning types, regardless of sleep quality, had fewer errors of omission. These students lower rate of lapses in attention is likely due to the test time occurring during their optimal time of day. Although the differences between morning students and those of evening orientation were non-significant, these findings suggest that test-taking performance during the preferred time of day is likely enhanced by greater attentional capacities, which leads to decreased errors of omission. This finding lends some credibility to the hypothesis that individuals perform better during their preferred time of day. In this instance, morning-types are less likely to miss responding to a target item, indicating improved sustained attention in the morning hours.

Other interesting and consistent trends, although non-significant, were noted on other task time administrations. During the midday and afternoon administrations, good sleepers made fewer errors of commission, while poor sleepers made fewer errors of omission. Good sleepers are likely better suited to inhibit habitual responses, indicating that prefrontal functioning is optimal after adequate sleep, whereas poor sleep quality elicits a reliance on habitual responding. Fafrowicz et al. (2010) found that individuals with poor sleep are more likely to commit errors of omission. These findings were not replicated in the current study, which found that individuals with poor sleep quality, regardless of chronotype, had lower rates of errors of omission during the midday and afternoon test times. Students with poor sleep quality performed better than their quality sleep peers by responding to non-target stimuli as indicated in the instructions. Doran, Van Dongen, and Dinges (2001) found that during times of sleep deprivation, and in an effort to combat tiredness, individuals will rely more on compensatory measures to maintain base line performance on vigilance tasks. This finding can be applied to the results of the current study, which found that students with poor sleep quality had lower levels of errors of omission, or missed non-targets (in the case of the SART). Such students may be more likely to increase arousal and alertness through compensatory means. Decreased arousal is likely a culprit for increased habitual responding in students who reported poor sleep quality, as indicated by higher rates of errors of commission and lower rates of errors of omission.

Implications

The results of the current study are applicable to a number of real-world settings and could be useful in optimizing both performance and safety in the workplace and academic settings. In academia, if students are able to coordinate class schedules that coincided with their chronotype preference and allowed for consistent sleep/wake patterns, decreases in truancy would likely occur. Performance (grades) would likely increase due to students being better able to attend in class, make fewer errors of omission/commission on assignments and tests, and complete more thoroughly projects because of better planning and decision-making. School schedules promoting good sleep quality and aligning with time-of-day preference would maximize student performance, which would also enhance utilization of school resources. Efficient use of resources due to optimum student performance would occur because fewer classes would need to be repeated due to decreased need for re-take tests/assignment make-ups and fewer classes would be missed by students. This would free up additional spots for other students and increase graduation rates for universities.

In other settings, such as medical centers and practices, fewer errors of omission and commission, which relate to loss of life in these places, would also decrease if doctors and other health care providers were able to have consistent sleep schedules and get good quality sleep. Their performance in their specialties would also improve if they were able to conduct their work during their optimum time of the day. By optimizing performance in these places with these individuals, fewer medical errors would be made, leading to decreases in accidental medical deaths and medical malpractice claims. In these instances, good quality sleep leading to optimum functioning could mean the difference between life and death.

In other settings, decreasing errors of commission and omission by increasing good quality sleep and scheduling tasks during optimum times of day could also decrease severe, life-threatening accidents. This could be particularly salient to cargo truck drivers and shift workers. In an industrial or organizational sense, employee production could be enhanced by efforts to improve sleep quality and assigning work hours that align with chronotype preference. These two constructs may also be beneficial in enhancing overall well-being, as sleep quality is heavily correlated to physical and psychological well-being, and maximizing productivity by scheduling tasks/responsibilities during optimal times of the day may increase self-efficacy.

Limitations

In the current study, unequal group membership, specifically more evening-types than morning types, is a limitation that may have affected outcomes by decreasing statistical power. In future research, emphasis on attaining equal sample sizes should be given in order to enhance generalizability. However, the present researcher believes that the current sample sizes of the two chronotypes and sleep quality conditions are likely reflective of the student population sampled. The self-report of sleep quality is another possible limitation to this study. Future research endeavors on these research questions may better assess the effects of sleep quality by employing actigraphs or other more objective measures of sleep quality. Another limitation of this study is the repeated measures design, where students completed the same two tasks at three different times throughout the wake-cycle. This methodological design led to some practice effects, and in the future, a counter balanced approach where a first administration for some participants would take place in the evening with the other two task administrations occurring the following day may help reduce the amount of practice effect during the afternoon testing time. In order to better elucidate chronotype preference, more extreme testing times could be used, for example, having the morning testing time at 0600 and the evening testing time after 1900.

