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Objectively measuring the effects of sleep on reading comprehension and sustained selective attention

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OBJECTIVELY MEASURING THE EFFECTS OF SLEEP ON READING COMPREHENSION AND SUSTAINED SELECTIVE ATTENTION

by

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ABSTRACT

The overall performance of a university is measured by retention rates of students. Because individuals who achieve lower grade point averages are at a higher risk of failing or dropping out of college, the academic performance of undergraduates should be the target of concern to maintain good retention rates. Academic performance, which is associated with attention and reading comprehension abilities, is affected by the sleep behavior of students. In regards to college students and sleep, research has indicated that college students demonstrate habitually poor sleep habits. Poor sleep habits have been linked to impaired attention and concentration abilities, but the measures used to quantify these associations have relied on self-report. Additionally, the effects of sleep and cognitive functioning has focused on clinical populations that meet the requirements of either a sleep disorder or Attention Deficit Hyperactivity Disorder, with limited research examining the effects of sleep behavior on a non-clinical population.

The purpose of this study was to test the objective measures of sleep behavior and cognitive functioning with healthy young adults enrolled in an undergraduate university. Specifically, this study focused on the role that the different stages of sleep play in cognitive functioning in addition to the roles of one's sleep quality and sleep quantity. Collected data were analyzed using one-way analysis of variance as well as multiple regression analyses. Results demonstrated that students' sleep architecture (i.e., sleep quantity, time spent in different sleep stages), daytime sleepiness, or sleep quality did not significantly impact sustained attention or reading comprehension; however, computation of effect sizes revealed a strong effect for sleep quantity and reading comprehension.

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CHAPTER ONE

INTRODUCTION

A continuing concern for many university leaders has been the retention rates of undergraduate students (Murtaugh, Burns, & Schuster, 1999) primarily because retentions rates serve as a measure of the overall performance of an institution (Astin, 1997). Academic performance is linked to attrition of college students, and an association exists between attention and academic performance (Schwanz, Palm, & Brallier, 2007; Steinmayr, Ziegler, & Träuble, 2010) as well as reading comprehension and academic performance (Taraban, Rynearson, & Kerr, 2000a; Taraban, Rynearson, & Kerr, 2000b). Specifically, college students demonstrating attention difficulties or impaired reading comprehension strategies (Taraban et al., 2000a) achieve lower grade point averages and are at risk of failing to complete their degree of study (Pope, 2010).

Researchers demonstrated that sleep characteristics contribute to the variation in individuals' cognitive functioning (Benitez & Gunstad, 2012; Golan, Shahar, Ravid, & Pillar, 2004; LeBourgeois, Avis, Mixon, Olmi, & Harsh, 2004; Van den Berg & Neely, 2006). Sleep characteristics affect cognitive functioning and include the quantity of sleep, the reported quality of sleep, and daytime sleepiness. Particularly, researchers have shown that individuals who are sleep deprived perform poorly on vigilance tasks as indicated by slower reaction times and more missed responses (Van den Berg & Neely, 2006). Similarly, individuals who reported poor sleep quality performed significantly worse on tasks requiring higher cognitive functioning than individuals who reported good sleep quality (Benitez & Gunstad, 2012). Finally, in regards to daytime sleepiness, researchers have established an association between reported daytime sleepiness and difficulty with attention and concentration (Golan et al., 2004; LeBourgeois et al., 2004).

College students demonstrate habitually poor sleep habits (Buboltz et al., 2009; Liguori, Schuna, & Mozumdar, 2011). On average, students estimated that they receive seven hours of sleep during the week and take 23 minutes approximately to fall asleep once they are in bed. On the weekend, students reported acquiring approximately eight hours of sleep. The majority of students reported feeling "mostly tired" in the morning because of these patterns. The replication of this response style occurred across universities. Even if a student reported obtaining an adequate amount of sleep quantity, there were still reports of daytime sleepiness, which is more support for the theory that the duration and quality of sleep predict daytime sleepiness (Riegel et al., 2012; Van Dongen, Maislin, Mullington, & Dinges, 2003). The purpose of this study was to evaluate the effects of sleep behavior on cognitive performance in college students and determine which sleep characteristics serve as better predictors of cognitive performance.

Statement of the Problem

There is an established association between impairment in cognitive functioning and sleep problems, but many of the studies have limitations. The measures used to quantify the presence of cognitive impairment in association with sleep problems rely mostly on self-report. Even though researchers identified that time spent in non-REM and REM sleep contribute to daytime sleepiness (Punjabi et al., 2002), there is limited research evaluating time spent in specific sleep stages and its effect on cognitive functioning. Additionally, research evaluating the effects of sleep on cognitive functioning has focused on clinical populations that meet the requirements of either a sleep disorder or Attention Deficit Hyperactivity Disorder, with limited research examining the effects of sleep behavior on a non-clinical population. This study sought to provide an objective measurement of sleep behavior and cognitive functioning not found in previous studies. This study proposed to test the objective measures of sleep behavior and cognitive functioning with healthy young adults enrolled in an undergraduate university.

Justification

Sleep interventions that educate college students about sleep hygiene have been effective in improving sleep behavior (Brown, Buboltz, & Soper, 2006; Buboltz, Soper, Brown, & Jenkins, 2002). Identifying specific sleep characteristics that contribute to impairment in cognitive functioning may help with the specialization of sleep interventions to expedite improved performance in cognitive functioning, which leads to improvement in academic performance. This study adds to the current literature on the effects of sleep and cognitive functioning, but it is unique in that it evaluated specifically the role that the different stages of sleep (i.e., deep sleep and REM sleep) and other sleep characteristics plays in sustained attention and reading comprehension.

Literature Review

Attention

Visual attention. Posner and Petersen (1990) introduced a theory of the attention system that generated discussion of the physiological intricacies of attending to information in our environment. They proposed that three basic features could explain the attention system. The first was the concept that the attention system was separate from the systems that controlled our memories and our cognitions. However, given this identified independence of the attention and data processing systems, there remained a supposition that the attention system interacted with other parts of the brain while simultaneously maintaining its own identity. The second feature that Posner and Peterson introduced was that the attention system was composed of a network of neural regions instead of limited to one particular brain region (i.e., anterior attention system and posterior attention system). The final feature that Posner and Petersen presented regarding the attention systems was that the areas of the brain identified as being involved in attention performed different functions of attention (i.e., the anterior attention system is important in language and the posterior attention system is important in spatial attention).

From the three basic features of their attention system, they specified that the attention system has three main roles in attending to information and identified these roles as being subsystems of attention: orienting, detecting, and alerting. Close examination of these three subsystems of attention revealed evidence to support their claims of the attention system having localized brain regions, of the tasks performed at each subsystem, and of the relationship that the attention system has to data processing.

Because of the limited research available to them at the time of the publication on any other aspect of attention, Posner and Petersen (1990) focused on visual attention for the majority of their investigation of the orienting, detecting, and alerting aspects of attention.

In regard to visual orienting, Posner and Petersen (1990) identified experiments that examined the spatial attention of monkeys, and through these experiments, it was determined that the spatial attention involves the posterior parietal lobe, the lateral pulvinar nucleus of the posterolateral thalamus, and the superior colliculus and that these three localized regions were also responsible for spatial attention in humans. Posner and Petersen (1990) also found evidence that the three areas involved in visual orienting were independently responsible for different jobs. Specifically, they identified that damage to the posterior parietal lobe created the inability to activate attention to the region that is contralateral to the site of the lesion. The resulting deficit of damage to the superior colliculus was the inability to shift attention. Posner and Petersen (1990) believed these two deficits to be associated with the system that controls saccadic eye movements. Finally, damage to the lateral pulvinar thalamus yielded an inability to shift attention to a stimulus in the environment contralateral to the lesion location without also shifting one's gaze. Posner and Petersen (1990) hypothesized how this circuitry works from this gathered evidence of covert visual attention. They suggested that once the parietal lobe releases its hold on the attended target, then the midbrain helps facilitate the transfer of attention to the desired area. The pulvinar is responsible then for examining the data collected.

Hemispheric localization is also important for visual orienting based on studies conducted with individuals with split brains. Posner and Petersen (1990) presented evidence to support their claim that the right hemisphere plays a larger role in the attention system than the left hemisphere by examining the attention deficits produced by lesions in the right hemisphere and comparing those mirrored lesions in the left hemisphere. They concluded that visual orienting tasks that are controlled by the left hemisphere are able to operate automatically (i.e., without attention) but the same is not true for visual orienting tasks controlled by the right hemisphere.

Posner and Petersen (1990) clarified that there is a difference between being alert in general and in attending to specific stimuli (i.e., detecting stimuli). They explain this difference in terms of the signal interference that is produced. When an individual is alert but not detecting a target stimulus, there is not as much interference with other cognitive processes than if an individual is attending to a stimulus. Additionally, Posner and Petersen (1990) identified that in visually processing words, the detection of target stimuli (i.e., words) correlates positively with the increase of blood flow to the anterior cingulate gyrus. They also reported that the anterior cingulate gyrus is also important in language processing.

There are two separate visual attention systems (the anterior attention system and the posterior attention system) that are associated with the function of the anterior cingulate gyrus in the attention system. These two attention systems are hierarchical. Posner, Walker, Friedrich, and Rafal (1987) examined the performance of individuals with parietal lesions following simultaneous completion of an auditory attention task (which requires the anterior attention system/language) and a visual search task (which requires the posterior attention system/visual orienting). Separate attention systems control language and visual orientation, but these systems interconnect through the anterior cingulate. Posner and Petersen (1990) postulated that these results may indicate that the attention systems are organized hierarchically, with the anterior attention system (language/semantics) relinquishing control to the posterior attention system (visual stimuli/word form) when it is done with processing attended information.

Posner and Petersen (1990) proposed that the anatomical area that is responsible for alertness in the attention system is located in the right cerebral hemisphere. Lesions in the right hemisphere yielded primary deficits in alertness as measured by galvanic skin responses, heart rate responses, performance on vigilance tasks, and blood flow and metabolic studies. It appears that the neurotransmitter norepinephrine interconnects with the maintenance of vigilance because when individuals present with lesions in the right cerebral hemisphere, they have a decrease in the production of norepinephrine.

Auditory attention. Kayser, Petkov, Lippert, and Logothetis (2005) expanded on Posner and Petersen's (1990) theory of attention and added to the limited research of auditory attention by providing a model to describe the workings of the auditory system. Kayser et al. (2005) described an auditory salience map that demonstrates how a particular auditory stimulus receives additional processing in the presence of competing auditory stimuli. They proposed that individuals could separate specific sounds from irrelevant auditory stimuli through different sets of filters in the auditory system. These filters extract the intensity of the sound (i.e., loudness of sound), the frequency contrast (i.e., pitch of sound), and the temporal contrast (i.e., location of sound). Next, a comparison is made between these three features (intensity, frequency contrast, and temporal contrast) using a center-surround mechanism and normalized to identify the more salient feature for that particular auditory stimulus. The resulting information for each feature combines to form the overall auditory salience map. The auditory salience map helps researchers predict what feature of an auditory stimulus is most salient in capturing our attention and allowing for easier detection. Additionally, because of the parallel mechanisms of the auditory salience map to a visual salience map, they propose there are similar pathways at the cortical level for salience of auditory and visual stimuli.

Menon and Uddin (2010) provide support to Kayser et al.'s (2005) claim of a similar cortical pathway for both auditory and visual stimuli in detecting salience. Specifically, Menon and Uddin (2010) suggest that the anterior insula in conjunction with the anterior cingulate cortex (ACC) form a 'salience network' for stimulus detection across sensory modalities. Sridharan, Levitin, and Menon (2008) also found evidence for the role of the right fronto-insular cortex (rFIC) in salient environmental events of both the auditory and visual modality. Functional magnetic resonance imaging (fMRI) experiments revealed that the activation of the rFIC preceded activation of the central executive network (CEN) and the default mode network (DMN). Additionally, fMRI experiments revealed that the rFIC controlled the on/off activation of the CEN and the DMN. These findings were consistent when individuals performed an auditory segmentation task and a visual oddball attention task. Therefore, when individuals are introduced to a salient sensory stimulus, the salient network (comprised of the rFIC and the ACC) activates the CEN to control performance on the cognitively demanding task.

Researchers rely on specific techniques and tools to identify the role that attention plays on processing auditory events. It is important to note that these same techniques and tools are used in researching visual attention as well. Researchers use event related potential (ERP) studies using electroencephalography (EEG) to identify the timing of the activation (Fritz, Elhilali, David, & Shamma, 2007) in addition to the use of functional magnetic resonance imaging (fMRI) to identify where the neural activation occurs. With ERP studies, researchers are able to identify the pre-attentive features of auditory attention (bottom-up processing) by measuring the initial voltage of brain wave activity using an EEG (Winkler, Czigler, Sussman, Horvath, & Balazs, 2005). Commonly, these waveforms occur as negative peaks within the first 100 milliseconds (N1) of the presence of an auditory event. A mismatch negativity (MMN) response occurs within the first 100 – 200 milliseconds of the presence of the auditory change following repeated presentations. This auditory change can be due to a variety of factors including a change in pitch, frequency, duration, or spatial location of the auditory event. The MMN plays a prominent role in auditory attention because it helps evaluate whether the novel sounds heard warrant attentional processing or a behavioral response (Fritz et al., 2007). MMN also plays a role in the top-down processing of auditory events, specifically when the individual is required to detect a specific sound. When focused attention is required, ERP show that neural activation occurs within 300 – 350 milliseconds of the presentation of the stimulus as indicated by the third positive peak of the waveform (P3), a waveform that reflects stimulus evaluation (Verleger, Jaśkowski, & Wascher, 2005).

Selective attention. Schneider and Shiffrin (1977) proposed a theory of information processing that utilizes automatic and controlled processes for detection, search, and attention. Long-term and short-term memory forms through the associated collection of nodes acquired from learning. Each node also has its own associated connections of information, and activation of the associated connections cause activation of the entire node. The activation of one node may also activate an additional node given particular contexts. Distinction between automatic and controlled processes is based on the way in which the nodes are activated.

According to Schneider and Shiffrin (1977), activation of the information processing system occurs when the activating sequence of nodes is caused by a particular input configuration that is either internal (i.e., caused by another node) or external (i.e., caused by external stimuli) and does not require the attention of the individual for the sequence to be activated. This automatic sequence of nodes differs from a single node because the activation of this sequence does not always include the activation of all of the nodes within that sequence. The automatic process of information relies on the nodes found in long-term memory; therefore, for any new automatic processes to be established, training of the information is necessary to insure proper development. Additionally, once the automatic process is developed, it is difficult to suppress its activation of nodes. One specific type of automatic sequence is the activation of a specific node through automatic attention responses. Specifically, if an individual identifies a specific input as a target, the presence of these inputs serves as the initiator of the activation of the sequence of nodes and allows for automatic detection, bypassing the controlled process of the information processing system.

Schneider and Shiffrin (1977) identify a controlled process as the activation of a temporary sequence of nodes controlled by the individual. Only one sequence can be activates at a time without the presence of interference because the activation of the sequence requires the active attention of the individual. Controlled processes are capacity limited but are beneficial in the presence of novel situations where automatic processes are absent. The degree of capacity limitation for controlled processes relates to the capacity limitations of the individual's short-term storage or working memory. The controlled process is utilized specifically in tasks that require the identification of targets in a novel task that has an unpredictable pattern of presentation or there has been limited practice.

According to Schneider and Shiffrin (1977), selective attention is the ability to identify or remember particular sensory information better in particular situations chosen by the individual. Selective attention deficit occurs when performance on the task decreases because of "information overload" (Schneider & Shiffrin, 1977). This information overload occurs in two types of situations. Divided attention deficit occurs when performance decreases because of "the necessity to give controlled processing to additional sensory inputs or additional memory elements" (Schneider & Shiffrin, 1977). Focused attention deficit occurs when performance decreases because of an individual's requirement to identify relevant inputs and ignore irrelevant inputs. These selective attention deficits provide additional evidence for our limited capacity in the controlled processing of information.

The theory of information processing that Schneider and Shiffrin (1977) propose specifies that one's ability to correctly detect, search for, and attend to information are determined by three major variables: how the information is presented, the memory load that is required, and the amount of practice acquired. When a presented search paradigm presented follows a varied layout of the specific targets, activation of the controlled process allows for correct detection of the target. However, when the search paradigm follows a consistent layout of the specific targets, the automatic process is activated. Superior performance on the search paradigm, measured by accuracy of detection and reaction time, occurs with the activation of the automatic process due to the limited requirement of memory load compared to the large requirement of memory for the controlled process.

Vigilant/sustained attention. Vigilant attention is the "process of maintaining conscious stimulus processing over periods longer than ten seconds and up to many minutes" (Langner & Eickhoff, 2013). When the stimulus is a simple, routine task, performance is managed by bottom-up processing wherein established task schema are triggered and activated (Johnston & Dark, 1986; Langner & Eickhoff, 2013; Schneider & Shiffrin, 1977). Bottom-up processing involves the presence of a stimulus (i.e., visual or auditory cue) that activates detectors of that stimulus, which in turn activate related detectors. The initial activation of these detectors is reliant on the clarity of the presented stimuli (i.e., can it be seen or heard clearly), and continued activation of these detectors is reliant on the strength of association established previously among these detectors from learning (Johnston & Dark, 1986). Vigilant attention is managed by a supervisory attentional system housed in the prefrontal cortex (Shallice, Burgess, & Robertson, 1996) that controls top-down processing required for sustaining attention for an extended period of time, even for simple, well-learned tasks (Langner & Eickhoff, 2013). Top-down processing is driven by previous knowledge and allows for the enhancement of processing sensory stimuli, detecting target stimuli and ignoring non-target stimuli, and orienting focus towards locations in which the target stimuli is predicted to appear (Sarter, Givens, & Bruno, 2001). Stuss, Shallice, Alexander, and Picton (1995) proposed that this supervisory attentional system consists of four system processes that assist in the maintenance of attention. Specifically, these four system processes supervise the level of activation of the task schema, energize the task schema when necessary, prevent the activation of competing schemata, and monitor the resulting attentional control.

In measuring performance on a simple vigilance task, an individual is required to attend to a predetermined target stimulus. There are three main paradigms used to measure performance (Langner & Eickhoff, 2013). The first paradigm involves the discrimination of target and non-target stimuli with a response required when the target stimulus appears while inhibiting a response in the presence of a non-target stimulus (e.g., Conners' Continuous Performance Test, Test of Sustained Selective Attention). Performance on this task is measured by the individual's ability to correctly identify the target and non-target stimuli and the time it takes for the response to occur. The second paradigm involves the continuous monitoring of target stimuli and indicating when there is a change in the presentation of the stimuli. This task measures an individual's speed in responding and focuses on the individual's ability to sustain readiness to respond to the stimuli (Langner et al., 2012). The third paradigm involves counting the number of times the target stimulus appears. All three paradigms manipulate the requirement of sustained attention for optimal performance. However, regardless of the simplicity of the required task, deficits in performance appear.

Devised hypotheses help explain the deficit in performance demonstrated during simple vigilance tasks. Overall, it appears that a deficiency in vigilance performance occurs because of the failure of the four-system process. Specifically, an individual's performance decreases when mental fatigue, boredom, self-regulation, and motivational changes are present. Mental fatigue occurs when the task imposes a burden on one's mental processes resulting in a decline in information processing resources (Grier et al., 2003; Langner & Eickhoff, 2013; Schneider & Shiffrin, 1977). When an individual's performance is affected by mental fatigue, the individual's supervisory attentional system failed to reactivate the task schema. Boredom occurs when the task fails to maintain an individual's arousal of the supervisory attentional system due to the limited workload required to perform the task (Langner & Eickhoff, 2013; Pattyn, Neyt, Henderickx, & Soetens, 2008). Hindered performance is explained by failure of the supervisory attentional system to inhibit the activation of competing schemata (Langner & Eickhoff, 2013). Pattyn et al. (2008) attempted to explain the vigilance decrement by investigating whether hindered performance relates to an overload of the attentional system (mental fatigue) or an under load (boredom). Recordings of performance on a stimulus detection paradigm and physiological readings revealed that the under load hypothesis better explains the vigilance decrement because individuals exhibit slower reaction times and an increase in error rate because of a shifting of attention to task irrelevant stimuli. They reasoned a lack of evidence supporting the overload hypothesis because of the lack of physiological reactivity to the presented task. However, the overload hypothesis better explains the vigilance decrement experienced with individuals who are sleep deprived as evidenced by the lack of cortical activation in regions of the brain associated with sustained attention (Chee et al., 2008). Additionally, using a stimulus discrimination paradigm, researchers demonstrated the existence of mental fatigue by associated subjective reports of stress induced by task performance (Grier et al., 2003). Similar findings also occurred when a stimulus detection paradigm was used (Langner et al., 2012). Self-regulation, the third contributor to vigilance performance, is a mental resource used in controlled processing (Langner et al., 2012). Given the limited capacity of control processes, Langner et al. (2012) proposed that self-regulation is a resource that depletes after continuous use. If self-regulation is a depletable resource, it explains the "overload" versus "under load" phenomena that occurs on a simple vigilance task. Specifically, they proposed that performance on a simple reaction task requires more self-control strength because of the lack of cognitive challenge present and the added effort needed to stay on task. Over time, self-control strength decreases and vigilance decrements arise. The decrease of self-control strength exemplifies mental fatigue and explains the depletion of a mental resource while also explaining the reason for a wandering mind. Therefore, regardless if the decrements are associated with boredom or mental fatigue, self-regulation serves as the underlying explanation for the presence of the vigilance decrement. The final contributor to vigilance performance involves motivation of the individual to sustain attention to the task in which a cost benefit analysis of performance happens on the cortical level (Hockey, 1997). Specifically, additional cognitive resources are recruited to assist the supervisory system to meet the demand of a task considered as high workload and elicit stress. Otherwise, original performance goals adjust (i.e., effort reduction). This theoretical framework of motivation explains both the failed reactivation of the task schema (mental fatigue) and the failure of inhibition of competing task stimuli (boredom). Individuals produce vigilance decrements out of mental fatigue when multiple cognitive resources are recruited to assist in task performance for an extended time. Additionally, individuals also produce vigilance decrements by readjusting their effort to the task and not inhibiting attention to competing stimuli in the environment.

Researchers identified specific brain areas that become activated during a sustained attention task with the use of positron emission tomography (PET), suggesting that these particular brain areas comprise the supervisory attentional system responsible for maintenance of sustained attention. For simple sustained attention task requiring target detection, researchers identified activation of the right frontal and parietal cortices, but these activations differed in terms of the type of presentation modality for the sustained attention task (Cohen et al., 1988; Langner et al., 2012; Pardo, Fox, & Raichle, 1991). Specifically, when individuals were presented with a somatosensory task of identifying changes in electrical stimulation of their big toe, the expected contralateral somatosensory areas for the somatosensory task demonstrated an increase in cerebral blood flow along with additional activation of the right prefrontal cortex, the right superior parietal cortex, and right temporal cortex (Pardo et al., 1991). Additionally, when individuals completed a visual vigilance task of identifying changes in lamination of a specified target, researchers observed an increased cerebral blood flow to the expected area of the medial striate along with the right prefrontal and right superior parietal cortices (Pardo et al., 1991). When individuals completed an auditory vigilance task, researchers observed stronger activity in the posterior portions of the superior and middle temporal gyri when compared across sensory modalities (Langner et al., 2012). Even when the modality of presentation was varied (i.e., visual vs. auditory vs. tactile), the common area that demonstrated activation was the prefrontal cortex (Cohen et al., 1988; Pardo et al., 1991).

Commonalities of brain activation on attention tasks support the theory of the supervisory attentional system. However, there are inter-individual differences in cognitive processing. The theoretical model of cognitive reserve proposed by Stern (2009) explains that these inter-individual differences are controlled by a cognitive reserve, more specifically a neural reserve (Stern, 2009). An increase in cognitive reserve capacity helps preserve cognitive functioning in the presence of increased task demands, and cognitive reserve capacity is influenced by an increase in neuronal connections. Socioeconomic status, degree of literacy, and leisure activities help strengthen neuronal connections and therefore contribute to a greater cognitive reserve capacity.

Reading Comprehension

Similar to attention tasks, reading requires a combination of automatic and control processes where the individual recognizes the presence of a word (automatic process) and relies on a memory bank of vocabulary to comprehend the connection of the ideas written (control process) (Walczyk, 2000). The amount of work ascribed to each process is dependent on the reading level of the individual as well as the text itself. When first learning to read, the subcomponents of reading (i.e., letter and word identification, word meaning recall, and proposition integration) are necessary to master before reading comprehension can occur and require control processes, which play a demanding role on attention (LaBerge & Samuels, 1974). As these subcomponents are practiced, they are learned and become less effortful, allowing more attentional resources available for comprehending what is being read (LaBerge & Samuels, 1974). Given the role of automatic and control processes in selective sustained attention task and the connection of reading comprehension to selective sustained attention (Solan, Shelley-Tremblay, Ficarra, Silverman, & Larson, 2003; Solan, Shelley-Tremblay, Hansen, & Larson, 2007), below is a review of the theories/models of reading that assist in explaining the role of automatic and control processes in reading comprehension.

Theories/models of reading. LaBerge and Samuels' (1974) Reading Automaticity Theory (RAT) focuses on the transference of reading subcomponents, such as word decoding, from control processing to automatic processing – an occurrence that is seen with beginning readers. According to their theory, practicing usage of these reading subcomponents leads to less need for attention and working memory. When the control processes of attention and working memory are no longer needed for the reading subcomponents, these resources can be allocated to focusing on comprehending what is being read. This theory proposes that individuals who utilize more automatic processes for reading will have better reading comprehension because more control process resources can be reserved for text modeling.

Unlike LaBerge and Samuels' (1974) theory, Perfetti's (1985) Verbal Efficiency Theory (VET) suggests that the automaticity of reading skills is not limited to word decoding. He proposes that other higher-level reading subcomponents, such as correctly referring a pronoun to its antecedent, can also become automatic. Specifically, verbal efficiency is a measure of how quickly and efficiently the reading subcomponents operate when they become automatic processes. When these subcomponents are automatized, less is required from the limited capacity control process to regulate attention and working memory and more resources can be allocated to other components of reading. Individuals with poorer verbal efficiency struggle with the ability to recall immediately what was read because of the need for the reallocation of resources away from other reading subcomponents necessary for text recall towards lower level subcomponents, such as decoding. Once the individual has mastered and automatized decoding, it becomes possible for other reading subcomponents to follow suit allowing for improved reading ability and reading comprehension.

Baker and Brown's (1984) Metacognitive Theory (MT) explains how experienced readers employ certain strategies to be able to comprehend what is being read even when certain obstacles are introduced. These readers are metacognitive in the sense that they are insightful regarding their thought process and are capable of controlling their thought processes and the processing of information read. Metacognitive follows a stepwise pattern in which the individual establishes a reading goal and determines the best efficient and effective strategy to meet the reading goal that was set. Once the strategy is determined, the individual executes the strategy and evaluates whether the chosen strategy was successful. If unsuccessful, the individual chooses another strategy.

Unlike the RAT or the VET, the concentration of MT is on the development of reading comprehension even though metacognition may improve with practice. Additionally, MT introduces separate terminology to describe the processes that occur. With MT, automatic processes are processes that individuals are not aware consciously of having occurred, and the conscious processes, not control processes, are what require attention and working memory. Some strategies, such as elaborative rehearsal, summarization, and comprehension monitoring, that require conscious awareness soon become automatic with practice.

The theory of Constructively Responsive Reading (CRR) emphasizes the strategies that effective readers use to comprehend what is read. While previous theories help explain how beginning readers develop, CRR focuses on advanced readers. The authors of CRR, Pressley and Afflerbach (1995), identify two reading behaviors of advanced readers: bottom-up reading and top-down reading. Bottom-up reading is used when individuals are presented with text that is not difficult and the established reading goal is reading comprehension. This reading strategy relies more on automatic processes and less attentional demand. However, when an individual is presented with text that is more complicated and the reading goal is reading comprehension, top-down reading is used to account for the increased need for attentional resources to compensate for the more difficult text. For the top-down reading approach, reliance is placed on the multiple metacognitive strategies available to meet the reading goal. A shift between bottom-up reading and top-down reading occurs often throughout the reading of a text.

Carver (1997) introduced the Rauding Theory (RT) to describe the relationship between the reading rate of an individual and the retention of information read. RT identifies varying depths of processing that occur when reading that range from shallow processing such as scanning the text to deeper processing such as text memorization, with the implication that greater depths of processing lead to better memory for what was read. In addition to identifying the different types of reading, RT also provides an overview of the varying elements that affect the depth of processing information, which include the complexity of the text, the instructions that guide the reader, and the importance of comprehending the presented text. Demand characteristics, such as time constraints, that are placed on the reading of the text result in changes of the depth of processing due to a need for an increase in reading rate and a change in strategy for text comprehension.

Walczyk's (2000) Compensatory – Encoding Model combines components of the theories previously presented to account for the changes that occur with automatic and control processing when different reading tasks are presented. Similar to CRR, the C-EM is applicable only to experienced readers. Many factors may mediate the ease of reading comprehension, and the C-EM specifies particular behaviors and strategies that help compensate for the obstacles that individuals may face. Because of the extra time these compensatory mechanisms require, the primary external factor that influences reading comprehension is the amount of time available.

According to predictions made by VET, verbal efficiency is presumed to positively correlate with reading comprehension (Perfetti, 1985); however, in cases where verbal efficiency and reading comprehension produce weak correlations (Walczyk, 1995), C-EM can be applied to explain the discontinuity. Specifically, it may be unlikely for there to be correlations between verbal efficiency and reading comprehension because individuals utilize compensatory mechanisms to counter the presented deficit of a verbal inefficiency to comprehend what is being read. The only factor that could affect this compensation would be limited time.

As mentioned previously, individuals who experience verbal inefficiency utilize other methods to compensate for this inefficiency without hindering reading comprehension. These methods can be divided into compensatory behaviors and compensatory strategies. In differentiating between the two, Walczyk (2000) specified that compensatory behaviors were useful in overcoming problems found with automatic processing with minimal disruption to text modeling, whereas compensatory strategies were helpful in overcoming situations that required control processing with a substantial disruption in text modeling. Examples of compensatory behaviors include techniques of slowing one's reading rate when experiencing decoding problems, limited working memory banks, difficulty with semantics, referring back to the text due to small working memory, reading aloud for decoding hurdles, and pausing to help with difficulty in integrating propositions. Overall, these techniques do not require many attentional resources. Examples of compensatory strategies include shifting attention from text modeling to accommodate other reading subcomponents and rereading the text if it is too complex or if the individual forgot what was just read. Another compensatory activity used in reading comprehension is comprehension monitoring. Comprehension monitoring refocuses the individual to understand effortfully what is being read through self-testing. Because comprehension monitoring requires a shift in attentional resources, it can also be considered a compensatory strategy.

With the C-EM, Walczyk (2000) stated that certain predictions of reading behavior are possible. One prediction is that the strength of the association between verbal efficiency and comprehension is moderated by the amount of time provided. Specifically, individuals allotted less time on a reading comprehension task will demonstrate a stronger correlation between verbal efficiency and reading comprehension. A second prediction of the model is that in the absence of time pressure, there will be a negative correlation between compensatory mechanisms and verbal efficiency. Individuals who present with a verbal efficiency deficit will utilize more compensatory behaviors and strategies than someone with adequate verbal efficiency. A third prediction of the model is that when an individual is not capable of resorting to a compensatory mechanism when reading a passage under time pressure, there will be a strong correlation between verbal efficiency and comprehension. Individuals with adequate verbal efficiency will demonstrate better reading comprehension when the ability to use compensatory mechanisms are removed, and this relationship is stronger than if compensatory mechanism usage were present. The final prediction provided by the C-EM is that individuals will utilize compensatory behaviors prior to resorting to compensatory strategies when these compensatory mechanisms are necessary.

Sleep

Stages of sleep. All human beings have a biological clock that is synched to the celestial changes of the earth's rotation. Similar to the earth's rotation, our biological clock functions on approximately a 24-hour schedule. We are categorized as diurnal because we remain active during daylight hours and sedentary during nighttime hours. Sleep serves to regulate our physiological systems and allow for optimal functioning. The periods of sleep and wakefulness are controlled by the basic processes of a circadian process, a homeostasis process, and an ultraradian process within sleep. The circadian process is guided by the central circadian clock located in the suprachiasmatic nucleus of the hypothalamus and dictates when individuals are most likely to seek rest. For most individuals, the central circadian clock is guided by zeitgebers, such as bright light or an alarm clock. However, when isolated from any external cues indicating the time of day, an individual's sleep-wake cycle is often correlated with changes in body temperature. Specifically, when an individual's body temperature reaches nadir (the lowest point in body temperature), sleep is more likely to occur. When these endogenous cues (body temperature) dictate the sleep-wake cycle, the cycle is categorized as being in a "free-running rhythm." The homeostatic process is controlled by previous periods of wakefulness and sleep and influences the circadian processes defined sleep propensity. The ultradian process controls the cycling of the dichotomous stages of sleep, non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. All three processes are interrelated in that an adjustment in one process leads to alterations in the other two processes. In other words, if an individual is unable to maintain sleep the night before (ultradian process), they are likely to become sleepy earlier and seek rest sooner than previous nights (homeostatic process). This pattern may affect sleep propensity the following night as well as future nights, which may lead to an adjustment in the time they typically go to bed (circadian process) (Zee & Turek, 1999).

Scientists once believed that sleep served no fundamental purpose in the regulation of neurological and physiological systems. However, following the invention of the electroencephalogram (EEG) and the introduction of polysomnography (PSG), it was discovered that brain and physiological activity continued even when an individual was unconscious and at rest and that sleep followed a recognizable pattern (Zee & Turek, 1999). The division of sleep follows two general phases, NREM and REM, with NREM sleep subdivided into four more stages: stage 1, stage 2, stage 3, and stage 4. The different stages of sleep are categorized by particular brain wave activity that varies in amplitude (height distance between the top and bottom of a wave) and frequency (how fast the waves rise and fall). Amplitude is measured in microvolts, and frequency is measured in cycles per second, with each cycle defined as the transition from one wave spike to the next (Hobson, 1989). The brain wave activity is captured by timeframes called epochs, which occur in an average of 30-second durations. Each subdivided sleep stage occurs in succession but varies in length of time and depth of sleep. Stage 1 sleep ensues during the intermediate phase of wakefulness and sleep. This stage lasts approximately a few minutes and is identified by theta brain wave activity. Theta brain wave activity produces a high frequency (4-8 cycles per second), low amplitude (50 – 100 microvolts) wave. Stage 2 sleep, the true onset of sleep, is characterized by sleep spindles and K complexes. Sleep spindles produce a frequency of 11.5 to 16 cycles per second and have a measured amplitude of 50 microvolts. K complexes produce a high frequency (.5 cycles per second) and a high amplitude wave and are proceeded by sleep spindles. Additionally, an individual is more likely to be awoken following a K complex than prior to one. Together, sleep spindles and K complexes make up approximately 20% of an epoch. Stages 3 and 4 are identified as slow wave sleep (SWS) or deep sleep and are characterized by the patterned high amplitude EEG waves known as delta waves. Delta waves have a frequency of less than 4 cycles per second, with slow waves being a subset of delta wave activity (2 cycles per second or less). Slow waves are also identified by their amplitude, which is standardized at 75 microvolts. The percentage of slow waves and delta activity that are present during an epoch help define the difference between Stage 3 sleep and Stage 4 sleep. An individual is said to be in Stage 3 sleep when the delta activity makes up approximately 20 – 50% of an epoch. An individual is characterized as being in Stage 4 sleep when an epoch is comprised of 50% or more of slow waves. An individual moves through these four stages of NREM sleep in approximately 50-70 minutes, after which they enter into REM sleep. REM sleep lasts approximately 40 – 50 minutes during which the brain is highly active yet muscle atonia occurs (Hobson, 1989). Additionally, individuals experience dreams during this stage of sleep. As an individual cycles through the NREM and REM stages of sleep, the duration of time spent in stages 3 and 4 decrease, whereas time spent in the REM stages of sleep increase. Both the NREM and REM stages of sleep serve important roles in the maintenance of physiological and neurological functioning. Percent of times vary for time spent in each sleep stage, but on average, an adult spends 50% in light sleep, 20% in REM sleep, and 30% in slow wave sleep (National Institute of Neurological Disorders and Stroke, 2014). The recommended total sleep time for young adults is seven to nine hours (Hirshkowitz et al., 2015).

NREM. Similar to the different brain wave activity that occurs throughout the different stages of sleep, differences exist between the benefits of NREM and REM sleep. Studies evaluating the physiological function of deep NREM sleep using functional magnetic resonance imaging revealed that NREM sleep might be responsible for the deactivation of particular cortical areas that remain overactive during periods of wakefulness (Kajimura et al., 1999) in addition to being responsible for the activation of other areas (Peigneux et al., 2004). Specifically, the fronto-parietal higher cortical areas are deactivated during NREM sleep, which suggests that NREM sleep may be responsible for allowing areas of the parietal cortex to "rest" in order to maintain optimal functioning during periods of wakefulness. It was also found that during SWS the reactivation of the hippocampus facilitates the process of long-term memory storage in the neocortex, which leads to stronger neocortical connections and improved retrieval (Walker, 2009).

NREM sleep significantly affects various aspects of cognitive functioning, including spatial memory, episodic memory, declarative memory, and sustained attention. Regarding spatial perception, Peigneux and colleagues (2004) examined the reactivation of areas of the hippocampal formation when individuals were in SWS following a declarative spatial memory task, which suggests that continuous processing of spatial memory occurs to strengthen the neural connections and allow for ease of recall. Additionally, there is evidence for the reactivation and consolidation of episodic memories during SWS. However, the positive association between episodic memories and SWS weakens as individuals get older (Scullin, 2013). NREM sleep is also associated with enhancement in declarative memory (Daurat, Terrier, Foret, & Tiberge, 2007; Gais, Plihal, Wagner, & Born, 2000; Plihal & Born, 1997). When individuals' texture discrimination skills were tested following a retention period, individuals who spent more time in slow wave sleep demonstrated significant performance improvement compared to time spent in REM sleep or time spent awake (Gais et al., 2000). Similarly, when testing recall of a paired-associates list, individuals recalled significantly more words following slow wave sleep than following REM sleep, which suggests that time spent in slow wave sleep is more beneficial than time spent in REM sleep (Plihal & Born, 1997). Another study analyzing the effects of SWS and REM sleep on recollection memory found that individuals who obtained sleep rich in SWS demonstrated better recognition than following sleep rich in REM sleep (Daurat et al., 2007). Reading abilities are also correlated with SWS activity. Specifically, the sleep architecture of children with dyslexia revealed that more slow spindles were present on the EEG than normal controls, which showed a positive association between time spent in stage 2 sleep of the NREM sleep cycle and reading deficits (Bruni et al., 2009). Finally, there is evidence suggesting that spending more time in slow wave sleep protects individuals from sustained attention impairment when sleep restriction is experienced. Individuals who were sleep deprived on four consecutive nights but received a slow wave sleep enhancing drug did not experience impairment on a continuous performance test compared to individuals who received a placebo (Walsh et al., 2006).

REM. There are multiple theories that attempt to explain the physiological function of REM sleep, including maintaining the catecholamine systems in the Central Nervous System, monitoring the central norepinephrine receptors, regulation of intentional behavior and mood, and its role in information processing. However, some of the most researched theories have been on the effect that REM sleep has on learning and memory (Zee & Turek, 1999). Crick and Mitchison (1983) proposed that, through dreaming, humans are able to "unlearn" certain information acquired. They justified their theory by first acknowledging that sleep serves an important physiological function and by secondly suggesting that because we forget the majority of our dreams, the major benefit from sleep must occur during the unconscious REM stage of sleep. They believed that because of the constant neural connections and associations that are made during learning, it was possible for our neural system to become overwhelmed and malfunction. They proposed that, as a self-preserving function, the brain learns to forget unimportant information through an alteration in the strengths of synaptic connections, which is assumed to occur during the unconscious REM stage of sleep when we dream. While this unimportant information is unlearned during REM sleep, synaptic connections for important information are strengthened as evidenced by activation of certain cortical regions. For example, individuals experienced an enhancement in amygdala-dependent emotional memory during REM sleep (Wagner, Degirmenci, Drosopoulos, Perras, & Born, 2005). Additionally, the restoration of the attention processes of automatic and selective attention occur during REM sleep as evidenced by a significant decrease in activity over the frontal and temporal cortices following a night of REM deprived sleep (Zerouali, Jemel, & Godbout, 2010). REM sleep has also been shown to enhance creative problem solving. In a study conducted by Cai, Mednick, Harrison, Kanady, and Mednick (2009), individuals who obtained more REM sleep performed significantly better on performing a creative problem solving task. The authors hypothesized that the observed difference was due to the increased activity of the cholinergic and noradrenergic receptors during REM sleep, which in turn improves the "integration of unassociated information for creative problem solving."