A potential explanation for the increase in errors of commission on the SART for both groups throughout the wake-cycle could be related to decreased arousal brought on by repeated exposure to the task. After multiple task administrations, the arousal due to novelty may have been lost and students, with a lowered interest, may have resorted to habitual responding. In order to combat this, counter-balancing may also be used. Additionally, various tasks/tests could be administered, which has been done in past research, to limit practice effects and maintain adequate arousal.

Future directions

The current study was unique in that it exposed students who either reported good or poor sleep quality to three administrations of tests examining sustained attention and planning and decision making throughout the wake-cycle. However, sleep quality was self-reported. In the future, and as noted above under limitations, the use of sleep graphs may be helpful in order to obtain a more objective measure of sleep quality. Additionally, the use of other tests to assess varying executive functions would expand the knowledge base regarding sleep quality and these higher mental processes. Further, setting a testing time later in the evening (i.e. after 1900 hours) may better elucidate the morning/evening preference of participants. Finally, counter-balancing techniques could be used to assess for or limit practice effects while maintaining reliability and validity of measures.

APPENDIX A

CONSENT FORM

The following is a brief summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: Chronotype Preference, Partial Sleep Deprivation, and Executive Functioning Throughout the Wake-Cycle

PURPOSE OF STUDY/PROJECT: The aim of this study is to examine the effects of chronotype preference and partial sleep deprivation on executive function tasks in college students throughout the wake-cycle.

PROCEDURE: Participants will anonymously complete a self-report survey indicating sleep patterns, habits, and morningness/eveningness preferences. Additionally, participants will anonymously complete a sustained attention task and a planning and decision-making task at three times throughout a day (0800, 1200, and 1600 hrs). All data will be de-identified and only the primary researcher will have access to the participants' responses.

INSTRUMENTS: The following instruments will be used during this study: The Pittsburgh Sleep Quality Index, the Adult Sleep/Wake Scale, the Morningness/Eveningness Questionniare, the Tower of London Task, and the Sustained Attention to Response Task.

RISKS/ALTERNATIVE TREATMENTS: The participant understands that Louisiana Tech is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

The following disclosure applies to all participants using online survey tools: This server may collect information and your IP address indirectly and automatically via "cookies".

EXTRA CREDIT: If extra credit is offered to students participating in research, an alternative extra credit that requires a similar investment of time and energy will also be offered to those students who do not choose to volunteer as research subjects.

BENEFITS/COMPENSATION:

I, ____________________, attest with my signature that I have read and understood the following description of the study, "________________________", and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University or my grades in any way. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my survey will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

_________________________________ ______________

Signature of Participant or Guardian Date

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Devin Merritt
dlm056@latech.edu
318-257-2488

Walter Buboltz, Ph.D.
buboltz@latech.edu
318-257-4039

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Stan Napper (257-3056)
Dr. Mary M. Livingston (257-2292 or 257-5067

APPENDIX B

DEMOGRAPHIC QUESTIONNAIRE

1. Age in years:_________

2. Gender: Male Female Transgendered: Male Female Other:_______________

3. With which ethnic group do you most identify (circle one)?

   African American Asian American Caucasian Hispanic/Latino/a Native American Other

4. Current status in school: Freshman Sophomore Junior Senior Graduate Other

5. Current GPA: __________

6. Major:___________________________

7. Current relationship status: Single In a relationship Engaged Married Separated

8. Current living arrangement: Dorm Apartment House

9. Family of Origin Socioeconomic Status: $0 - $50,000 $50,0001 - $100,000 $100,001 +

10. Do you use sleeping aids? Yes No If yes, what kind? ___________________

11. How many nights per week do you use sleeping aids?____________________

12. Did you use a sleeping aid last night? Yes No

13. What was your bed time last night:_________________

14. How long did it take you to fall asleep last night? __________________

15. What was your wake time this morning?_____________________

16. Do you use stimulants, such as coffee or other caffeinated beverages: Yes No

17. If yes to number 18, how often do you use the above mentioned substances per week? ________________

18. Did you consume coffee or a caffeinated beverage this morning?

Pittsburgh Sleep Quality Index

Please respond to the following questions by filling in the blank space.