Sleep quantity. Individuals need about eight hours of sleep each night (Wright et al., 2006). Zaharna and Guilleminault (2010) characterize sleep deprivation as multiple successive nights of inadequate sleep, yet it is important to distinguish the difference between total sleep deprivation and partial sleep deprivation. Total sleep deprivation entails at least 24 hours of complete wakefulness and results in impairments in psychomotor vigilance, working memory, and overall cognitive functioning, as well as reports of daytime sleepiness (Van Dongen et al., 2003). Partial sleep deprivation entails multiple successive nights of six hours of sleep or less and results in equally debilitating impairments in psychomotor vigilance, working memory, overall cognitive functioning, and reports of daytime sleepiness as seen with total sleep deprivation (Van Dongen et al., 2003). In a review of the consequences of partial sleep deprivation, Banks and Dinges (2007) identified that partial sleep deprivation can occur in three ways: sleep fragmentation, selective sleep stage deprivation, and sleep restriction. Sleep fragmentation involves the disruption of the progression through sleep stages, which hinders the physiological benefits of sleep. This type of partial sleep deprivation is common among individuals diagnosed with a sleep disorder (i.e., sleep apnea). Selective sleep stage deprivation involves sleep fragmentation of a particular sleep stage. This type of partial sleep deprivation may be manipulated through medication or found with individuals diagnosed with a sleep disorder where a particular sleep stage has the primary disruptions. Sleep restriction is the most common of the three partial sleep deprivations and involves a reduced amount of sleep in association with the amount of sleep needed. Similar to sleep fragmentation and selective sleep stage deprivation, sleep restriction also affects time spent in the different sleep stages. Specifically, when individuals experience a sleep debt (i.e., four hours of total sleep), there is a decrease in time spent in NREM stage 2 sleep because individuals tend to fall asleep rather quickly and a decrease in time spent in REM sleep. However, there is no decrease in time spent in slow wave sleep compared to a typical eight-hour total sleep night (Banks & Dinges, 2007; Goel, Rao, Durmer, & Dinges, 2009).

As previously mentioned, sleep deprived individuals demonstrate impaired performance on vigilant attention tasks. Lim and Dinges (2008) explored these effects through an extensive literature review of research conducted on sleep deprivation and attention. Researchers focused on vigilant attention in evaluating the effects of sleep deprivation because of the assumption that poor cognitive performance is attributable to the lack of ability to sustain attention to the identified task and because of consistent findings that vigilance is affected by periods of inadequate sleep. The effect of sleep deprivation on vigilant attention has been evaluated by measuring reaction time for a menial attention task that lasts approximately 10 minutes. Individuals considered sleep deprived consistently demonstrated a slower response time, an increase in errors, and a decline in performance due to fatigue within minutes of beginning the task; however, there is variability in the presence of deficits. Doran, Van Dongen, and Dinges (2001) introduced the state instability hypothesis to explain performance variability following sleep deprivation. As explained by the state instability hypothesis, sleep deprived individuals experience an overwhelming urge to sleep. When this occurs, they resist this urge by directing more effort towards the task but are unable to sustain this effort, which results in lapses in attention through continued performance. Doran et al. (2001) argue that a compensatory effort better explains variations in performance than boredom and can hide the true effects of sleep deprivation. Additionally, Goel et al. (2009) argue that variability in neurocognitive effects of chronic partial sleep deprivation are due to individual differences in susceptibility to impairment following continuous sleep loss as suggested by the cognitive reserve theory previously discussed (Stern, 2009).

In addition to affecting attention, sleep deprivation also affects working memory. This was evidenced in a study conducted by Smith, McEvoy, and Gevins (2002) that monitored individuals' performance on a working memory task who were sleep deprived for up to 21 hours. Results of their study revealed that following a night of sleep deprivation, individuals had a lower accuracy scores and slower response times compared to their alert baseline levels. Similar results were found in a meta-analysis conducted by Lim and Dinges (2008). The effects of short-term total sleep deprivation were evaluated across 176 articles, and the results indicated that there is a significant moderate effect of total sleep deprivation on working memory performance, specifically on accuracy and response time. Their findings also indicated that simple attention and vigilance tasks were most affected by short-term sleep deprivation and that performance on a complex attention task remained intact. In evaluating the effects of working memory using a reading comprehension task, researchers failed to find any difference in performance of individuals following 24 hours of total sleep deprivation (Quigley, Green, Morgan, Idzikowski, & King, 2000); however, there has been no research investigating the effects of partial sleep deprivation on reading comprehension performance.

Sleep restriction has also been shown to negatively affect academic performance. Gaultney (2011) examined the sleep hygiene of college students with a 50-item survey used for identifying sleep characteristics, and compared their responses to their current grade point average. Her results revealed a weak relationship between sleep habits and academic performance. Specifically, individuals who reported obtaining consistent sleep of good duration also reported receipt of higher grades. Additionally, her research revealed that students who met the qualifications of at least one sleep disorder reported lower grade point averages than students who did not meet the qualifications of any sleep disorders.

Sleep quality. Sleep quality is an index of one's length of time spent in deep sleep, morning wakefulness, and sleep satisfaction (Pilcher, Ginter, & Sadowsky, 1997) and focuses on explaining how restful a night's sleep was. There have been efforts to standardize the measure of sleep quality to quantify quality of sleep and evaluate its effects on daily functioning. In the construction of these measures, researchers determined that the key components to be measured included length of time to fall asleep, total hours slept, total number of awakenings, wake after sleep onset, a rating of daytime functioning, and use of sleep aids (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989;

Urponen, Partinen, Vuori, & Hasan, 1991). Length of time to fall asleep, total sleep time, nighttime awakenings, and wake after sleep onset served as significant negative predictors of sleep quality.

An important aspect of standardizing the measure of sleep quality is assuring a consistent operational definition of sleep quality. Harvey, Stinson, Whitaker, Moskovitz, and Virk (2008) expanded on the efforts to standardize the measurement of sleep quality by comparing the subjective interpretation of sleep quality by individuals diagnosed with insomnia to those of a non-clinical population. Both populations agreed that components of sleep quality include how well rested one feels when awakening in the morning, how rejuvenated one feels after awakening, and how alert one is able to remain throughout the day. The clinical population added how well one slept as an important component, whereas the non-clinical population believed a rating of whether one obtained enough sleep and how tired one feels throughout the day should be included as a measureable component of sleep quality. While some differences in interpretations did emerge, both populations expressed an agreement that the measurement of feelings of tiredness upon awakening and throughout the day should be a defined component of sleep quality. Akerstedt, Hume, Minors, and Waterhouse (1997) also evaluated the best predictors of subjective sleep quality and determined that sleep quality was better predicted by individual reports of the calmness of sleep and the ease of falling asleep, in addition to the to the physiological sleep measures of total sleep time and time spent in slow wave sleep (deep sleep).

Additionally, there is an investigation into the physiological measures of sleep as potential objective measures of sleep quality. A polysomnography (PSG), which measures brain waves, oxygen levels, heart rate, breathing rate, eye movements, and leg movements, is the standard assessment of sleep mechanisms (Mayo Clinic, 2011). Data collected from a PSG allows one to calculate the key ingredients believed to define sleep quality, which includes the quantity and time of sleep occurrence, the quantity of sleep disturbances that occur, and the amount of time spent in each sleep stage (Krystal & Edinger, 2008). Yet, even with the rich data that is acquired with a PSG, Krystal and Edinger (2008) suggest that there is also a significant amount of data that is lost due to break down of the nature of sleep into four discrete stages, which fails to serve as an adequate representation of the continuous nature of sleep. They propose that there be alternative objective measures of sleep considered in the establishment of an objective measure of sleep quality, such as examining the EEG pattern of sleep waves or the amount of movement that occurs during sleep. They also suggest the strategy of combining multiple measures, subdividing individuals being evaluated into subgroups based on particular features (i.e., clinical vs. nonclinical or particular physiological characteristics), and analyzing and subgrouping sleep quality within individuals rather than between individuals for multiple nights to identify a pattern of sleep quality.

In evaluating the effects sleep quality, research shows that poor sleep quality is associated with one's overall well-being. Pilcher and colleagues (1997) evaluated the relationship between self-reported sleep quality of university students and the effects that sleep has on physical health as well as mood and affect. Their results indicated that individuals who reported poorer sleep quality also reported experiencing greater physical problems and more anxiety and depression. Additionally, Krishnan and colleagues (2008) evaluated the association between reported sleep quality and quality of life and found that poor sleep quality was negatively associated with roles of physical functioning, vitality, and emotions. Inversely, Pilcher and Ott (1998) evaluated the relationship between reported sleep quality and health and well-being of college students and found that when reported sleep quality improved so did students' physical and psychological health.

Poor sleep quality has also been shown to affect the cognitive functioning of a variety of populations with mixed results. Benitez and Gunstad (2012) evaluated the effect of sleep quality on cognitive functioning of healthy young adults. They operationally defined cognitive functioning as a measure of attention and executive functioning specifically. They found that individuals who reported poor sleep quality demonstrated poor performance on executive functioning tasks, but there was no relationship between reported sleep quality and performance on an attention task. Howell, Jahrig, and Powell (2004) also targeted college aged adults and assessed the effects of sleep quality on academic performance. Overall, there were no associations between reported sleep quality and academic performance; however, when students were separated by course load, there was a significant positive relationship between sleep quality and academic performance (i.e., better sleep quality yielded better GPA). Similarly, Ellis, Walczyk, Buboltz, and Felix (2014) assessed the effect of sleep quality on reading comprehension performance. They found that there was no correlation between reading skills and sleep quality, but individuals who reported the poorest sleep quality performed significantly better on a reading comprehension task than individuals who reported moderate sleep quality.

Naismith,Winter, Gotsopoulos, Hickie, and Cistulli (2004) also evaluated the effect of sleep quality on cognitive functioning within individuals diagnosed with sleep apnea. The areas of cognitive functioning that were evaluated included neuropsychological performance, processing speed, working memory, verbal memory, language, visuospatial functioning, executive functioning, affect, and sleepiness. Sleep quality was measured by a decrease in time spent in REM sleep and a decrease in sleep efficiency. Results indicated that sleep quality was negatively associated with neuropsychological performance when processing speed was important as well as with depression and tension-anxiety levels. A similar study evaluated the effect of sleep quality on cognitive performance but with a healthy geriatric population (Nebes, Buysse, Halligan, Houck, & Monk, 2009). Sleep quality was measured by a self-report questionnaire and areas of cognitive performance that were of interest included information processing speed, working memory, inhibitory function, attention shifting, abstract reasoning, and episodic memory. Results of the study revealed a significant difference between "good sleepers" and "poor sleepers" as indicated by the sleep quality measurement on performance in working memory, attention shifting, and abstract problem solving but no differences between sleep quality and speed of information processing, response inhibition, or immediate/delayed verbal memory. Yun et al. (2015) also evaluated the effects of sleep quality and sustained attention on middle and late adulthood. They found that poor sleep quality was not associated with poor performance on the Psychomotor Vigilance Test.

Young school children have also been assessed in determining the association of sleep quality and cognitive performance. Steenari and colleagues (2003) evaluated sleep quality and its related effects on auditory/working memory in school children aged 6 to 13. A measure of sleep quality was obtained through Actigraph monitors and auditory/working memory was assessed using the n-back task paradigm. Similar to previous findings, results indicated sleep efficiency was negatively associated with response accuracy.

Daytime sleepiness. Daytime sleepiness is associated with fragmented sleep, restricted sleep, and poor sleep quality (Braeckman, Verpraet, Van Risseghem, Pevernagie, & De Bacquer, 2011; Carskadon & Dement, 1977; Guilleminault, Stoohs, Clerk, Cetel, & Maistros, 1993) and serves as a measure of sleep propensity (i.e., tendency to fall asleep). Daytime sleepiness has also been associated with time spent in particular sleep stages. Specifically, research suggests that greater disturbances in individuals' non-REM sleep cycles compared to REM sleep characterize daytime sleepiness (Punjabi et al., 2002). In measuring daytime sleepiness, researchers quantified reports of individuals' likelihood of falling asleep at particular moments during the day and established cutoff scores indicative of high levels of daytime sleepiness (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973; Johns, 1991).

Aside from its association with sleep quality and sleep quantity, daytime sleepiness is also associated with cognitive functioning. Ohayon and Vecchierini (2002) examined the effects of self-reported daytime sleepiness and cognitive functioning in the elderly, as measured by the Cognitive Difficulties Scale. Results indicated a higher incidence of reported attention-concentration deficits for individuals who experienced excessive daytime sleepiness, even when controlled for sleep duration. Yun and colleagues (2015) also evaluated the effect of excessive daytime sleepiness on sustained attention with older adults using an objective measure of sustained attention performance and similarly found that individuals who reported higher daytime sleepiness demonstrated significantly poorer sustained attention performance. Similar results were found when the relationship between daytime sleepiness and attention/concentration impairments were evaluated in children (Golan et al., 2004). Results indicated a significant positive association between children diagnosed with Attention Deficit Hyperactivity Disorder and objective daytime somnolence. Additionally, individuals diagnosed with sleep-wake disorders, who also endorsed greater daytime sleepiness, performed significantly worse on the Psychomotor Vigilance Test than the control group (Thomann, Baumann, Landolt, & Werth, 2014).

There have been mixed results in the association between daytime sleepiness and other measures of cognitive performance. In evaluating the effect of daytime sleepiness on academic activities, Campos-Morales, Valencia-Flores, Castaño-Meneses, Castañeda-Figueiras, and Martínez-Guerrero (2005) did not find any significant associations between reading comprehension and reported daytime sleepiness; however, there was a significant association between mathematical skills and reported daytime sleepiness. Additionally, when individuals with diagnosed sleep apnea were evaluated on various measures of cognitive functioning, deficits were only found in the area of academic achievement associated with mathematical skills (Giordani et al., 2008), which suggests that daytime sleepiness is related to academic achievement, but the relationship is restricted to arithmetic.

Hypotheses

Hypotheses 1 and 1a

There will be a significant mean difference in sustained selective auditory attention between short and long deep sleep for the final night. It is expected that individuals who spend more time in deep sleep will perform significantly better on a sustained selective auditory attention task.

- 1a: There will be a significant mean difference in sustained selective auditory attention between short and long deep sleep averaged over three nights. Specifically, it is expected that individuals who average more time in deep sleep over three nights will perform significantly better on a sustained selective auditory attention task.

Justification for Hypothesis 1 and 1a

NREM sleep might be responsible for the deactivation of particular cortical areas that remain overactive during periods of wakefulness, including areas of the brain responsible for spatial perception, attention, and language. The deactivation of these cortical areas allows for "rest" in order to maintain optimal functioning during periods of wakefulness (Kajimura et al., 1999). Additionally, individuals who experienced enhanced slow wave sleep (i.e., deep sleep) during consecutive nights of sleep restriction demonstrated improved performance on a psychomotor vigilance task (Walsh et al., 2006). Therefore, it was expected that individuals who spend more minutes in deep sleep would demonstrate improved performance on a sustained selective attention task.

Hypotheses 2 and 2a

There will be a significant mean difference in sustained selective auditory attention between the short and long REM sleep in one night. It is expected that individuals who spend more time in REM sleep will perform significantly better on a sustained selective auditory attention task.

- 2a: There will be a significant mean difference in sustained selective auditory attention between the short and long REM sleep averaged over three nights. Specifically, it is expected that individuals who average more time in REM sleep over three nights will perform significantly better on a sustained selective auditory attention task.

Hypothesis 3

There will be a significant mean difference in sustained selective auditory attention between short and long sleep length for the final night. It is expected that individuals who obtain more sleep will perform significantly better on a sustained selective auditory attention task.

Justification for Hypotheses 2, 2a, and 3

During sleep restriction, individuals experience less time in REM sleep and stage 2 NREM sleep (Banks & Dinges, 2007). One consequence of sleep restriction is a decrease in behavioral alertness, which is measured by a sustained attention task. Van Dongen and colleagues (2003) determined that individuals who were restricted to sleep regimens of four and six hours demonstrated significant impairment in behavioral alertness compared to individuals who received eight hours of sleep. Therefore, individuals who spend less time in REM sleep because of a decrease in overall sleep length also demonstrate a deficit in behavioral alertness.

Hypothesis 4

There will be a significant mean difference in sustained selective auditory attention between good and poor sleep quality for the final night. It is expected that individuals with good sleep quality will perform significantly better on a sustained selective auditory attention task.

Justification for Hypothesis 4

Studies have shown that sleep quality affects cognitive functioning (Benitez & Gunstad, 2012; Naismith et al., 2004; Nebes et al., 2009; Steenari et al., 2003). Cognitive functioning involves the conscious effort of the individual to attend to sensory information for a period of time (Schneider & Shiffrin, 1977; Langner & Eickhoff, 2013). When performance on attention shifting, specifically, was evaluated against reported sleep quality, individuals who reported poor sleep quality demonstrated poorer attention capabilities (Nebes et al., 2009).

Hypothesis 5

There will be a significant mean difference in sustained selective auditory attention between low and high daytime sleepiness. It is expected that individuals who report lower daytime sleepiness will perform significantly better on a sustained selective auditory attention task.

Justification for Hypothesis 5

Research into the contributing factors of daytime sleepiness revealed an association between daytime sleepiness and fragmented sleep, restricted sleep, and poor sleep quality (Braeckman et al., 2011; Carskadon & Dement, 1977; Guilleminault et al., 1993), as well as with the number of disturbances during NREM sleep (Punjabi et al., 2002). Given the strong relationship between daytime sleepiness and sleep quality and quantity, it was expected that similar effects found between sleep quality and quantity on sustained attention would also be found with daytime sleepiness. Additionally, previous studies showed a positive relationship between reported daytime sleepiness and attention/concentration impairments (Ohayon & Vecchierini, 2002; Golan et al., 2004).

Hypotheses 6 and 6a

There will be a significant mean difference in reading comprehension between short and long deep sleep for the final night. It is expected that individuals who spend more time in deep sleep will perform significantly better on a reading comprehension task.

- 6a: There will be a significant mean difference in reading comprehension between short and long deep sleep averaged over three nights. Specifically, it is expected that individuals who average more time in deep sleep over three nights will perform significantly better on a reading comprehension task.

Justification for Hypotheses 6 and 6a

Enhanced declarative memory has been linked to time spent in slow wave sleep (Daurat et al., 2007; Plihal & Born, 1997). Additionally, visual discrimination skills responsible for reading comprehension, which employs procedural memory processes, improve with the activation of slow wave sleep (Gais et al., 2000). Therefore, more time spent in slow wave sleep suggests possible improvement in reading comprehension.

Hypotheses 7 and 7a

There will be a significant mean difference in reading comprehension between short and long REM sleep for the final night. It is expected that individuals who spend more time in REM sleep will perform significantly better on a reading comprehension task.

- 7a: There will be a significant mean difference in reading comprehension between short and long REM sleep averaged over three nights. Specifically, it is expected that individuals who average more time in REM sleep over three nights will perform significantly better on a reading comprehension task.

Hypothesis 8

There will be a significant mean difference in reading comprehension between short and long sleep length for the final night. It is expected that individuals who obtain more sleep will perform significantly better on a reading comprehension task.

Justification for Hypotheses 7, 7a, and 8

As mentioned previously, individuals who obtain less sleep experience less time in REM sleep (Banks & Dinges, 2007), which results in a deficit in behavioral alertness (Van Dongen et al., 2003). There is also evidence of an association between attention and reading comprehension (Pilcher et al., 2007; Solan et al., 2003; Solan et al., 2007) in which deficits in attention affect reading comprehension performance. Therefore, it was assumed that time spent in REM sleep would affect performance on a reading comprehension task and the effect associated with REM sleep would also be associated with sleep length.

Hypothesis 9

There will be a significant mean difference in reading comprehension between good and poor sleep quality. It is expected that individuals who report better sleep quality will perform significantly better on a reading comprehension task.

Justification for Hypothesis 9

Reading comprehension requires the activation of the controlled processes of the information processing system, which is associated with detection of, searching for, and attending to specific information (Schneider & Shiffrin, 1977). Therefore, reading comprehension performance is dependent on attention to the task (Solan et al., 2003). Studies have shown that cognitive functioning, which includes the ability to attend to and comprehend information, is affected by reported sleep quality (Benitez & Gunstad, 2012; Naismith et al., 2004; Nebes et al., 2009; Steenari et al., 2003).

Hypothesis 10

There will not be a significant mean difference in reading comprehension between low and high daytime sleepiness.

Justification for Hypothesis 10

While there is evidence to suggest that daytime sleepiness is associated with academic performance, there is a lack of supporting evidence to suggest that reports of daytime sleepiness will be instrumental in identifying differences in performance on a reading comprehension task (Campos-Morales et al., 2005; Giordani et al., 2008).

Hypotheses 11 and 11a

The combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, sleep length for one night, and daytime sleepiness will serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness.

- 11a: The combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness will serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness.

Justification for Hypotheses 11 and 11a

All five variables (minutes in deep sleep, minutes in REM sleep, sleep length, sleep quality, and daytime sleepiness) have individual associations with attention. It was assumed that because of each variable's individual relationship with attention, together these variables would account for a significant amount of variance in performance on a sustained selective attention task. However, no studies have explored the predictive value of these variables regarding a sustained selective attention task. This hypothesis tested which variables served as the best predictors of sustained selective attention.

Hypotheses 12 and 12a

The combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, and sleep length for one night will serve as significant positive predictors of reading comprehension performance.

- 12a: The combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, and averaged sleep length will serve as significant positive predictors of reading comprehension performance.

Justification for Hypotheses 12 and 12a

All four variables (minutes in deep sleep, minutes in REM sleep, sleep length, and sleep quality) have individual associations with reading comprehension. It was assumed that because of each variable's individual relationship with reading comprehension, together these variables would account for a significant amount of variance in reading comprehension performance. However, no studies have explored the predictive value of these variables regarding reading comprehension. This hypothesis tested which variables served as the best predictors.

CHAPTER TWO

METHOD

Participants

Participants for this experiment included 80 undergraduate students recruited from a midsize southern university. Of those 80 students, only 46 participants were included in the study because of technical difficulties with the sleep monitoring apparatus (*n* = 26) and software program for measuring attention (*n* = 5) as well as attrition (*n* = 3). Of the 46 participants who were included in the study, 33 (71.7%) were females and 13 (28.3%) were males. The majority were Caucasian (73.9%) followed by African American (21.7%) and Hispanic (4.3%). Participants' ages ranged from 18 – 59 with the median age being 20 years old (*M* = 21.46, *SD* = 6.22). Grade classification included nine freshmen (19.6%), 18 sophomores (39.1%), nine juniors (19.6%), and 10 seniors (21.7%) with a mean grade point average of 3.18. Half of the participants reported no difficulty with their vision and 47.8% reported that glasses or contacts corrected their vision. Additionally, the majority of participants (n = 45, 97.8%) reported no hearing difficulties. Similarly, the majority of participants (n = 39, 84.8%) reported having never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, and no participants endorsed English as a second language. Participants received extra credit points as provided by the instructor in addition to earning a chance of winning one of five $20 American Express gift cards.

Apparatus

Zeo Wireless System

Zeo (manufactured by Zeo, Inc. founded in 2003) is a wireless sleep monitoring device worn as a headband that tracks sleep patterns, specifically, the number of awakenings throughout the night indicated by sleep disruptions of at least two minutes, the length of time one spends in deep sleep, and the length of time one spends in REM sleep. Information is stored on a docking station. Validation studies for the Zeo conducted by Shambroom, Fabregas, and Johnstone (2012) revealed substantial validity for measuring sleep stages ($K = .758$) when compared to a polysomnography and strong validity for measuring sleep/wakefulness ($K = .926$). The data for amount of time spent in deep sleep, the amount of time spent in REM sleep, and the total sleep length was dichotomized by median split to define short versus long intervals.

Instruments

Test of Sustained Selective Attention

The Test of Sustained Selective Attention (TOSSA) is a computerized continuous performance test that measures an individual's sustained attention. For this test, individuals hear a series of beeps ranging from two to four consecutive beeps. A group of three beeps is the intended target. When the individual hears the group of three beeps, s/he is required to push the space bar as quickly as possible. The individual is to refrain from hitting the space bar after hearing the groups of two beeps or four beeps. The test has eight measurement blocks and the speed of the presentation of beeps change for the eight blocks of time, with some having groups of beeps presented in slow intervals and others having the groups of beeps presented in rapid intervals. The TOSSA program calculates the concentration strength (CS), the detection strength (DS), and the response inhibition strength (RIS) of each individual's performance, with the CS index being the index of interest for this study. The CS index is the product of the DS index and the RIS index divided by 100. These scores are compared an individual's performance to a variety of clinical populations and healthy norm groups. Test-retest reliabilities using Spearman's rho are adequate for the above indices: CS = .84, DS = .82, and RIS = .77. The TOSSA CS demonstrates good construct validity, with significant correlations to the Stroop Color Work Test ($r = .41$), the Trail Making Test ($\rho = -.40$), and the WAIS-III.

Sleep Quality Index

The Sleep Quality Index (SQI) is an eight item self-report questionnaire that measures general sleep difficulties over a three-month period, including falling asleep, remaining asleep, and early morning awakening. There are three multiple-choice items provided for each of the eight questions. The responses for each item are coded 0, 1, or 2 with a score of 2 indicating severe symptoms. A total sleep quality score is the summation of the scores from the eight items. Scores ranging from 0 to 1 indicate good sleep quality; scores ranging from 2 to 8 indicate occasional sleep difficulties; scores ranging from 9 to 16 indicate poor sleep quality. Urponen et al. (1991) reported the SQI as a valid measure of sleep quality due to its significant relationship with subjective health. Additionally, the SQI has acceptable internal consistency with Cronbach's alpha scores of .73 and .75 for men and women respectively (Urponen et al., 1991). This sample produced a Cronbach alpha score of .58. Due to a small sample size in some of the sleep quality categories, the data was dichotomized by median split to define the varying levels of sleep quality into a poor quality and good quality group.

Epworth Sleepiness Scale

The Epworth Sleepiness Scale (ESS) is an eight-item self-report questionnaire that measures perceived level of general daytime sleepiness (Johns, 1991). Individuals rate eight different situations in which they could fall asleep on a 4-point scale (0-3). The tallied scores provide a total ESS score that can range from 0 to 24, with scores greater than 10 indicating greater daytime sleepiness (Johns, 1991). A score of 0 – 9 indicates normal daytime sleepiness and a score of 10-24 indicates clinical daytime sleepiness. The ESS is highly correlated to the Multiple Sleep Latency Test (Carskadon & Dement, 1977), which is considered the gold standard for measuring sleepiness (ρ= -0.42, $n = 44$, $p < 0.01$). The ESS has demonstrated high test-retest reliability ($\rho = 0.82$, $n = 87$, $p < 0.001$) and high internal consistency ($\alpha = 0.88 – 0.74$). Internal consistency for this sample was slightly lower ($\alpha = .62$). This sample produced a Cronbach alpha score of .62. Participants' scores on the ESS were dichotomized by median split to define low and high levels of daytime sleepiness.

Reading Comprehension Task

Four passages with each comprised of 12 sentences on varied topics, such as history and the government, were presented in one of four random orders to the participants to control for order effects. The passages included Flesch-Kincaid Reading levels of 10.0 grade level or higher (Kincaid, Fishburne, Rogers, & Chissom, 1975). Participants were restricted in the time allowed to read each passage. This researcher determined the time restriction by piloting the passages and identifying the average reading time for the passages. In order to ensure mild time pressure, participants were limited to the median amount of time it took readers in the pilot study to complete the passages (Walczyk, Kelly, Meche, & Braud, 1999). The sentence verification test (SVT), established by Royer, Hastings, and Hook (1979), followed each passage to test reading comprehension. Four types of test sentences were used to test reading comprehension: (a) an original sentence (copy of sentence that appeared in the passage), (b) a paraphrase sentence (paralleled version of the original sentence in which the meaning is not changed but the wording is significantly altered), (c) a meaning-change sentence (the entire meaning of the original sentence is altered by changing a couple of words in the sentence), and (d) a distractor sentence (syntax and content is similar to passage but unrelated) (Royer, 2001). Participants read four versions of each type of test sentence (16 sentences total). Eight of these sentences had the same meaning as a sentence in the passage. Upon reading the sentence, the participant indicated whether the sentence had the same meaning as a sentence in the passage without referring back to the passage. Accuracy scores were measured. A total comprehension accuracy score was computed, with possible scores ranging from 0 and 64. The total comprehension accuracy score served as the reading comprehension score.

Demographic Questionnaire

A demographic questionnaire was used to gather general information about participants, including gender, age, year in school, whether they are hearing and/or visually impaired, and if so, what corrective devices are used (e.g., glasses or hearing aids). Additionally, the questions determined whether individuals were previously diagnosed with ADHD, a sleep/breathing disorder, a learning disorder, or a reading disorder as well as whether English is their second language (ESL). Scores of individuals who met criteria for ESL, who have a sleep/breathing disorder, a learning disorder, and/or a reading disorder diagnosis were further evaluated for inclusion in the analysis.

Procedure

Recruitment

The experimenter recruited participants from varying undergraduate psychology courses. Potential participants heard a brief description of the experiment as well as posited benefits for participation, which included earning extra credit if granted by the instructor, receiving direct feedback about sleep patterns, and earning a chance to win one of five $20 American Express gift cards. Interested students signed up for specific experiment times for both part one and part two of the study and provided preferred contact information (either telephone number or email address) for the experimenter to communicate reminders and/or room changes.

Phase I

Upon arrival, participants read and completed a consent form explaining the study. Consenting participants were assigned a subject number to assure anonymity of their data and their responses to the questionnaires. The subject number was matched to the data files for the sleep stage analysis, the demographic questionnaire, the SQI, the Reading Comprehension Task, and the TOSSA. They completed a demographic questionnaire, and were provided with a Zeo headband and docking station. The experimenter provided instructions and demonstrations on how to use the wireless sleep monitoring device. Prior to leaving, participants who agreed to participate scheduled an appointment time for three days later to return the device and docking station and complete the Reading Comprehension Task, the SQI, and the TOSSA. This initial appointment took approximately 20 minutes. Additionally, participants specified a preferred contact medium and provided their contact information for reminders of additional experiment phases.

Phase II

Participants wore the sleep monitoring device for three successive nights to track their sleep. Each morning, participants rated their quality of sleep on the device. The experimenter sent reminders of the final experiment phase on the third day to participants' preferred contact medium designated by the participant to decrease recidivism rates.

Phase III

At their pre-scheduled time, participants arrived at a pre-designated room to return the Zeo device and docking station. The testing environment was well lit with adequate room temperature and free of external distractions. A maximum of four individuals were tested at any one testing session because of limited testing resources. All participants completed the reading comprehension test and were assigned randomly to one of two groups in which half of the individuals completed the paper and pencil portion and the other half completed the computer-administered section. Next, participants completed the second test. Finally, participants received feedback regarding their acquired sleep and how their time spent in deep sleep and REM sleep compared with the general population. Additionally, the experimenter thanked participants for their participation and their names were entered into the drawing for one of five $20 American Express gift cards. This appointment took approximately 30 minutes.

Hypothesis Testing and Data Analysis

Descriptive statistics for the demographic and study variables were calculated for the overall sample, which included the mean, median, standard deviation, range, and reliability. The computed median helped identify the median split for length of time spent in deep sleep (final night and averaged across three nights), length of time spent in REM sleep (final night and averaged across three nights), total sleep length (final night and averaged across three nights), sleep quality, and daytime sleepiness. Next, all independent variables were dichotomized by median split and descriptive statistics were calculated for each dichotomized variable. All study variables were analyzed for parametric assumptions and outliers. Pearson *r* correlations were performed on all continuous variables of interest in this study. Finally, one sample *t*-tests analyzed mean score differences of the sample and the population to determine if significant differences were present.

Hypothesis 1 stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep for the final night, specifically that individuals who spent more time in deep sleep for the final night would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in deep sleep for the final night (short and long). Length of time spent in deep sleep was identified through the digital records of the Zeo device. Group classification for short and long deep sleep for the final night was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 1a stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep averaged over three nights, specifically that individuals who averaged more time in deep sleep over three nights would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was averaged time spent in deep sleep across three nights (short and long). Length of time spent in deep sleep averaged across three nights was identified through the digital records of the Zeo device. Group classification for short and long deep sleep average across three nights was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 2 stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep for the final night, specifically that individuals who spent more time in REM sleep for the final night would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in REM sleep for the final night (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification short and long REM sleep was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 2a stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep averaged over three nights, specifically that individuals who averaged more time in REM sleep over three nights would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in REM sleep averaged across three nights (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification short and long REM sleep averaged across three nights was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 3 stated that there would be a significant mean difference in sustained selective auditory attention between short and long sleep length for the final night, specifically that individuals who obtained more sleep on the final night would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was sleep length for the final night (short and long). Total length of sleep for the final night was identified through the digital records of the Zeo device. Group classification short and long sleep length for the final night was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 4 stated that there would be a significant mean difference in sustained selective auditory attention between good and poor sleep quality, specifically that individuals who obtained better sleep quality would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was reported sleep quality (poor and good). Sleep quality was measured by the sleep quality score provided from the SQI. Group classification for poor and good sleep quality was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 5 stated that there would be a significant mean difference in sustained selective auditory attention between low and high daytime sleepiness. Specifically, individuals who reported lower daytime sleepiness would perform significantly better on a sustained selective auditory attention task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was reported daytime sleepiness (low and high). Daytime sleepiness was measured by the general daytime sleepiness score provided from the ESS. Group classification for low and high daytime sleepiness was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA.

Hypothesis 6 stated that there would be a significant mean difference in reading comprehension between short and long deep sleep for the final night, specifically that individuals who spent more time in deep sleep for the final night would perform significantly better on a reading comprehension task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in deep sleep for the final night (short and long). Length of time spent in deep sleep was identified through the digital records of the Zeo device. Group classification for short and long deep sleep for the final night was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 6a stated that there would be a significant mean difference in reading comprehension between short and long deep sleep averaged over three nights, specifically that individuals who averaged more time in deep sleep over three nights would perform significantly better on a reading comprehension task. This hypothesis was tested by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was averaged time spent in deep sleep across three nights (short and long). Length of time spent in deep sleep averaged across three nights was identified through the digital records of the Zeo device. Group classification for the short and long average times spent in deep sleep across three nights was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 7 stated that there would be a significant mean difference in reading comprehension between short and long REM sleep in the final night, specifically that individuals who spent more time in REM sleep in the final night would perform significantly better on a reading comprehension task. This hypothesis was tested using a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in REM sleep for the final night (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification for short and long time spent in REM sleep for the final night was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 7a stated that there would be a significant mean difference in reading comprehension between short and long REM sleep averaged over three nights; specifically, individuals who averaged more time in REM sleep over three nights would perform significantly better on a reading comprehension task. This hypothesis was tested using a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was time spent in REM sleep averaged across three nights (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification for short and long REM sleep times averaged across three nights was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 8 stated that there would be a significant mean difference in reading comprehension between short and long sleep length for the final night, specifically that individuals who obtained more sleep would perform significantly better on a reading comprehension task. This hypothesis was tested using a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was sleep length for the final night (short and long). Sleep length was identified through the digital records of the Zeo device. Group classification for short and long total sleep times for the final night was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 9 stated that there would be a significant mean difference in reading comprehension between good and poor sleep quality, specifically that individuals who reported better sleep quality would perform significantly better on a reading comprehension task. This hypothesis was tested using a one-way analysis of variance with Bonferroni correction ($\alpha = .007$). The independent variable was reported sleep quality (poor and good). Sleep quality was measured by the sleep quality score provided from the SQI. Group classification for poor and good sleep quality was dichotomized from the collected data by a median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 10 stated that there would not be a significant mean difference in reading comprehension between low and high daytime sleepiness. This hypothesis was testing by running a one-way analysis of variance with Bonferroni correction ($\alpha = .007$).

The independent variable was reported sleep quality (low and high). Daytime sleepiness was measured by the general daytime sleepiness score provided from the ESS. Group classification for low and high daytime sleepiness was dichotomized from the collected data by median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT.

Hypothesis 11 stated that the combination of minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, sleep length for the final night, and daytime sleepiness will serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness. This hypothesis was tested by running a standard multiple regression analysis. The predictor variables were minutes spent in deep sleep, minutes spent in REM sleep, sleep quality, sleep length, and daytime sleepiness. The criterion variable was sustained selective auditory attention.

Hypothesis 11a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness would serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness. This hypothesis was tested by running a standard multiple regression analysis. The predictor variables were averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness. The criterion variable was sustained selective auditory attention.

Hypothesis 12 stated that the combination of minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, and sleep length for the final night would serve as significant positive predictors of reading comprehension. This hypothesis was tested by running a standard multiple regression analysis. The predictor variables were minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, and sleep length for the final night. The criterion variable was reading comprehension performance.

Hypothesis 12a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, and averaged sleep length would serve as significant positive predictors of reading comprehension performance. This hypothesis was tested by running a standard multiple regression analysis. The predictor variables were averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, and averaged sleep length. The criterion variable was reading comprehension performance.

CHAPTER THREE

RESULTS

The purpose of this chapter is to present the results of the examination of the relationship among sustained selective auditory attention, reading comprehension, the time spent in deep sleep, the time spent in REM sleep, total sleep quantity, sleep quality, and daytime sleepiness. Sample characteristics are presented first, followed by descriptive statistics of the variables. Finally, the results of the research are presented by hypotheses.

Participants

Participants for this experiment were 80 undergraduate students. Of those 80 students, only 46 participants were included in the analysis because of technical difficulties with the sleep monitoring apparatus (*n* = 26) and software program for measuring attention (*n* = 5) as well as attrition (*n* = 3). Of the 46 participants who were included in the study, 33 (71.7%) were females and 13 (28.3%) were males. The majority were Caucasian (73.9%), followed by African American (21.7%) and Hispanic (4.3%). Participants' ages ranged from 18 – 59, with the median age being 20 years old. Grade classification were nine freshman (19.6%), 18 sophomores (39.1%), 9 juniors (19.6%), and 10 seniors (21.7%), with a mean grade point average of 3.18. Half of the participants reported no difficulty with their vision, and 47.8% reported that glasses or contacts corrected their vision. Additionally, the majority of participants (*n* = 45, 97.8%) reported no hearing difficulties. Similarly, the majority of participants (*n* = 39, 84.8%) reported having never been diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability, and no participants endorsed English as a second language.

Descriptive statistics for sleep quality, daytime sleepiness, sleep length (averaged across three nights and for final night), time spent in REM sleep (averaged across three nights and for final night), and time spent in deep sleep (averaged across three nights and for final night) were obtained and compared to normative samples. Overall, participants reported a mean sleep quality rating of 5.91 (*Mdn* = 6; *SD* = 2.80; *Range* = 0 – 12). Following the median split, individuals in the good sleep quality group averaged a sleep quality rating of 3.30 (*SD* = 1.59; *Range* = 0 – 5), and individuals in the poor sleep quality group averaged a sleep quality rating of 7.92 (*SD* = 1.60; *Range* = 6 – 12). Results of a one sample *t*-test revealed that the overall mean on the Sleep Quality Index for the current sample (*M* = 5.91) was not significantly different than the mean (*M* =5.23) Urponen et al. (1991) obtained when developing the Sleep Quality Index scale, $t(45) = 1.67$, $p = .103$.

Regarding daytime sleepiness, participants reported an average daytime sleepiness rating of 8.44 (*Mdn* = 9; *SD* = 3.20; *Range* = 2 – 16). Following the median split, individuals in the low daytime sleepiness group averaged a rating of 5.73 (*SD* = 1.78; *Range* = 2 – 8) and individuals in the high daytime sleepiness group averaged a rating of 11.04 (*SD* = 1.69; *Range* = 9 – 16). Results of a one sample *t*-test revealed that the overall mean on the Epworth Sleepiness Scale for the current sample (*M* = 8.44) was significantly higher than the mean (*M* = 5.9) Johns (1991) obtained when developing the

Epworth Sleepiness Scale, *t*(45) = 5.35 , *p* = .000, which was based on a non-student population. However, a comparison of mean scores from the current sample (*M* = 8.44) to the sample of college students (*M* = 9.0) Howell et al. (2004) assessed revealed no significant differences on the Epworth Sleepiness Scale, *t*(44) = -1.17, *p* = .249.

Average sleep length, time spent in REM sleep, and time spent in deep sleep were evaluated both across the three nights that individuals wore the Zeo device and on the final night. Due to difficulty with the device, averaged scores across the three nights had a smaller sample size (*n* = 28) than scores obtained on the final night (*n* = 46).

Regarding averaged sleep length across the three nights, participants obtained a mean sleep length of 408.29 minutes (*Mdn* = 413.50; *SD* = 65.56; *Range* = 235 – 520). Following the median split, individuals in the short sleep length group averaged 358.86 minutes of sleep (*SD* = 47.73; *Range* = 235 – 413) and individuals in the long sleep length group averaged 457.71 minutes of sleep (*SD* = 37.22; *Range* = 414 – 520). Results of a one sample *t*-test revealed that the overall mean of average sleep length across three nights for the current sample (*M* = 408.29) was significantly higher than the mean (*M* = 335.40) Shambroom et al. (2012) obtained when evaluating sleep length for the reliability of the Zeo wireless devise, *t*(27) = 5.88, *p* = .000. A comparison of total sleep time across three nights for the current sample (*M* = 408.29) was significantly lower than the reported averaged of total sleep time for Americans (*M* = 456.00) according the NSF's 2014 Sleep Health Index (Hirshkowitz et al., 2015), *t*(27) = -3.85, *p* = .000.