1. During the past month, what time have you usually gone to bed at night?
   BED TIME ___________
2. 2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?
   NUMBER OF MINUTES ___________
3. During the past month, what time have you usually gotten up in the morning?
   GETTING UP TIME ___________
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)
   HOURS OF SLEEP PER NIGHT ___________

For each of the next questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .

a) Cannot get to sleep within 30 minutes

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

b) Wake up in the middle of the night or early morning

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

c) Have to get up to use the bathroom

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

d) Cannot breathe comfortably

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

e) Cough or snore loudly

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

f) Feel too cold

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

g) Feel too hot

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

h) Had bad dreams

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

i) Have pain

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

j) Other reason(s), please describe____

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

6. During the past month, how would you rate your sleep quality overall?

Very good __________ Fairly good __________ Fairly bad __________ Very bad __________

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?
No problem at all __________
Only a very slight problem __________
Somewhat of a problem __________
A very big problem __________

10. Do you have a bed partner or roommate?
No bed partner or room mate __________
Partner/room mate in other room __________
Partner in same room, but not same bed __________
Partner in same bed __________

Adult Sleep/Wake Scale

Please respond by filling in the response that best fits you.

	Never	Once in a while	Some-times	Quite Often	Frequently, if not always	Always
When it is time to go to bed...						
1. ...I want to stay up and do other things instead (for example: read, work, or watch TV).	①	②	③	④	⑤	⑥
In general...						
2. ...I have to make myself go to bed.	①	②	③	④	⑤	⑥
3. ...it is very hard for me to go to bed on time.	①	②	③	④	⑤	⑥
4. ...I "put off" or delay going to bed.	①	②	③	④	⑤	⑥
5. How long you usually "put off" or delay bedtime?	< 15 min ①	15 to 30 min ②	30 to 60 min ③	60 to 90 min ④	90 to 120 min ⑤	> 120 min ⑥
When I'm in bed and trying to fall asleep...	**Never**	**Once in a while**	**Some-times**	**Quite Often**	**Frequently, if not always**	**Always**
6. ...I am not sleepy.	①	②	③	④	⑤	⑥
7. ...I am unable to settle down.	①	②	③	④	⑤	⑥
In general...						
8. ...I have trouble going to sleep.	①	②	③	④	⑤	⑥
9. ...I try to make myself go to sleep.	①	②	③	④	⑤	⑥
10. ...I fall asleep quickly.	①	②	③	④	⑤	⑥
11. How long does it usually take you to fall asleep after you turn out the light?	< 15 min ①	15 to 30 min ②	30 to 60 min ③	60 to 90 min ④	90 to 120 min ⑤	> 120 min ⑥
After I initially fall asleep, but during the night...	**Never**	**Once in a while**	**Some-times**	**Quite Often**	**Frequently, if not always**	**Always**
12. ...I toss and turn in the bed.	①	②	③	④	⑤	⑥
13. ...I am very restless.	①	②	③	④	⑤	⑥

14. ...I awaken more than once.	①	②	③	④	⑤	⑥
In general...	**Never**	**Once in a while**	**Some-times**	**Quite Often**	**Frequently, if not always**	**Always**
15. ...I sleep soundly through the night.	①	②	③	④	⑤	⑥
16. How many times do you usually awaken each night?	**0 x** ①	**1 x** ②	**2 x** ③	**3 x** ④	**4 x** ⑤	**> 4 x** ⑥
After arousing or awakening in the middle of the night...	**Never**	**Once in a while**	**Some-times**	**Quite Often**	**Frequently, if not always**	**Always**
17. ...I have a hard time going back to sleep.	①	②	③	④	⑤	⑥
18. ...I drift back off to sleep easily.	①	②	③	④	⑤	⑥
19. ... I am calm and relaxed.	①	②	③	④	⑤	⑥
20. ...I roll over and go right back to sleep.	①	②	③	④	⑤	⑥
21. How long does it take you to go back to sleep after arousing or awakening?	**< 15 min** ①	**15 to 30 min** ②	**30 to 60 min** ③	**60 to 90 min** ④	**90 to 120 min** ⑤	**> 120 min** ⑥

In the morning, I wake up...	**Never**	**Once in a while**	**Some-times**	**Quite Often**	**Frequently, if not always**	**Always**
22. ...and feel ready to get up for the day.	①	②	③	④	⑤	⑥
23. ...rested and alert.	①	②	③	④	⑤	⑥
24. ...and just can't get going.	①	②	③	④	⑤	⑥
In general...						
25. ...I am slow-to-start in the morning.	①	②	③	④	⑤	⑥
26. ...I find it difficult to get out of the bed in the morning.	①	②	③	④	⑤	⑥

Morningness/Eveningness Questionnaire

Please respond to the following questions by circling the response that best describes you.