For the final night, participants obtained a mean sleep length of 388.91 minutes (*Mdn* = 384.50; *SD* = 84.33; *Range* = 221 – 555). Following the median split, individuals in the short sleep length group averaged 321.39 minutes of sleep (*SD* = 50.62;

Range = 221 – 382) and individuals in the long sleep length group averaged 456.43 minutes of sleep (*SD* = 49.52; *Range* = 387 – 555). Results of a one sample *t*-test revealed that the overall mean of average sleep length of the final night for the current sample (M = 388.91) is significantly higher than the mean (M = 335.40) Shambroom et al. (2012) obtained when evaluating total sleep time using the Zeo device, $t(45) = 4.304$, $p = .000$. Total sleep time for the current sample (M = 388.91) was also significantly lower than the reported averaged of total sleep time for Americans (M = 456.00) according the NSF's 2014 Sleep Health Index (Hirshkowitz et al., 2015), $t(45) = -5.40$, $p = .000$.

In evaluating time spent in REM sleep averaged across three nights, participants obtained a mean time of 112.46 minutes (*Mdn* = 111.50; *SD* = 37.50; *Range* = 55 – 200). Following the median split, individuals in the short REM sleep group obtained a mean of 82.14 minutes of sleep (*SD* = 16.45; *Range* = 55 – 111) and individuals in the long REM sleep group obtained a mean of 142.79 minutes of sleep (*SD* = 25.89; *Range* = 112 – 200). Results of a one sample *t*-test revealed that the overall mean time spent in REM sleep across three nights for the current sample (M = 112.46) was significantly higher than the mean (M = 80.9) Shambroom et al. (2012) obtained when evaluating time spent in REM sleep using the Zeo device, $t(27) = 4.54$, $p = .000$. A comparison of the percent of time spent in REM over three nights for the current sample (M =.27) was made to the average percent of time spent in REM sleep (M = .20) for normal adults according to the NINDS (2014). A one-sample *t*-test revealed a significantly higher difference for the current sample's percentage of time spent in REM, $t(27) = 5.97$, $p = .000$.

For the final night, participants obtained a mean of 116.35 minutes of REM sleep (*Mdn* = 111.50; *SD* = 47.93; *Range* = 19 – 239). Following the median split, individuals in the short REM sleep group obtained a mean of 78.52 minutes of REM sleep (*SD* = 23.24; *Range* = 19 – 111), and individuals in the long REM sleep group obtained a mean of 154.17 minutes of REM sleep (*SD* = 34.16; *Range* = 112 – 239). Results of a one sample *t*-test revealed that the overall mean time spent in REM sleep for the final night for the current sample (*M* = 116.35) was significantly higher than the (*M* = 80.9) Shambroom et al. (2012) mean obtained when evaluating time spent in REM sleep using the Zeo device, $t(45) = 5.02, p = .000$. A similar comparison was made between the percent of time spent in REM for one night (*M* = .29) to normal adults (*M* = .20) according to NINDS (2014) and revealed a significantly higher difference of the percent of time spent in REM for the current sample, $t(45) = 7.46, p = .000$.

In evaluating time spent in deep sleep averaged across three nights, participants obtained a mean time of 72.00 minutes (*Mdn* = 66.00 ; *SD* = 27.50; *Range* = 44 – 153). Following the median split, individuals in the short deep sleep group obtained a mean of 51.83 minutes of sleep (*SD* = 5.81; *Range* = 44 – 62) and individuals in the long deep sleep group obtained a mean of 87.13 minutes of sleep (*SD* = 27.71; *Range* = 66 – 153). Results of a one sample *t*-test revealed that the overall mean time spent in deep sleep across three nights for the current sample (*M* = 72.00) was significantly higher than the mean (*M* = 51.2) Shambroom et al. (2012) obtained when evaluating time spent in deep sleep using the Zeo device, $t(27) = 4.00 , p = .000$. A similar comparison was made between the percent of time spent in deep sleep averaged across three nights (*M* = .18) to a normal adult (*M* = .30) according to NINDS (2014) and revealed a significantly lower difference of percent of time spent in deep sleep for the current sample, $t(27) = -9.69, p = .000$.

In measuring deep sleep for the final night, participants obtained a mean of 64.37 minutes of deep sleep (*Mdn* = 60; *SD* = 20.74; *Range* = 26 – 113). Following the median split, individuals in the short deep sleep group obtained a mean of 47.35 minutes of deep sleep (*SD* = 9.09; *Range* = 26 – 59), and individuals in the long deep sleep group obtained a mean of 79.17 minutes of deep sleep (*SD* = 16.04; *Range* = 60 – 113). Results of a one sample *t*-test revealed that the overall mean time spent in deep sleep for the final night for the current sample (*M* = 64.37) was significantly higher than the mean (*M* = 51.2) Shambroom et al. (2012) obtained when evaluating time spent in deep sleep using the Zeo device, $t(42) = 4.17, p = .000$. A similar comparison was made between the percent of time spent in deep sleep for one night (*M* = .17) to a normal adult (*M* = .30) according to NINDS (2014) and revealed a significantly lower difference of percent of time spent in deep sleep for the current sample, $t(42) = -16.18, p = .000$.

Table 1 presents the reliability coefficients, means, standard deviations, and ranges for sleep quality (represented by the Sleep Quality Index), daytime sleepiness (represented by the Epworth Sleepiness Scale), sleep length averaged across three nights, sleep length for the final night, REM sleep averaged across three nights, REM sleep for the final night, deep sleep averaged across three nights, and deep sleep for the final night summarized above. Additionally, Table 1 presents the dichotomized means, standard deviations, and ranges for all of the above variables.

Table 1

Means, Standard Deviations, Range, and Reliabilities for Independent Variables

Variables	*M*	*SD*	*Range*	α
SQI	5.91	2.80	0 – 12	.58
Good Sleep Quality	3.30	1.59	0 – 5	
Poor Sleep Quality	7.92	1.60	6 –12	
ESS	8.44	3.20	2 – 16	.62
Low Daytime Sleepiness	5.73	1.78	2 – 8	
High Daytime Sleepiness	11.04	1.69	9 – 16	
Sleep Length Avg.	408.29	65.56	235 – 520	-
Short Sleep Length Avg.	358.86	47.73	235 – 413	-
Long Sleep Length Avg.	457.71	37.22	414 – 520	-
Sleep Length Final	388.91	84.33	221 – 555	-
Short Sleep Length Final	321.39	50.62	221 – 382	-
Long Sleep Length Final	456.43	49.52	387 – 555	-
REM Sleep Avg.	112.46	37.50	55 – 200	-
Short REM Sleep Avg.	82.14	16.45	55 – 111	-
Long REM Sleep Avg.	142.79	25.89	112 – 200	-
REM Sleep Final	116.35	47.93	19 – 239	-
Short REM Sleep Final	78.52	23.24	19 – 111	-
Long REM Sleep Final	154.17	34.16	112 – 239	-
Deep Sleep Avg.	72.00	27.50	44 – 153	-
Short Deep Sleep Avg.	51.83	5.81	44 – 62	-
Long Deep Sleep Avg.	87.13	27.71	66 – 153	-
Deep Sleep Final	64.37	20.74	26 – 113	-
Short Deep Sleep Final	47.35	9.09	26 – 59	-
Long Deep Sleep Final	79.17	16.04	60 – 113	-

Note: SQI = Sleep Quality Index; ESS = Epworth Sleepiness Scale. Dash denotes single scale score; no reliability calculated.

Sleep Quality Condition (Good vs. Poor)

Sleep quality data were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. No assumptions were violated. A median split of the data was used to obtain group divisions of good versus poor sleep quality in which scores lower than the median were designated as good sleep quality and scores higher than the median were designated as poor sleep quality. Of the 46 participants, 20 individuals were rated as achieving good sleep quality, and 26 were rated as achieving poor sleep quality.

Good sleep quality group. The 20 individuals in the good sleep quality group were 30% male (*n* = 6) and 70% female (*n* = 14), with a mean age of 20.2 (*SD* = 1.4; *Range* = 18-23) and a mean grade point average of 3.14 (SD = .38; Range = 2.10-3.70). The good sleep group were 20% African American (*n* = 4), 70% Caucasian (*n* = 14), and 10% Hispanic (*n* = 2). Educationally, 10% were freshmen (*n* = 2), 45% were sophomores (*n* = 9), 30% were juniors (*n* = 6), and 15% were seniors (*n* = 3). Visually, 52.6% (*n* = 10) had no difficulty with vision, and 47.4% (*n* = 9) wore glasses or contacts. No participants reported no difficulty with hearing (*n* = 20). Additionally, 85% (*n* = 17) have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 15% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

Poor sleep quality group. The 26 individuals in the poor sleep quality group were 26.9% male (*n* = 7) and 73.1% female (*n* = 19), with a mean age of 22.4 (*SD* = 8.1; *Range* = 18-59) and a mean grade point average of 3.22 (SD = .48; Range = 2.50 – 4.10). The poor sleep group were 23.1% African American (*n* = 6) and 76.9% Caucasian (*n* = 20). Educationally, 26.9% were freshmen (*n* = 7), 34.6% were sophomores (*n* = 9), 11.5% were juniors (*n* = 3), and 26.9% were seniors (*n* = 7). Visually, 50% (*n* = 13) had no difficulty, and 50% (*n* = 13) wore glasses or contacts. The majority of participants reported no difficulty with hearing (96.2%, *n* = 25), with 3.8% (*n* = 1) reporting hearing difficulties. Additionally, 84.6% (*n* = 22) have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 15.4% (*n* = 4) reporting a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly in gender, *F*(1, 43) = .29, ethnicity, *F*(1, 41) = .00, visual difficulties, *F*(1, 43) = .114, diagnosis of a sleep or breathing disorder, *F*(1, 43) = .01, grade point average, *F*(1, 44) = 2.45, or age, *F*(1, 44) = 3.94. The groups were significantly different across education level, *F*(3, 41) = 5.78. A Levene's test was not computed for hearing difficulties because there were not enough pairs to compute the Levene statistic.

Daytime Sleepiness Condition (Low vs. High)

Daytime sleepiness data were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. A median split divided low versus high daytime sleepiness; scores lower than the median were designated as low daytime sleepiness, and scores higher than the median were designated as high daytime sleepiness. High daytime sleepiness was substantially negatively skewed and one outlier was identified. Removal of the outlier corrected the violation of normality and no other assumptions were violated. From sample of 45 participants, 22 individuals reported low daytime sleepiness and 23 individuals reported high daytime sleepiness.

Low daytime sleepiness group. The 22 individuals in the low daytime sleepiness group were 27.3% male (*n* = 6) and 72.7% female (*n* = 16), with a mean age of 20.3

(*SD* = 1.6; *Range* = 18-24) and a mean grade point average of 3.17 (SD = .42; Range = 2.50 – 4.00). The low daytime sleepiness group were 13.6% African American (*n* = 3) and 86.4% Caucasian (*n* = 19). Educationally, 18.2% were freshmen (*n* = 4), 40.9% were sophomores (*n* = 9), 18.2% were juniors (*n* = 4), and 22.7% were seniors (*n* = 5). Regarding vision, 61.9% (*n* = 13) had no difficulty with vision, and 38.1% (*n* = 8) wore glasses or contacts. The majority of participants reported no difficulty with hearing (95.5%, *n* = 21), with 4.5% (*n* = 1) reporting hearing difficulties. Additionally, 86.4% (*n* = 20) have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 13.6% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

High daytime sleepiness group. The 23 individuals in the high daytime sleepiness group were 30.4% male (*n* = 7) and 69.6% female (*n* = 16), with a mean age of 22.7 (*SD* = 8.6; *Range* = 18-59) and a mean grade point average of 3.20 (SD = .46; Range = 2.10 – 4.10). The high daytime sleepiness group were 26.1% African American (*n* = 6), 65.2% Caucasian (*n* = 15), and 8.3% Hispanic (*n* = 2). Educationally, 21.7% were freshmen (*n* = 5), 34.8% were sophomores (*n* = 8), 21.7% were juniors (*n* = 5), and 22.7% were seniors (*n* = 5). Regarding vision, 41.7% (*n* = 10) had no difficulty with vision, and 58.3% (*n* = 14) wore glasses or contacts. No participants reported difficulty with hearing (100%, *n* = 24). Additionally, 83.3% (*n* = 19) have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 16.7% (*n* = 4) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly across gender, *F*(1, 42) = .08, ethnicity, *F*(1, 40) = 2.58, education level, *F*(3, 40) = .47, visual difficulties *F*(1, 42) = .48, diagnosis of a sleep or breathing disorder, *F*(1, 42) = .57, or grade point average, *F*(1, 43) = .01, but there were significant differences across age, *F*(1, 43) = 4.45. A Levene's test was not computed for hearing difficulties because there were not enough pairs to compute the Levene statistic.

Sleep Length Condition Averaged Across Three Nights (Short vs. Long)

Sleep length data averaged across three nights were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. No assumptions were violated. A median split separated short from long sleep length; scores lower than the median were designated as short sleep length, and scores higher than the median were designated as long sleep length. Of the 46 participants, sleep length across three nights was only available for 28 participants in which 14 individuals obtained short sleep length and 14 obtained long sleep length.

Short sleep length group. The 14 individuals in the short sleep length group were 28.6% male (*n* = 4) and 71.4% female (*n* = 10), with a mean age of 22.71 (*SD* = 10.52; *Range* = 18-59) and a mean grade point average of 3.80 (SD = .42; Range = 2.50 – 3.80). The short sleep length group were 28.6% African American (*n* = 4) and 71.4% Caucasian (*n* = 10). Educationally, 21.4% were freshmen (*n* = 3), 50% were sophomores (*n* = 7), 21.4% were juniors (*n* = 3), and 7.1% were seniors (*n* = 1). Regarding visual impairments, 50% (*n* = 7) reported none, and 50% (*n* = 7) wore glasses or contacts. No participants reported hearing difficulties. Additionally, no participants reported a previous diagnosis of a breathing disorder (i.e., asthma, COPD) or a learning disability. Similarly, no participants endorsed English as a second language.

Long sleep length group. The 14 individuals in the long sleep length group were 21.4% male (*n* = 3) and 78.6% female (*n* = 11), with a mean age of 20.50 (*SD* = 1.29; *Range* = 19-23) and a mean grade point average of 3.18 (SD = .44; Range = 2.50 – 4.10). The long sleep length group were 21.4% African American (*n* = 3) and 78.6% Caucasian (*n* = 11). Educationally, 14.3% were freshmen (*n* = 2), 42.9% were sophomores (*n* = 6), 7.1% were juniors (*n* = 1), and 35.7% were seniors (*n* = 5). Regarding vision, 38.5% (*n* = 5) reported no difficulty with vision and 61.5% (*n* = 8) wore glasses or contacts. One individual did not respond regarding visual difficulties. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability (78.6%, *n* = 11), with 21.4% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. English was a primary language for all.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, *F*(1, 25) = .39, ethnicity, *F*(1, 25) = .39, education level, *F*(3, 23) = 2.14, visual difficulties *F*(1, 25) = .23, grade point average, *F*(1, 26) = .05, or age, *F*(1, 26) = 2.96. A Levene's test was not computed for hearing difficulties or diagnosis of a sleep or breathing disorder because there were not enough pairs to compute the Levene statistic.

Sleep Length Condition for Final Night (Short vs. Long)

Sleep length data for the final night were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. No assumptions were violated. A median split of the data was used to obtain group divisions of short versus long sleep length in which scores lower than the median were designated as short sleep length and scores higher than the median were designated as long sleep length. Of the 46 participants, 23 individuals obtained short sleep length and 23 obtained long sleep length.

Short sleep length group. The 23 individuals in the short sleep length group were 34.8% male (*n* = 8) and 65.2% female (*n* = 15), with a mean age of 21.61 (*SD* = 8.3; *Range* = 18-29) and a mean grade point average of 3.14 (SD = .49; Range = 2.10 – 4.10). The short sleep length group were 17.4% African American (*n* = 4), 73.9% Caucasian (*n* = 17), and 8.7% Hispanic (*n* = 2). Educationally, 26.1% were freshmen (*n* = 6), 47.8% were sophomores (*n* = 11), 21.7% were juniors (*n* = 5), and 4.3% were seniors (*n* = 1). In regards to difficulty with vision, 47.8% (*n* = 11) reported no difficulty, and 52.2% (*n* = 12) reported that glasses or contacts corrected their vision. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability (87.0%, *n* = 20), with 13.0% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

Long sleep length group. The 23 individuals in the long sleep length group were 21.7% male (*n* = 5) and 78.3% female (*n* = 18), with a mean age of 21.3 (*SD* = 3.3; *Range* = 18-32), and with a mean grade point average of 3.23 (SD = .38;

Range = 2.50 – 4.00). The long sleep length group were 26.1% African American (*n* = 6) and 73.9% Caucasian (*n* = 17). Educationally, 13.0% were freshmen (*n* = 3), 30.4% were sophomores (*n* = 7), 17.4% were juniors (*n* = 4), and 39.1% were seniors (*n* = 9). Regarding vision, 52.2% (*n* = 12) reported no difficulty with vision, and 43.5% (*n* = 10) wore glasses or contacts. One individual did not indicate visual ability. The majority of participants did not report hearing difficulties, with 4.3% (*n* = 1) endorsing difficulty with hearing. Additionally, the majority of participants reported never being diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability (82.6%, *n* = 19), with 17.4% (*n* = 4) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, *F*(1, 43) = 1.24, ethnicity, *F*(1, 41) = 1.16, visual difficulties *F*(1, 43) = .09, diagnosis of a sleep or breathing disorder, *F*(1, 43) = .32, grade point average, *F*(1, 44) = .66, or age, *F*(1, 44) = .66, but there were significant differences in education, *F*(3, 41) = 7.69. A Levene's test was not computed for hearing difficulties because there were not enough pairs to compute the Levene statistic.

REM Sleep Condition Averaged Across Three Nights (Short vs. Long)

REM sleep data averaged across three nights were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. No assumptions were violated. A median split of the data divided short from long REM sleep length; scores lower than the median were designated as short REM sleep length and scores higher than the median were designated as long REM sleep length. Of the 46 participants, REM sleep length across three nights was only available for 28 participants in which 14 individuals obtained short REM sleep length and 14 obtained long REM sleep length.

Short REM sleep group. The 14 individuals in the short REM sleep group were 28.6% male (*n* = 4) and 71.4% female (*n* = 10), with a mean age of 23 (*SD* = 10.45; *Range* = 18-59) and a mean grade point average of 3.19 (SD = .40; Range = 2.50 – 3.80). The short REM sleep group were 21.4% African American (*n* = 3) and 78.6% Caucasian (*n* = 11). Educationally, 21.4% were freshmen (*n* = 3), 42.9% were sophomores (*n* = 6), 14.3% were juniors (*n* = 2), and 21.4% were seniors (*n* = 3). Visually, 50% (*n* = 7) reported no difficulty with vision, and 50% (*n* = 7) wore glasses or contacts. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability, with 14.3% (*n* = 2) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

Long REM sleep group. The 14 individuals in the long REM sleep group were 21.4% male (*n* = 3) and 78.6% female (*n* = 11), with a mean age of 20.21 (*SD* = 1.25; *Range* = 19-32) and a mean grade point average of 3.17 (SD = .45; Range = 2.50 – 4.10). The long REM sleep group were 28.6% African American (*n* = 4) and 71.4% Caucasian (*n* = 10). Educationally, 14.3% were freshmen (*n* = 2), 50% were sophomores (*n* = 7), 14.3% were juniors (*n* = 2), and 21.4% were seniors (*n* = 3). Visually, 38.5% (*n* = 5) reported no difficulty with vision, and 61.5% (*n* = 8) wore glasses or contacts. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability, with 7.1% (*n* = 1) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, *F*(1, 25) = .39, ethnicity, *F*(1, 25) = .04, education level, *F*(3, 23) = 1.93, visual difficulties *F*(1, 25) = .23, grade point average, *F*(1, 26) = .12, or age, *F*(1, 26) = 2.92. A Levene's test was not computed for hearing difficulties or diagnosis of a sleep or breathing disorder because there were not enough pairs to compute the Levene statistic.

REM Sleep Condition for Final Night (Short vs. Long)

REM sleep data were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. No assumptions were violated. A median split of the data divided short from long REM sleep length; scores lower than the median were designated as short REM sleep length, and scores higher than the median were designated as long REM sleep length. From the 46 participants, 23 individuals obtained short REM sleep and 23 obtained long REM sleep.

Short REM sleep group. The 23 individuals in the short REM sleep group were 26.1% male (*n* = 6) and 73.9% female (*n* = 17), with a mean age of 21.6 (*SD* = 8.3; *Range* = 18-59) and a mean grade point average of 3.24 (SD = .44; Range = 2.50 – 4.10). The short REM sleep group were 26.1% African American (*n* = 6) and 73.9% Caucasian (*n* = 17). Educationally, 26.1% were freshmen (*n* = 6), 39.1% were sophomores (*n* = 9), 21.7% were juniors (*n* = 5), and 13.0% were seniors (*n* = 3). Visually, 43.5% (*n* = 10) had no difficulty with vision, and 56.5% (*n* = 13) wore glasses or contacts. The majority of participants had no hearing difficulties (95.7%, *n* = 22), with 4.3% (*n* = 1) endorsing a difficulty with hearing. Additionally, the majority of participants reported never being diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability (82.6%, *n* = 19), with 17.4% (*n* = 4) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

Long REM sleep group. The 23 individuals in the long REM sleep group were 30.4% male (*n* = 7) and 69.6% female (*n* = 16), with a mean age of 21.4 (*SD* = 3.3; *Range* = 18-32) and a mean grade point average of 3.13 (SD = .43; Range = 2.10 – 4.00). The long REM sleep group were 17.4% African American (*n* = 4), 73.9% Caucasian (*n* = 17), and 8.7% Hispanic (*n* = 2). Educationally, 13.0% were freshmen (*n* = 3), 39.1% were sophomores (*n* = 9), 17.4% were juniors (*n* = 4), and 30.4% were seniors (*n* = 7). Visually, 56.5% (*n* = 13) had no difficulty with vision, and 39.1% (*n* = 9) wore glasses or contacts. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability (87.0%, *n* = 20), with 13.0% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, *F*(1, 43) = .01, ethnicity, *F*(1, 41) = 1.16, education level, *F*(3, 41) = 2.01, visual difficulties *F*(1, 43) = .11, diagnosis of a sleep or breathing disorder, *F*(1, 43) = .76, grade point average, *F*(1, 44) = .45, or age, *F*(1, 44) = .36. A Levene's test was not computed for hearing difficulties because there were not enough pairs to compute the Levene statistic.

Deep Sleep Condition Averaged Across Three Nights (Short vs. Long)

Deep sleep data averaged across three nights were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. A median split of the data divided short from long deep sleep length; scores lower than the median were designated as short deep sleep length, and scores higher than the median were designated as long deep sleep length. Of the 46 participants, deep sleep length across three nights was only available for 28 participants; 12 individuals obtained short deep sleep length, and 16 obtained long deep sleep length. Long deep sleep was severely positively skewed and homogeneity of variance was violated. One outlier was identified. Removal of the outlier and an inverse transformation corrected the violation of normality and no other assumptions were violated. Of the remaining 27 participants, 12 individuals obtained short deep sleep length and 15 obtained long deep sleep length prior to the inverse transformation. Following the inverse transformation, 14 individuals were categorized as obtaining short deep sleep length and 13 as obtaining long deep sleep length.

Short deep sleep group. The following are descriptive statistics representative of the data prior to the inverse transformation. The 12 individuals in the short deep sleep group were 21.7% male (*n* = 5) and 58.3% female (*n* = 7), with a mean age of 23.58 (*SD* = 11.21; *Range* = 19-59) and a mean grade point average of 3.17 (*SD* = .41; *Range* = 2.60 – 3.80). The short deep sleep group were 25.0% African American (*n* = 3) and 75.0%

Caucasian (*n* = 9). Educationally, 8.3% were freshmen (*n* = 1), 50.0% were sophomores (*n* = 6), 25.0% were juniors (*n* = 3), and 16.7% were seniors (*n* = 2). Visually, 50.0% (*n* = 6) had no difficulty with vision, and 50.0% (*n* = 6) wore glasses or contacts. No participants reported hearing difficulties. Additionally, no participants reported a diagnosis of a breathing disorder (i.e., asthma, COPD) or a learning disability, and no participants endorsed English as a second language.

The following are descriptive statistics representative of the data after the inverse transformation. The 14 individuals in the short deep sleep group were 14.8% male (*n* = 4) and 37% female (*n* = 10), with a mean age of 23 (*SD* = 10.47; *Range* = 18-59) and a mean grade point average of 3.22 (*SD* = .49; *Range* = 2.50 – 4.10). The short deep sleep group were 11.1% African American (*n* = 3) and 40.7% Caucasian (*n* = 11). Educationally, 11.1% were freshmen (*n* = 3), 25.9% were sophomores (*n* = 7), 3.7% were juniors (*n* = 1), and 11.1% were seniors (*n* = 3). Visually, 26.9% (*n* = 7) had no difficulty with vision, and 26.9% (*n* = 7) wore glasses or contacts. No participants reported difficulty with hearing. Additionally, no participants a diagnosis of a breathing disorder (i.e., asthma, COPD) or a learning disability, and no participants endorsed English as a second language.

Long deep sleep group. The following are descriptive statistics representative of the data prior to the inverse transformation. The 15 individuals in the long deep sleep group were 13.3% male (*n* = 2) and 86.7% female (*n* = 13), with a mean age of 20.13 (*SD* = 1.46; *Range* = 18-23) and a mean grade point average of 3.21 (*SD* = .45; *Range* = 2.50 – 4.10). The long deep sleep group were 26.7% African American (*n* = 4) and 73.3% Caucasian (*n* = 11). Educationally, 26.7% were freshmen (*n* = 4), 40.0% were sophomores (*n* = 6), 6.7% were juniors (*n* = 1), and 26.7% were seniors (*n* = 4). Visually, 40.0% (*n* = 6) had no difficulty with vision, and 53.3% (*n* = 8) wore glasses or contacts. One individual did not report status of visual difficulty. No participants reported hearing difficulties. The majority of participants have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability (93.3%, *n* = 14), with 6.7% (*n* = 1) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

The following are descriptive statistics of the sample after the inverse transformation. The 13 individuals in the long deep sleep group were 11.1% male (*n* = 3) and 37% female (*n* = 10), with a mean age of 20.23 (*SD* = 1.17; *Range* = 19 – 22) and a mean grade point average of 3.16 (*SD* = .45; *Range* = 2.50 – 3.80). The long deep sleep group were 14.8% African American (*n* = 4) and 33.3% Caucasian (*n* = 9). Educationally, 7.4% were freshmen (*n* = 2), 18.5% were sophomores (*n* = 5), 11.1% were juniors (*n* = 3), and 11.1% were seniors (*n* = 3). Visually, 19.2% (*n* = 5) had no difficulty with vision, and 26.9% (*n* = 7) wore glasses or contacts. One individual did not report status of visual difficulty. No participants reported hearing difficulties. The majority of participants have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 11.1% (*n* = 3) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, *F*(1, 24) = .71, ethnicity, *F*(1, 24) = .20, education level, *F*(3, 22) = 1.05, visual difficulties *F*(1, 24) = .23, grade point average, *F*(1, 25) = .13, or age, *F*(1, 25) = 3.75. A Levene's test was not computed for hearing difficulties or diagnosis of a sleep or breathing disorder because there were not enough pairs to compute the Levene statistic.

Deep Sleep Condition for Final Night (Short vs. Long)

Deep sleep data were examined for accuracy of data entry, missing values, outliers, and assumptions of normality and homogeneity of variance. A median split of the data divided short from long deep sleep length in which scores lower than the median were designated as short deep sleep length and scores higher than the median were designated as long deep sleep length. Long deep sleep was substantially positively skewed and one outlier was identified. Following the removal of the outlier, a log transformation was computed and two additional outliers were identified. Removal of the outliers and a log transformation corrected the violation of normality, and no other assumptions were violated. Of the remaining 43 participants, 20 individuals obtained short deep sleep and 23 obtained long deep sleep. There were no differences in categorization following the log transformation.

Short deep sleep group. The following are descriptive statistics representative of the data prior to the reflected log transformation. The 20 individuals in the short deep sleep group were 35.0% male (*n* = 7) and 65.0% female (*n* = 13), with a mean age of 22.45 (*SD* = 8.78; *Range* = 18-59) and a mean grade point average of 3.17 (*SD* = .52; *Range* = 2.10 – 4.10). The short deep sleep group were 20% African American (*n* = 4), 70.0% Caucasian (*n* = 14), and 10% Hispanic (*n* = 2). Educationally, 25.0% were freshmen (*n* = 5), 35.0% were sophomores (*n* = 7), 15.0% were juniors (*n* = 3), and 25.0% were seniors (*n* = 5). Visually, 55.0% (*n* = 11) had no difficulty with vision, and

45.0% (*n* = 9) wore glasses or contacts. No participants reported hearing difficulties. Additionally, the majority of participants reported never being diagnosed with breathing disorder (i.e., asthma, COPD) or a learning disability (95.0%, *n* = 19), with 5.0% (*n* = 1) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language. There were no differences in descriptive statistics following the log transformation for short deep sleep.

Long deep sleep group. The following are descriptive statistics representative of the data prior to the log transformation. The 23 individuals in the long deep sleep group were 17.4% male (*n* = 4) and 82.6% female (*n* = 19), with a mean age of 20.43 (*SD* = 2.79; *Range* = 18-32) and a mean grade point average of 3.21 (*SD* = .36; *Range* = 2.50 – 3.80). The long deep sleep group were 21.7% African American (*n* = 5) and 78.3% Caucasian (*n* = 18). Educationally, 17.4% were freshmen (*n* = 4), 39.1% were sophomores (*n* = 9), 26.1% were juniors (*n* = 6), and 17.4% were seniors (*n* = 4). Visually, 43.5% (*n* = 10) had no difficulty with vision, and 52.2% (*n* = 12) wore glasses or contacts. One individual did not report on status of visual difficulty. The majority of participants reported no difficulty with hearing (95.7%, *n* = 22), with 4.3% reporting hearing difficulties (*n* = 1). Additionally, 73.9% (*n* = 17) have never been diagnosed with a breathing disorder (i.e., asthma, COPD) or a learning disability, with 26.1% (*n* = 6) endorsing diagnosis of a breathing disorder or a learning disability. No participants endorsed English as a second language. There were no differences in descriptive statistics following the log transformation for long deep sleep.

A Levene's test of homogeneity of variance tested homogeneity across gender, ethnicity, education level, visual difficulties, hearing difficulties, diagnosis of a sleep or breathing disorder, grade point average, and age. The groups did not differ significantly on gender, $F(1, 40) = .49$, ethnicity, $F(1, 48) = .01$, education level, $F(3, 38) = .48$, visual difficulties, $F(1, 40) = .30$, grade point average, $F(1, 41) = 1.59$, or age, $F(1, 41) = 2.01$. The groups differed significantly regarding diagnosis of a sleep or breathing related disorder, $F(1, 40) = 29.43$. A Levene's test was not computed for hearing difficulties because there were not enough pairs to compute the Levene statistic.

Sustained Selective Auditory Attention and Reading Comprehension

Table 2 presents the reliability coefficients, means, standard deviations, and ranges for the Test of Sustained Selective Attention (TOSSA) – Concentration Strength and the Sentence Verification Test (SVT) across the sleep quality, daytime sleepiness, sleep length, REM sleep, and deep sleep conditions. In testing assumption of normality, the current sample mean from the TOSSA Concentration Strength index was compared to the normative sample using a one-sample *t*-test. Results indicate that the current sample mean ($M = 90.57$) is not significantly different from the normed mean of healthy individuals ($M = 91.25$) Kovacs (2012) obtained, $t(45) = -.605, p = .549$. However, the distribution of the TOSSA Concentration Strength index was severely negatively skewed and several outliers were identified. Removal of three outliers corrected the violation of normality. Additionally, in testing assumption of normality for reading comprehension using the SVT, results of the Kolmogorov-Smirnov test of normality revealed no significant differences in normality, $D(46) = .108, p = .200$. When compared to a similar sample (M = 42.65 (Ellis et al., 2014), performance on the SVT (M = 42.59) was not significantly different, $t(45) = -.11, p = .92$.

Table 2

Means, Standard Deviations, Range, and Reliabilities for Entire Sample

Variables	*M*	*SD*	*Range*	α
TOSSA (CS)	92.06	5.28	77 – 100	-
Good Sleep Quality	91.97	4.91	79 – 98	-
Poor Sleep Quality	92.12	5.62	77 – 100	-
Low Daytime Sleepiness	92.48	5.07	77 – 99	-
High Daytime Sleepiness	91.73	5.64	79 – 100	-
Short Sleep Length Avg.	91.15	5.31	79 – 98	-
Long Sleep Length Avg.	90.61	6.29	77 – 98	-
Short Sleep Length Final	91.97	5.70	77 – 98	-
Long Sleep Length Final	92.15	4.98	81 – 100	-
Short REM Sleep Avg.	91.45	5.69	79 – 98	-
Long REM Sleep Avg.	90.34	5.93	77 – 98	-
Short REM Sleep Final	91.59	6.11	77 – 98	-
Long REM Sleep Final	92.47	4.53	81 – 100	-
Short Deep Sleep Avg.	92.58*	5.11*	79 – 98*	-
Long Deep Sleep Avg.	90.21*	5.12*	81 – 97*	-
Short Deep Sleep Final	93.28*	4.83*	79 – 100*	-
Long Deep Sleep Final	91.55*	4.82*	81 – 98*	-
SVT	42.59	5.47	28 – 55	.60
Good Sleep Quality	41.50	5.92	28 – 55	.65
Poor Sleep Quality	43.42	5.05	34 – 53	.56
Low Daytime Sleepiness	43.27	6.16	28 – 55	.68
High Daytime Sleepiness	42.09	4.86	34 – 53	.50
Short Sleep Length Avg.	40.00	5.14	28 – 51	.51
Long Sleep Length Avg.	42.36	3.61	36 – 47	.13
Short Sleep Length Final	40.70	5.12	28 – 51	.52
Long Sleep Length Final	44.48	5.24	34 – 55	.59
Short REM Sleep Avg.	40.79	5.82	28 – 51	.63
Long REM Sleep Avg.	41.57	2.88	36 – 47	-.43
Short REM Sleep Final	41.30	5.81	28 – 55	.63
Long REM Sleep Final	43.87	4.89	34 – 53	.52
Short Deep Sleep Avg.	40.43*	4.70*	28 – 47*	.46*
Long Deep Sleep Avg.	42.38*	4.19*	37 – 51*	.33*
Short Deep Sleep Final	41.85*	5.97*	28 – 52*	.70*
Long Deep Sleep Final	43.26*	4.64*	37 – 55*	.46*

Note: TOSSA(CS) = Test of Sustained Selective Attention – Concentration Strength; SVT = Sentence Verification Test. Dash denotes single scale score; no reliability calculated. *Scores provided reflect transformation.

A Levene's test of homogeneity of variance determined whether groups differed significantly on any of the variables. The test revealed that the group variances were not significantly different for the TOSSA concentration strength when outliers were removed: Sleep Quality, $F(1, 41) = .52$; Daytime Sleepiness, $F(1, 40) = .84$; Sleep Length Avg., $F(1, 25) = .38$; Sleep Length Final, $F(1, 41) = .20$; REM Sleep Avg., $F(1, 25) = .01$; REM Sleep Final, $F(1, 41) = 2.54$; Deep Sleep Avg., $F(1, 24) = .49$; and Deep Sleep Final, $F(1, 38) = .24$. Similarly, group variances were not significantly different for Reading Comprehension: Sleep Quality, $F(1, 44) = .42$; Daytime Sleepiness, $F(1, 43) = .89$; Sleep Length Avg., $F(1, 26) = .20$; Sleep Length Final, $F(1, 44) = .18$; REM Sleep Avg., $F(1, 26) = 3.92$; REM Sleep Final, $F(1, 44) = .07$; Deep Sleep Avg., $F(1, 25) = .03$; and Deep Sleep Final, $F(1, 41) = .69$.

Correlations Between Variables

Table 3 presents the correlations between all of the continuous variables in the study. Sleep Length Final was significantly positively related to the SVT ($r = .45, p < .05$), REM sleep Final ($r = .84, p < .01$), Deep sleep Final ($r = .49, p < .05$), Sleep Length Average ($r = .79, p <.01$), and REM sleep Average ($r = .62, p < .01$). REM sleep Final was significantly positively related to Sleep Length Average ($r = .58, p < .01$) and REM sleep Average ($r = .78, p < .01$). Deep sleep Average was significantly positively related to Deep sleep Final ($r = .67, p < .01$). REM sleep Average was significantly positively related to Sleep Length Average ($r = .71, p < .01$). Finally, Deep sleep Average was significantly negatively related to the SQI ($r = -.41, p < .05$).

Table 3

Correlation Matrix of All Continuous Variables

Variable	1	2	3	4	5	6	7	8	9	10
1 SVT	-									
2 Sleep Length Final	.45*	-								
3 REM Sleep Final	.36	.84**	-							
4 Deep Sleep Final	.16	.49*	.37	-						
5 Sleep Length Avg.	.27	.79**	.58**	.30	-					
6 REM Sleep Avg.	.10	.62**	.78**	.11	.71**	-				
7 Deep Sleep Avg.	.02	.10	.05	.67**	.17	.00	-			
8 TOSSA	.18	.04	-.06	-.34	.23	.18	-.22	-		
9 SQI	.28	.17	.08	-.18	.28	.13	-.41*	-.03	-	
10 ESS	-.08	-.00	.13	.12	-.03	.06	.09	-.29	.23	-

Note. SVT = Sentence Verification Test; TOSSA = Test of Sustained Selective Attention; SQI = Sleep Quality Index; ESS = Epworth Sleepiness Scale. * $p < .05$ two-tailed, ** $p < .01$ two-tailed.

Data Analysis

Hypothesis 1 and 1a

Hypothesis 1 stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep for the final night. It was expected that individuals who spent more time in deep sleep for the final night would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) on the log transformed data for time spent in deep sleep for the final night tested for a significant difference in sustained selective auditory attention between time spent in deep sleep (short and long). The independent variable was time spent in deep sleep for the final night (short and long). Length of time spent in deep sleep was identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention as measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 38) = .24, p = .63$. No significant difference was found between time spent in deep sleep (short and long) and performance on the sustained auditory attention task, $F(1, 38) = 1.28, p = .27, \omega^2 = .01$. A trend in scores revealed that individuals who obtained shorter deep sleep performed better on the sustained auditory attention task ($M = 93.28$, $SE = 1.11$) than individuals who obtained longer deep sleep ($M = 91.55$, $SE = 1.05$). The results do not support Hypothesis 1.

Hypothesis 1a stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep averaged over three nights. Specifically, it was expected that individuals who averaged more time in deep sleep over three nights would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction (α = .007) was run using the inverse transformation of time spent in deep sleep averaged over three days to determine if there were significant differences in sustained auditory attention. The independent variable was averaged time spent in deep sleep across three nights (short and long). Length of time spent in deep sleep averaged across three nights was identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 24) = .49, p = .49$. There was no significant difference in performance on the TOSSA between average time spent in deep sleep (short and long), $F(1, 24) = 1.41, p = .25, \omega^2 = .02$. A similar trend in data was found here as in Hypothesis 1 in which individuals who spent a shorter time in deep sleep performed better on the sustained auditory attention task (M = 92.58, SE = 1.42) than individuals who spent longer time in deep sleep (M = 90.21, SE = 1.42). The results do not support Hypothesis 1a.

Hypothesis 2 and 2a

Hypothesis 2 stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep for the final night. It was expected that individuals who spent more time in REM sleep for the final night would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in sustained selective auditory attention between time spent in REM sleep (short and long). The independent variable was time spent in REM sleep for the final night (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention as measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 41) = 2.54, p = .12$. There was no significant difference between time spent in REM sleep (short and long) for the final night and sustained auditory attention, $F(1, 41) = .29, p = .59, \omega^2 = -.02$. However, there was a tendency for individuals who spent more time in REM sleep to perform better on the sustained auditory attention task ($M = 92.47$, $SE = .94$) than individuals who spent less time in REM sleep ($M = 91.59$, $SE = 1.37$). The results do not support Hypothesis 2.

Hypothesis 2a stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep averaged over three nights. Specifically, it was expected that individuals who averaged more time in REM sleep over three nights would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) was run using the same variables except the independent variable was time spent in REM sleep averaged across three nights (short and long). Length of time spent in REM sleep was identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention as measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 25) = .01, p = .93$. There was no significant difference between average time spent in REM sleep (short and long) for three nights and sustained selective auditory attention, $F(1, 25) = .25, p = .62, \omega^2 = -.03$. However, there was a tendency for individuals who spent less time in REM sleep to perform better on the sustained selective auditory attention task ($M = 91.45$, $SE = 1.58$) than individuals who spent more time in REM sleep ($M = 90.34$, $SE = 1.59$). The results do not support Hypothesis 2a.