1. *Approximately* what time would you get up if you were entirely free to plan your day?
   [5] 5:00-6:30 AM [4] 6:30-7:45 AM [3] 7:45-9:45 AM [2] 9:45-11:00 AM
   [1] 11:00 AM-12 Noon

2. *Approximately* what time would you go to bed if you were entirely free to plan you evening?
   [5] 8:00-9:00 PM [4] 9:00-10:15 PM [3] 10:15 PM-12:30 AM
   [2] 12:30-1:45 AM [1] 1:45-3:00 AM

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?
   [4] Not at all [3] Slightly [2] Somewhat [1] Very much

4. How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?
   [1] Very difficult [2] Somewhat difficult [3] Fairly easy [4] Very easy

5. How alert do you feel during the first half and hour after you wake up in the morning?
   [1] Not at all alert [2] Slightly alert [3] Fairly alert [4] Very alert

6. How hungry do you feel during the first half an hour after you wake up?
[1] Not at all hungry [2] Slightly hungry [3] Fairly hungry [4] Very hungry

7. During the first half hour after you wake up in the morning, how do you feel?
[1] Very tired [2] Fairly tired [3] Fairly refreshed [4] Very refreshed

8. If you had no commitments the next day, what time would you go to bed compared to your usual time?
[4] Seldom or never later [3] Less than 1 hour later [2] 1-2 hours later
[1] More than 2 hours later

9. You have decided to do physical activity. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM (*07-08 h*). Bearing in mind nothing but your internal "clock," how do you think you would perform?
[4] Would be in good form [3] Would be in reasonable form
[2] Would find it difficult [1] Would find it very difficult

10. At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?
[5] 8:00-9:00 PM [4] 9:00-10:15 PM [3] 10:15 PM-12:45 AM
[2] 12:45-2:00 AM [1] 2:00-3:00 AM

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirely free to plan your day. Considering only your "internal clock," which one of the four testing times would you choose?
[6] 8-10 AM [4] 11 AM- 1 PM [2] 3 PM-5 PM [0] 7-9 PM

12. If you got into bed at 11 PM (23 *h*), how tired would you be?
[0] Not tired at all [2] A little tired [3] Fairly Tired [5] 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 in the morning. Which one of the following are you most likely to do?
[4] Will wake up at usual time, but will not fall back asleep
[3] Will wake up at usual time and will doze thereafter
[2] Will wake up at usual time, but will fall asleep again
[1] Will not wake up until later than usual

14. One night you have to remain awake between 4-6 AM (04-06 *h*) in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?
[1] Would not go to bed until the watch is over
[2] Would take a nap before and sleep after
[3] Would take a good sleep before and nap after
[4] Would sleep only before the watch

15. You have two hours of physical work. You are entirely free to plan your day. Considering only your "internal clock," which of the following times would you choose?
[4] 8-10 AM [3] 11 AM- 1 PM [2] 3-5 PM [1] 7-9 PM

16. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10-11 PM (22-23 *h*). Bearing in mind only your "internal clock," how well do you think you would perform?
[1] Would be in good form [2] Would be in reasonable form
[3] Would find it difficult [4] Would find it very difficult

17. Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?
[5] 5 hours starting between 4-8 AM
[4] 5 hours starting between 8-9 AM
[3] 5 hours starting between 9 AM- 2 PM
[2] 5 hours starting between 2-5 PM
[1] 5 hours starting between 5 PM-4 AM

18. A *approximately* what time of the day do you usually feel your best?
[5] 5-8 AM [4] 8-10 AM [3] 10 AM- 5 PM [2] 5-10 PM
[1] 10 PM-5 AM

19. One hears about "morning types" and "evening types." Which one of these types do you consider yourself to be?
[6] Definitely a morning type
[4] Rather more a morning type than an evening type
[2] Rather more an evening type than a morning type
[1] Definitely an evening type

APPENDIX C

IRB APPROVAL

LOUISIANA TECH
UNIVERSITY

MEMORANDUM

OFFICE OF UNIVERSITY RESEARCH

TO: Dr. Walter Buboltz and Mr. Devin Merritt

FROM: Dr. Stan Napper, Vice President Research & Development

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: January 29, 2015

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"Chronotype Preference, Partial Sleep Deprivation, and Executive Functioning throughout the Wake-cycle"

HUC 1265

The proposed study's revised procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Informed consent is a critical part of the research process. The subjects must be informed that their participation is voluntary. It is important that consent materials be presented in a language understandable to every participant. If you have participants in your study whose first language is not English, be sure that informed consent materials are adequately explained or translated. Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

Projects should be renewed annually. ***This approval was finalized on January 29, 2015 and this project will need to receive a continuation review by the IRB if the project, including data analysis, continues beyond January 29, 2016.*** Any discrepancies in procedure or changes that have been made including approved changes should be noted in the review application. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of University Research.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Research or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

If you have any questions, please contact Dr. Dr. Mary Livingston at 257-2292 or 257-5066.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

P.O. BOX 3092 • RUSTON, LA 71272 • TEL: (318) 257-5075 • FAX: (318) 257-5079

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