Hypothesis 3

Hypothesis 3 stated that there would be a significant mean difference in sustained selective auditory attention between short and long sleep length for the final night. It was expected that individuals who obtained more sleep on the final night would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in sustained selective auditory attention between sleep length for the final night (short and long). The independent variable was sleep length for the final night (short and long). Average sleep length was identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention. Sustained selective auditory attention was measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 41) = .20, p = .66$. There was no significant difference between time slept for the final night (short and long) and sustained selective auditory attention, *F*(1, 41) = .01, $p = .91$, $\omega^2 = -.02$. The trend in the data revealed that individuals who slept longer the night before performed better on the TOSSA ($M = 92.15$, $SE = 1.06$) than individuals who had less sleep ($M = 91.97$, $SE = 1.24$). The results do not support Hypothesis 3.

Hypothesis 4

Hypothesis 4 stated that there would be a significant mean difference in sustained selective auditory attention between reported good and poor sleep quality. It was expected that individuals who reported better sleep quality would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in sustained auditory attention between reported sleep quality (poor and good). The independent variable was reported sleep quality (poor and good). Sleep quality was measured by the sleep quality score provided from the SQI. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention as measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, *F*(1, 41) = .52, $p = .48$. There was no significant difference across sleep quality (poor and good) in performance on the TOSSA, *F*(1, 41) = .01, $p = .93$, $\omega^2 = -.02$. A trend in the data revealed that individuals who reported poor sleep quality performed better on the TOSSA ($M = 92.12$, $SE = 1.12$) than those who reported good sleep quality ($M = 91.97$, $SE = 1.16$). The results do not support Hypothesis 4.

Hypothesis 5

Hypothesis 5 stated that there would be a significant mean difference in sustained selective auditory attention between low and high daytime sleepiness. It was expected that individuals who reported lower daytime sleepiness would perform significantly better on a sustained selective auditory attention task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in sustained auditory attention between reported daytime sleepiness (low and high). The independent variable was reported daytime sleepiness (low and high). Daytime sleepiness was measured by the general daytime sleepiness score provided from the ESS. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was sustained selective auditory attention as measured by the CS index provided from the TOSSA. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 40) = .84, p = .37$. There was no significant difference between reported daytime sleepiness (low and high) and sustained selective auditory attention, $F(1, 40) = .20, p = .66, \omega^2 = -.02$. However, the results revealed that there was a tendency for individuals with reported low daytime sleepiness to perform better on the sustained selective auditory attention task ($M = 92.48$, $SE = 1.16$) than those who reported high daytime sleepiness ($M = 91.73$, $SE = 1.18$). The results do not support Hypothesis 5. See Table 4 for a summary of results for Hypotheses 1 through 5.

Table 4

Results of the ANOVA for Sustained Selective Auditory Attention

	df	*F*	*p*	ω^2
Deep sleep Final	1,38	1.278	.265	.01
Deep sleep Avg	1,24	1.406	.247	.02
REM sleep Final	1, 41	.292	.592	-.02
REM sleep Avg	1, 24	.249	.622	-.03
Sleep Length Final	1, 41	.013	.911	-.02
Sleep Quality	1, 41	.008	.927	-.02
Daytime Sleepiness	1, 40	.203	.655	-.02

Hypotheses 6 and 6a

Hypothesis 6 stated that there would be a significant mean difference in reading comprehension between short and long deep sleep on the final night. It was expected that individuals who spent more time in deep sleep on the final night would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) on the log transformed data for time spent in deep sleep on the final night tested for a significant difference in reading comprehension between time spent in deep sleep (short and long). The independent variable was time spent in deep sleep for the final night (short and long) as identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 41) = .79, p = .38$. No significant difference was found between time spent in deep sleep in the final night (short and long) and performance on the reading comprehension task, $F(1, 41) = .72, p = .40$, $\omega^2 = -.01$. A trend in scores revealed that individuals who obtained more time in deep sleep on the final night performed better on the SVT ($M = 43.22$, $SE = .95$) than individuals who obtained shorter time in deep sleep on the final night ($M = 41.85$, $SE = 1.33$). The results do not support Hypothesis 6.

Hypothesis 6a stated that there would be a significant mean difference in reading comprehension between short and long deep sleep averaged over three nights. Specifically, it was expected that individuals who averaged more time in deep sleep over three nights would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) was run using the inverse transformation of time spent in deep sleep averaged over three days (short and long) to test for a significant difference in reading comprehension. The independent variable was averaged time spent in deep sleep across three nights (short and long) as identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 25) = .01$, $p = .92$. There was no significant difference in performance in reading comprehension between average time spent in deep sleep (short and long), $F(1, 25) = 1.23$, $p = .28$, $\omega^2 = .01$. A similar trend in data was found here as in Hypothesis 6 in which individuals who spent a more average time in deep sleep performed better on the SVT ($M = 42.31$, $SE = 1.12$) than individuals who spent less average time in deep sleep ($M = 40.43$, $SE = 1.26$). The results do not support Hypothesis 6a.

Hypothesis 7 and 7a

Hypothesis 7 stated that there would be a significant mean difference in reading comprehension between short and long REM sleep for the final night. It was expected that individuals who spent more time in REM sleep for the final night would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in reading comprehension between time spent in REM sleep (short and long). The independent variable was time spent in REM sleep for the final night (short and long) as identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 44) = .05, p = .82$. There was no significant difference between time spent in REM sleep for the final night (short and long) and reading comprehension, $F(1, 44) = 2.75, p = .10, \omega^2 = .04$. However, there was a tendency for individuals who spent more time in REM sleep in the final night to have better reading comprehension ($M = 43.87, SE = 1.02$) than individuals who spent less time in REM sleep ($M = 41.26, SE = 1.20$). The results do not support Hypothesis 7.

Hypothesis 7a stated that there would be a significant mean difference in reading comprehension between short and long REM sleep averaged over three nights. Specifically, it was expected that individuals who averaged more time in REM sleep over three nights would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) was run using the same variables except scores for time spent in REM sleep was averaged over three days. The independent variable was time spent in REM sleep averaged across three nights (short and long) as identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 26) = 3.93, p = .06$. There was no significant difference between average time spent in REM sleep for three nights (short and long) and reading comprehension, $F(1, 26) = .25, p = .62, \omega^2 = -.03$. A trend in the data revealed that individuals who spent more average time in REM sleep had better reading comprehension ($M = 41.57, SE = .77$) than individuals who spent less average time in REM sleep ($M = 40.71, SE = 1.52$). The results do not support Hypothesis 7a.

Hypothesis 8

Hypothesis 8 stated that there would be a significant mean difference in reading comprehension between short and long sleep length for the final night. It was expected that individuals who obtained more sleep would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) tested for a significant difference in reading comprehension between sleep length for the final night (short and long). The independent variable was sleep length for the final night (short and long) as identified through the digital records of the Zeo device. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, *F*(1, 44) = .23, *p* = .64. Based on the Bonferroni correction, there was not a significant difference between reading comprehension and sleep length (short and long), *F*(1, 41) = 3.99, *p* = .05, ω^2 = .10. However, a trend in the data revealed that individuals who slept longer on the final night of the experiment performed better on the reading comprehension task (*M* = 44.09, *SE* = 1.07) than individuals who slept less (*M* = 39.93, *SE* = 1.33). The results do not support Hypothesis 8.

Hypothesis 9

Hypothesis 9 stated that there would be a significant mean difference in reading comprehension between reported good and poor sleep quality. It was expected that individuals who obtained better sleep quality would perform significantly better on a reading comprehension task. A one-way analysis of variance with Bonferroni correction (α = .007) tested for a significant difference in reading comprehension between reported sleep quality (poor and good). The independent variable was reported sleep quality (poor and good) as measured by the sleep quality score provided from the SQI. Group classification for the independent variable was dichotomized from the collected data by a median split. The dependent variable was reading comprehension as measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, *F*(1, 44) = .48, p = .49. There was no significant difference between reading comprehension and reported sleep quality (poor and good), *F*(1, 44) = 1.37, *p* = .25, ω^2 = .01. A trend in the data revealed that individuals who reported poor sleep quality performed better on the SVT (*M* = 43.38, *SE* = .98) than individuals who reported good sleep quality (*M* = 41.50, *SE* = 1.32). The results do not support Hypothesis 9.

Hypothesis 10

Hypothesis 10 stated that there would not be a significant mean difference in reading comprehension between low and high daytime sleepiness. A one-way analysis of variance with Bonferroni correction ($\alpha = .007$) was used to determine whether there were significant differences in reading comprehension between reported daytime sleepiness (low and high). The independent variable was reported sleep quality (low and high). Daytime sleepiness was measured by the general daytime sleepiness score provided from the ESS. Group classification for the independent variable was dichotomized from the collected data by median split. The dependent variable was reading comprehension. Reading comprehension was measured by the total comprehension accuracy score provided from the SVT. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(1, 43) = .81, p = .38$. There were no significant differences between reading comprehension and reported daytime sleepiness (low and high), $F(1, 43) = .48, p = .49, \omega^2 = -.01$. However, a trend in the data revealed that individuals who reported low daytime sleepiness had better reading comprehension (*M* = 43.23, *SE* = 1.30) than individuals who reported high daytime sleepiness (*M* = 42.09, *SE* = 1.01). The results support Hypothesis 10. See Table 5 for a summary of results for Hypotheses 6 through 10.

Table 5

Results of the ANOVA for Reading Comprehension

	df	F	p	ω^2
Deep sleep Final	1, 41	.722	.401	-.01
Deep sleep Avg	1, 25	1.234	.277	.01
REM sleep Final	1, 44	2.752	.104	.04
REM sleep Avg	1, 26	.253	.619	-.03
Sleep Length Final	1, 44	6.380	.015	.10
Sleep Quality	1, 44	1.370	.248	.01
Daytime Sleepiness	1, 43	.483	.491	-.01

Hypotheses 11 – 11a

Hypothesis 11 stated that the combination of minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, sleep length for the final night, and daytime sleepiness will serve as significant predictors of sustained selective auditory attention, with all variables being positive related to sustained selective auditory attention except daytime sleepiness. A standard multiple regression analysis was used to determine whether all five predictor variables (minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, sleep length for the final night, and daytime sleepiness) significantly contribute to the criterion variable, sustained auditory attention, as indicated by significant beta values. An analysis of the data revealed three significant outliers and a violation of multicollinearity for sleep length (VIF = 3.93) and time spent in REM sleep (VIF = 3.23). The removal of the three outliers did not correct this violation; therefore, the ability to assess the unique effects of these predictor variables is reduced. Using the enter method, it was found that the combination of minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, sleep length for the final night, and daytime sleepiness explain a significant amount of the variance in performance of sustained selective auditory attention, $F(5, 30) = 2.67, p = .04, R^2 = .31, R^2_{Adjusted} = .19$. The analysis revealed that only deep sleep ($\beta = -.50, t\,(30) = -2.68, p = .01$) significantly predicted performance on a sustained selective auditory attention task, whereas minutes spent in REM sleep ($\beta = .19, t(30) = .72, p = .48$), sleep quality ($\beta = -.01, t\,(30) = -.07, p = .94$), sleep length ($\beta = -.08, t\,(30) = -.29, p = .78$), and daytime sleepiness ($\beta = -.29, t\,(30) = -1.78, p = .09$) were not significant predictors. The results partially support Hypothesis 11. See Table 6 for a summary of results for Hypothesis 11.

Table 6

Results of the Multiple Regression for Hypothesis 11

	B	*SE B*	β
Deep sleep Final	-14.24	5.31	-.50*
REM sleep Final	.02	.02	.19
Sleep Length Final	-.00	.01	-.08
Sleep Quality	-.02	.22	-.01
Daytime Sleepiness	-.35	.20	-.29

Note: R^2=.31 and $R^2_{Adjusted} = .19$. * $p < .05$.

Hypothesis 11a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness would serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness. To test Hypothesis 11a, the predictor variables, averaged minutes in deep sleep and averaged minutes in REM sleep, and averaged sleep length replaced data collected from one night in the standard multiple regression analysis. An analysis of the data revealed that all underlying assumptions were met and no outliers were identified. Using the enter method, it was found that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness did not explain a significant amount of the variance in performance of sustained selective auditory attention, $F(5, 19) = 1.20, p = .35, R^2 = .24, R^2_{Adjusted} = .04$. Additionally, the analysis revealed that none of the variables was a significant predictor of sustained selective auditory attention. The results do not support Hypothesis 11a. See Table 7 for a summary of results for Hypothesis 11a.

Table 7

Results of the Multiple Regression for Hypothesis 11a

	B	*SE B*	β
Deep sleep Avg	446.44	282.43	.36
REM sleep Avg	.00	.04	-.00
Sleep Length Avg	.03	.03	.35
Sleep Quality	-.32	.43	-.18
Daytime Sleepiness	-.42	.41	-.22

Note: R^2=.24 and $R^2_{Adjusted}$ = .04.

Hypotheses 12 – 12a

Hypothesis 12 stated that the combination of minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, and sleep length for the final night would serve as significant positive predictors of reading comprehension. A standard multiple regression analysis was used to determine whether all four predictor variables (minutes spent in deep sleep for the final night, minutes spent in REM sleep for the final night, sleep quality, and sleep length for the final night) significantly contributed to the criterion variable, reading comprehension. An analysis of the data revealed six significant outliers and a violation of multicollinearity for sleep length (VIF = 3.64) and time spent in REM sleep (VIF = 2.91). The removal of the two outliers did not correct this violation; therefore, the ability to assess the unique effects of these predictor variables is reduced. Using the enter method, it was found that the combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, and sleep length for one night explained a significant amount of the variance in reading comprehension, $F(4, 32) = 2.77, p = .04, R^2 = .26, R^2_{Adjusted} = .16$. Additionally, the analysis revealed that only sleep length ($\beta = .75, t(32) = 2.60, p = .01$) significantly predicted performance on a reading comprehension task, whereas minutes spent in REM sleep ($\beta = -.37, t(32) = -1.43, p = .16$), sleep quality ($\beta = .13, t(32) = .83, p = .42$), and minutes spent in deep sleep ($\beta = -.10, t(32) = -.53, p = .60$) were not significant predictors. The results partially support Hypothesis 12. See Table 8 for a summary of results for Hypothesis 12.

Table 8

Results of the Multiple Regression for Hypothesis 12

	B	*SE B*	β
Deep sleep Final	-2.51	4.72	-.10
REM sleep Final	-.03	.02	-.37
Sleep Length Final	.03	.01	.75*
Sleep Quality	.16	.19	.13

Note: R^2=.26 and $R^2_{Adjusted} = .16$. * $p < .05$.

Hypothesis 12a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, and averaged sleep length would serve as significant positive predictors of reading comprehension performance. To test hypothesis 12a, the predictor variables, averaged minutes in deep sleep, averaged minutes in REM sleep, sleep quality, and averaged sleep length were included in a standard multiple regression analysis. An analysis of the data revealed that all underlying assumptions were met and no outliers were identified. Using the enter method, it was found that the combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, and sleep length for one night explained a significant amount of the variance in reading comprehension, $F(4, 22) = 3.89, p = .02, R^2 = .41, R^2_{Adjusted} = .31$. Additionally, the analysis revealed that only average time in deep sleep ($\beta = -.54, t\,(22) = -3.03, p = .01$) significantly predicted performance on a reading comprehension task, whereas minutes spent in REM sleep ($\beta = -.06, t(22) = -.25, p = .81$), sleep length ($\beta = .16, t\,(22) = .62, p = .54$) and sleep quality ($\beta = .32, t\,(22) = 1.76, p = .09$) were not significant predictors. The results partially support Hypothesis 12a. See Table 9 for a summary of results for Hypothesis 12a.

Table 9

Results of the Multiple Regression for Hypothesis 12a

	B	*SE B*	β
Deep sleep Avg	-453.39	149.89	-.54*
REM sleep Avg	-.01	.03	-.06
Sleep Length Avg	.01	.02	.16
Sleep Quality	.49	.28	.32

Note: R^2=.41 and $R^2_{Adjusted} = .31$. $*p < .05$

CHAPTER FOUR

DISCUSSION

This chapter presents a general overview of the results as well as a discussion of each hypothesis. Implications of this study, limitations, and suggestions for future research are also presented.

General Overview of Results

A focus of this study was on examining the relationship of sleep and attention as well as sleep and reading comprehension. The primary factors examined in this study included self-reported sleep quality and daytime sleepiness, as well as objective measures of total sleep length, time spent in REM sleep, and time spent in deep sleep with an analysis of the impact of sleep architecture on sustained selective attention and reading comprehension. In terms of sleep architecture, individuals reported occasional sleep difficulties, which is consistent with the individuals used to validate the measure (Urponen et al., 1991). The average self-reported daytime sleepiness measured by the ESS fell within the normal range of daytime sleepiness and was consistent with average scores of student populations (Howell et al., 2004).

Analysis of the sample's sleep architecture revealed that students are averaging the recommended sleep length, although on the lower end of the range recommended by the National Sleep Foundation (NSF) (Hirshkowitz et al., 2015). Even though this sample fell within the recommended range, average sleep time was significantly lower than mean sleep of the general American population in 2014 (Hirshkowitz et al., 2015). There was a similar trend in the data when evaluating individuals' sleep length for the final night of the study, who obtained more REM sleep and deep sleep, both averaged across three days and in the final night, than individuals in the study used to validate the Zeo device (Shambroom et al., 2012). Additionally, participants in this sample spent a greater percent of time in REM sleep than the normal population but a smaller percent of time in deep sleep than the normal population (NINDS, 2014).

Analyses showed that total sleep length for the final night was significantly positively related to time spent in REM sleep for final night/averaged nights, time spent in deep sleep for the final night, sleep length averaged across three nights, and reading comprehension performance. Additionally, there were significant positive relationships between total sleep length (averaged across three nights) and time spent in REM sleep (averaged across three nights) and time spent in REM sleep for the final night. Time spent in deep sleep for the final night was significantly positively related to average time spent in deep sleep across three nights, and there was a significant negative relationship between reported sleep quality and average time spent in deep sleep across three nights. The strongest association of variables examined was between total sleep length for the final night and time spent in REM sleep for the final night.

Overall performance on the TOSSA concentration strength scale was similar to the normative sample (Kovacs, 2012), and reading comprehension performance was similar to a comparable sample (Ellis et al., 2014). The analysis of the effect of sleep architecture (i.e., total sleep length, time spent in REM sleep, time spent in deep sleep) and self-reported sleep quality and daytime sleepiness on sustained selective attention produced small effect sizes. Additionally, no variables were associated with performance on the TOSSA. However, all variables together (i.e., time spent in deep sleep for the final night, time spent in REM sleep for the final night, overall sleep length for the final night, sleep quality, and daytime sleepiness) significantly predicted performance on the sustained selective auditory attention task, with only time spent in deep sleep for the final night being a unique contributor with all other variables held constant. Similar results were not found when time spent in deep sleep, time spent in REM sleep, and overall sleep length were averaged across three consecutive nights. The combined variables did not significantly predict performance on the TOSSA. In evaluating the impact of sleep architecture, sleep quality, and daytime sleepiness on reading comprehension, there were small effect sizes for all variables except total sleep length on the final night in which there was a moderate effect. Additionally, only total sleep length was associated with reading comprehension performance. However, all variables together (i.e., time spent in deep sleep for the final night, time spent in REM sleep for the final night, overall sleep length for the final night, and sleep quality) significantly predicted reading comprehension performance, with only sleep length for the final night being a unique contributor with all other variables held constant. Similar results were found when sleep architecture was averaged across three consecutive nights, except average time spent in deep sleep was the only unique contributor.

Hypothesis 1 and 1a

Hypothesis 1 stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep for the final night.

Specifically, it was expected that individuals who spent more time in deep sleep would perform significantly better on a sustained selective auditory attention task, with performance on a sustained selective auditory attention task determined by calculated concentration strength. Hypothesis 1a stated that there would be a significant mean difference in sustained selective auditory attention between short and long deep sleep averaged over three consecutive nights. It was expected that individuals who averaged more time in deep sleep over the three nights would perform significantly better on a sustained selective auditory attention task. The results of the one-way ANOVA did not support either hypothesis, which is inconsistent with previous research. Prior research has shown there is a tendency for individuals who obtain more slow wave sleep (SWS) to perform significantly better on a continuous performance task than individuals who obtain less SWS (Walsh et al., 2006). Additionally, individuals who experience sleep deprivation, which affects time spent in deep sleep, tend to experience more lapses in attention (Chee et al., 2008). Participants in this study not only exhibited no significant differences in performance on a continuous performance task but also exhibited an opposite trend of previous research investigating SWS and sustained attention. Individuals who spent less time in deep sleep had a tendency of performing better on the continuous performance task than individuals who spent more time in deep sleep.

One possible explanation for the inconsistency in findings is the small sample size as well as differences in the measure used to detect sustained attentional impairment. Walsh et al. (2006) used the popular Psychomotor Vigilance Test (PVT), which uses reaction time as a major component in assessing sustained attention and is more susceptible to effects of sleep deprivation. For this study, a measure of concentration strength from the TOSSA is less reliant on reaction time in evaluating the presence of attention impairment and, therefore, is less susceptible to psychomotor retardation induced by sleep deprivation. A second explanation is that individuals may develop short-term compensation strategies when experiencing mild mental fatigue from sleep deprivation (Stern, 2009). These short-term compensation strategies may be possible because of the short time duration of the TOSSA and may not have been useful if the task were longer. Previous research demonstrated that more time spent in NREM sleep allows more time for the area of the brain associated with vigilant attention to rest, thereby protecting an individual from mental fatigue and decrements in vigilant attention performance (Chee et al., 2008; Kajimura et al., 1999). However, even if mental fatigue is present, other factors may overcome the effect of mental fatigue, such lack of boredom and sufficient self-regulation and motivation on the task. Alternatively, it may be possible that individuals who did not require additional cognitive resources to attend to the task experienced boredom and shifts in attention.

Hypothesis 2 and 2a

Hypothesis 2 stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep for the final night. Specifically, it was expected that individuals who spent more time in REM sleep would perform significantly better on a sustained selective auditory attention task. Hypothesis 2a stated that there would be a significant mean difference in sustained selective auditory attention between short and long REM sleep averaged over three consecutive nights. Similarly, it was expected that individuals who averaged more time in REM sleep over three nights would perform significantly better on a sustained selective auditory attention task. The results of the one-way ANOVA did not support either hypothesis. Even though the results did not produce significant differences, the trend in the data for Hypothesis 2 was consistent with previous research. When an individual spends less time in REM sleep, there has been a demonstration of decreased vigilant attention (Banks & Dinges, 2007; Van Dongen et al., 2003). Similarly, in this study, individuals who obtained more REM sleep tended to perform better on the attention task than individuals who obtained less REM sleep. However, the opposite occurred when analyzing data for Hypothesis 2a – individuals who averaged less REM sleep tended to perform better on the attention task than those who averaged more REM sleep, which is not consistent with previous research.

The lack of statistically significant yet similar trending data for Hypothesis 2 may be from inadequate sample size as well as differences in the measure of attention. Van Dongen and colleagues (2003) also used the PVT, which as previously explained, is more sensitive to the effects of sleep deprivation due to increased reliance on reaction time, unlike the measure of concentration strength for the TOSSA. An explanation for the positive trend in data is that time spent in REM sleep affects sustained selective auditory attention and more time spent in REM sleep the night prior to a vigilant attention assessment has the tendency to yield better results. Therefore, college students who have less time in REM sleep may have trouble attending to information that requires vigilant attention (i.e., lecture classes, exams). Additionally, an explanation for the opposite trend in data found in Hypothesis 2a is that a mean decrease in time spent in REM sleep across three days is less impactful on attention than the amount of time spent in REM sleep the night prior to measuring attention. Specifically, even if an individual averages a shorter amount of time spent in REM sleep over a three-day period, as long as the individual spends a sufficient amount of time in REM sleep on the final night, attention may be better than if an insufficient of amount time in REM sleep was acquired on the final night. This suggests that cumulative sleep wakefulness may be more impactful on performance than cumulative sleep debt (Van Dongen et al., 2003).

Hypothesis 3

Hypothesis 3 stated that there would be a significant mean difference in sustained selective auditory attention between short and long sleep length for the final night. Specifically, individuals who obtained more sleep would perform significantly better on a sustained selective auditory attention task. The results of the one-way ANOVA did not support this hypothesis. However, consistent with prior research, a trend in the data indicated that individuals who slept longer the night before the attention task performed better than individuals who did not obtain as much sleep. These findings mirror those of Van Dongen et al. (2003) in which individuals who experienced chronic partial sleep deprivation demonstrated deficits in cognitive performance. Aside from limited sample size, variations in type of data analysis and assessment measures used may explain the lack of significant findings. Consistent with other statistically significant research in the assessment of sleep and attention, Van Dongen et al. (2003) used the PVT to measure performance, whereas this study used the concentration strength index from the TOSSA to measure level of attention. Additionally, no relationship may exist between sleep length and sustained attention and previous research may be wrong. Finally, Van Dongen et al. (2003) evaluated performance differences by comparing alpha scores using an *F* test, which may be more sensitive in detecting statistical significance because of the inclusion of inter-individual differences in sleep deprivation, whereas the use of a one-way ANOVA for this study assumes homogeneity among subjects in evaluating the effects of sleep deprivation. Even though results were not significant, the trend in the data suggests that students may demonstrate improved vigilant attention when they acquire more sleep the night prior. This knowledge may be helpful in adjusting students' study habits prior to exams that require vigilant attention. Specifically, an increase in study time the night prior to an exam may not be beneficial if the consequence is extended wakefulness.

Hypothesis 4

Hypothesis 4 stated that there would be a significant mean difference in sustained selective auditory attention between good and poor sleep quality. Specifically, it was expected that individuals who obtained better sleep quality would perform significantly better on a sustained selective auditory attention task. The results of the one-way ANOVA did not support this hypothesis, and this is inconsistent with previous research, which indicated that poor sleep quality is associated with poorer cognitive functioning (Benitez & Gunstad, 2012; Naismith et al., 2004; Nebes et al., 2009; Steenari et al., 2003), including attention capabilities (Nebes et al., 2009). Current findings were contradictive in that individuals who reported poor sleep quality performed better on the sustained attention task compared to individuals who reported good sleep quality. In addition to the limited sample size, another explanation for the inconsistent findings is that sleep quality is unrelated to performance in sustained attention. While most studies demonstrate a significant relationship of sleep quality and cognitive performance, evidence for the specific relationship of sleep quality to sustained attention is lacking for nonclinical college adults (i.e., sleep disorder or attention disorder absent), which is the focus of the present study. A second explanation is that improved performance in spite of poor sleep quality may reflect compensatory strategies used when a sleep deficit has occurred. Students may compensate by focusing attention if the task is of short duration with deficits not becoming prominent until an extended period of time (i.e., lecture classes of longer duration). Poor sleep quality may be more subjectively evident when the sleep deficit is during deep sleep as opposed to REM sleep, as suggested by similar trend in data found in Hypothesis 1 and 1a.

Hypothesis 5

Hypothesis 5 stated that there would be a significant mean difference in sustained selective auditory attention between low and high daytime sleepiness. It was expected that individuals who report lower daytime sleepiness would perform significantly better on a sustained selective auditory attention task. The results of the one-way ANOVA did not support this hypothesis; still, there was a tendency for individuals who reported low daytime sleepiness to perform better on the attention task than those who reported high daytime sleepiness, which is consistent with previous research. Prior research has shown that increased daytime sleepiness is associated with greater cognitive impairments across age cohorts (Golan et al., 2004; Thomann et al., 2014; Ohayon & Vecchierini, 2002; Yun et al., 2015) as well as across clinical and nonclinical populations. Similar to the above-mentioned hypotheses, a small sample size is one explanatory factor in the failure to find statistical significance. Additionally, when sustained attention was measured directly (Thomann et al., 2014; Yun et al., 2015), the chosen dependent variables were response time and lapses produced by the PVT, unlike the less vulnerable measurement of concentration strength that was used in the current study. In summary, individuals who experience less daytime sleepiness tend to perform better on tasks that require sustained selective auditory attention. Therefore, college students who experience greater levels of daytime sleepiness may have a more difficult time attending to information presented in lecture classes.

Hypothesis 6 and 6a

Hypothesis 6 stated that there would be a significant mean difference in reading comprehension between short and long deep sleep for the final night. Specifically, it was expected that individuals who spent more time in deep sleep would perform significantly better on a reading comprehension task. Hypothesis 6a stated that there would be a significant mean difference in reading comprehension between short and long deep sleep averaged over three nights. Specifically, it was expected that individuals who averaged more time in deep sleep over three nights would perform significantly better on a sustained selective auditory attention task. Similar to Hypothesis 6, it was expected that individuals who averaged more time in deep sleep over three nights would perform significantly better on a reading comprehension task. The results of the one-way ANOVA did not support either hypothesis, and while this is inconsistent with previous research, a trend in the data for both hypotheses revealed that individuals who spent more time in deep sleep had better reading comprehension than those who spent less time in deep sleep, which is consistent with previous research. Even though previous research did not assess directly reading comprehension, performance on a declarative memory task and procedural memory task, which involves similar cognitive functions as reading comprehension, improved when individuals spent more time in slow wave/deep sleep

(Gais et al., 2000; Plihal & Born, 1997). In addition to variation in objective measurement, previous research evaluated the delayed retention aspect of declarative and procedural memory, whereas this study evaluated the residual effects of deep sleep on encoding and recall. Therefore, one explanation for the current findings may be that the benefits of increased time in deep sleep are only restorative and significant only for memory consolidation rather than facilitation of immediate recognition tasks. Even though a large effect is unlikely, students who spend more time in deep sleep, either on average or on the night prior, may exhibit better reading comprehension abilities. Therefore, in preparation for exams, which requires reading comprehension skills, it would behoove students to get adequate sleep (i.e., 6 – 8 hours).

Hypothesis 7 and 7a

Hypothesis 7 stated that there would be a significant mean difference in reading comprehension between short and long REM sleep for the final night. It was expected that individuals who spent more time in REM sleep would perform significantly better on a reading comprehension task. Hypothesis 7a stated that there would be a significant mean difference in reading comprehension between short and long REM sleep averaged over three nights. Similarly, it was expected that individuals who averaged more time in REM sleep over three nights would perform significantly better on a reading comprehension task. The results of the one-way ANOVA did not support either hypothesis. Aside from the insignificance found, data showed that there was a tendency for individuals who both averaged more time in REM sleep and spent more time in REM sleep on the final night to have better reading comprehension than those who spent less time in REM sleep, which is consistent with previous research. Although there is limited research on the effects of sleep and reading comprehension in general, there is even less research evaluating the effects of REM sleep on reading comprehension specifically. However, an explanation of these results is based on the assumption that time spent in REM sleep is associated with overall sleep length (Banks & Dinges, 2007). With this assumption along with evidence that sleep deprivation is associated with poor reading comprehension (Pilcher et al., 2007), I suggest that decreased time in REM sleep yields decreased reading comprehension abilities. One explanation for the lack of significance for the current study is the reading level for the provided passages. The Flesch-Kincaid Reading levels for the passages were 10.0 grade level or higher. Because it is expected that college students have a reading level of at least 12.0 grade level or higher, the lower reading level of the passages may not have required top-down reading, and therefore may not have required as much attentional demand (Pressley & Afflerbach, 1995). This may have allowed individuals to utilize compensatory strategies, even with time restraints, and offset any possible deficits that may have been detectable had the passages required more attentional demand (Walczyk, 2000). Even though the results were not significant with small effect sizes, students may benefit from spending more time in REM sleep because of the slight increase in reading comprehension performance. For students this slight increase may be appreciated because it may be the difference between an A or a B.

Hypothesis 8

Hypothesis 8 stated that there would be a significant mean difference in reading comprehension between short and long sleep length for the final night. It was expected that individuals who obtained more sleep would perform significantly better on a reading comprehension task. Although the result of the one-way ANOVA did not support this hypothesis, the data was consistent with previous research (reviewed in the discussion of results for Hypotheses 7 and 7a). A trend in data revealed that individuals who obtained more sleep demonstrated better reading comprehension than those who obtained less sleep. Even though these findings were consistent with previous research, it is interesting that approaching significant differences in reading comprehension were found with overall sleep length and not in REM sleep given the positive association between overall sleep length and time spent in REM sleep found elsewhere (Banks & Dinges, 2007). An explanation is that reading comprehension ability is more affected by time spent in stage 2 sleep rather than either deep sleep or REM sleep. Bruni et al. (2009) identified that children with dyslexia spent significantly more time in stage 2 sleep than other NREM sleep stages compared to normal controls, which suggests a possible relationship between time spent in light sleep and reading comprehension ability. For students, these findings demonstrate the importance of obtaining an adequate amount of sleep the night prior to an exam. By acquiring adequate sleep, students may better comprehend complex test questions presented, which may help improve exam scores.

Hypothesis 9

Hypothesis 9 stated that there would be a significant mean difference in reading comprehension between good and poor sleep quality. Specifically, it was expected that individuals who reported better sleep quality would perform significantly better on a reading comprehension task. The results of the one-way ANOVA did not support this hypothesis, and the trend in the data was inconsistent with previous research. Even though research is limited on the effects of sleep quality on aspects of reading comprehension (i.e., working memory, verbal efficiency, and attention), evidence suggests a relationship between sleep quality and cognitive functioning (Benitez & Gunstad, 2012; Naismith et al., 2004; Nebes et al., 2009; Steenari et al., 2003). Specifically, individuals who report higher sleep quality demonstrate better cognitive functioning. However, the data from the current study revealed that there was a tendency for individuals who reported poor sleep quality to have better reading comprehension than those who reported good sleep quality, which presents the opposite trend of previous research in sleep quality and cognitive functioning. These findings were actually consistent with the only other study that evaluated the direct relationship between sleep quality and reading comprehension in which individuals self-identified as poor sleepers performed better on a reading comprehension task than those self-identified as medium quality sleepers (Ellis et al., 2014).

A similar trend in the data was found for sleep quality and attention (hypothesis 4) as well as deep sleep and attention (hypotheses 1 and 1a). As previously described in hypotheses 1, 1a, and 4, the trend in data may be because of compensatory attention strategies (that individuals employ when faced with a top-down processing task (Pressley & Afflerbach, 1995; Shallice et al., 1996), as well as inter-individual differences in the effect of sleep on cognitive functioning. Lifestyle behaviors, such as exercise and study habits, that impact both sleep quality and one's ability to cope with cognitive impairment, could also explain the unexpected trend of improved reading comprehension with poor sleepers. Specifically, although exercising and/or studying close to bedtime may produce poor sleep quality, both activities help strengthen the neuronal network, which produces an increased cognitive reserve. This effect of sleep on reading comprehension may also be nonlinear, which would suggest that students' reading comprehension performance might shift to demonstrate a positive effect (i.e., improved reading comprehension performance with improve sleep quality) if the reading comprehension task were longer.

Hypothesis 10

Hypothesis 10 asserted that there would not be a significant mean difference in reading comprehension between low and high daytime sleepiness. Specifically, it was expected that regardless of reported daytime sleepiness individuals would have similar reading comprehension performance. The results of the one-way ANOVA supported this hypothesis, which was consistent with the literature. According to the research evaluating the effect daytime sleepiness has on academic performance, no significant associations have been found between daytime sleepiness and reading comprehension, but individuals who reported increased daytime sleepiness demonstrated deficits in mathematical skills (Campos-Morales et al., 2005; Giordani et al., 2008).

The trend in the data revealed that individuals who reported lower daytime sleepiness demonstrated better reading comprehension than those who reported higher daytime sleepiness. For the present study, this suggests that daytime sleepiness may not affect reading comprehension because of individuals' utilization of underlying compensatory strategies for reading comprehension even when time constraints are present. For students specifically, their perception of their level of daytime sleepiness will unlikely affect exam performance, but students who do not experience daytime sleepiness may have a slight advantage over students who do experience daytime sleepiness.

Hypothesis 11 and 11a

Hypothesis 11 stated that the combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, sleep length for one night, and daytime sleepiness will serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness. The results of the multiple regression analysis did not fully support this hypothesis. Although the combination of variables explained a significant amount of the variance for sustained selective auditory attention, the only variable that produced significant contributions with all other variables held constant is deep sleep, which was negatively associated with performance rather than positively associated. Specifically, for every extra minute spent in deep sleep for one night, there will be a .50 standardized unit decrease in attention. It is important to note that there was no significant difference in sustained selective auditory attention when separately analyzing each of the above-mentioned variables, but the trend in data for time spent in deep sleep and performance on the attention task was consistent with the results of the multiple regression analysis.

One explanation for the lack of significance with other variables could be the presence of multicollinearity for sleep length and time spent in REM sleep for the final night. This finding supports previous research that examined the association with sleep length and daytime sleepiness (Carskadon & Dement, 1977), REM sleep (Banks & Dinges, 2007), sleep quality (Akerstedt et al., 1997), and how time spent in deep sleep is unaffected by total sleep length (Banks & Dinges, 2007). Given that all variables together significantly predict sustained attention, the disassociation of time spent in deep sleep to the other variables may explain its higher degree of unique contribution.

Another explanation for the findings involves the measure chosen to represent sustained attention. Concentration strength on the TOSSA is the combined examination of one's ability to correctly identify the target stimulus and inhibit a response for distracting stimuli, whereas the PVT, a more sensitive measure of the effect of sleep deprivation on attention, includes reaction time. It appears that reaction time slowed by sleep deprivation is more prominent than any observable attention deficits. Finally, even though no significant differences between time spent in deep sleep and concentration strength were found when evaluated in isolation of other variables, support was found for the concept of inter-individual differences and variation in individual's response to sleep loss (Van Dongen et al., 2003). Specifically, the arbitrary cutoff scores used to identify differences in time spent in deep sleep may have failed to capture the full effect of time spent in deep sleep on attention, which would explain the variation in significance.

Hypothesis 11a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, averaged sleep length, and daytime sleepiness would serve as significant predictors of sustained selective auditory attention, with all variables being positively associated with sustained selective auditory attention except daytime sleepiness. Unlike the results for Hypothesis 11, the combination of variables did not account for a significant amount of variance for performance of selective auditory attention and no variables produced significant contributions to the overall regression model. An explanation for these findings is that the scores averaged across three days did not account for the inter-individual differences of the effect that sleep may have on attention and its fluctuation over time. Similar to the explanation provided for Hypothesis 11, the measure of concentration strength may not have been sensitive to the effects of sleep on attention. Finally, it could be that the sleep architecture from the final night of the evaluation had more of an impact on attention performance than the cumulative nights.

Hypothesis 12 and 12a

Hypothesis 12 stated that the combination of minutes spent in deep sleep in one night, minutes spent in REM sleep in one night, sleep quality, and sleep length for one night would serve as significant positive predictors of reading comprehension. The results of this multiple regression analysis did not fully support this hypothesis. Although the combination of variables explained a significant amount of the variance for reading comprehension ability, the only variable that produced significant contributions with all other variables held constant is sleep length, which was positively associated with performance. Specifically, for every extra minute slept for one night, there will be a .75 standardized unit increase in reading comprehension performance. These findings were consistent with results evaluating differences in reading comprehension based on sleep length. Similar to the explanation provided for Hypothesis 8, time spent in REM sleep and time spent in stage 2 sleep is affected more by total sleep length than time spent in deep sleep. Therefore, it may be possible that time spent in stage 2 sleep, which was not evaluated in the present study, is more impactful on reading comprehension than other components of the sleep architecture, given its association with total sleep length (Banks & Dinges, 2007). Additionally, although it contributed to the explanation of the total variance, sleep quality was not a significant contributor alone in explaining the variance in reading comprehension ability. One reason for this could be the response style of participants and low internal consistency measured in comparison to the original population.

Hypothesis 12a stated that the combination of averaged minutes spent in deep sleep, averaged minutes spent in REM sleep, sleep quality, and averaged sleep length would serve as significant positive predictors of reading comprehension performance. Similarly as hypothesis 12, the results of this multiple regression analysis did not fully support the hypothesis. The combination of variables did explain a significant amount of variance for reading comprehension ability, but the only variable that produced significant contributions with the other variables held constant was average time in deep sleep, which was negatively associated with reading comprehension. Specifically, for every extra minute of deep sleep averaged, there will be a .54 unit decrease in reading comprehension performance. These findings were inconsistent with Hypothesis 6a in which although no significance was found, a trend in the data revealed improved reading comprehension when more time was spent in deep sleep over a three day period. One possible explanation for the results is the cumulative effect of averaging more time in NREM sleep. Specifically, time spent in deep sleep is impacted less by variations in total sleep length (Banks & Dinges, 2007) and, therefore, is assumed to remain constant across the three-day evaluation period. However, time spent in stage 2 sleep, which also comprises the NREM sleep cycle andfluctuates with the variation in total sleep length (Banks & Dinges, 2007). Averaging more time in deep sleep rather than stage 2 sleep may have been a detriment to reading comprehension performance because the lower reading level (Flesch-Kincaid reading level of 10.6) of the passages may have allowed for individuals to use compensatory strategies, which may have led to boredom. This pattern may be more representative of a curvilinear relationship with reading comprehension and unidentifiable when evaluated using a one-way ANOVA.

Implications

The present study raises important implications regarding the sleep architecture, sleep quality, and daytime sleepiness of college students and the interplay between variations of these variables and cognitive functioning, specifically in regards to sustained attention and reading comprehension. The first implication concerns the sleep pattern of college students compared to the general population. It appears that college students obtain less total sleep than the average population, although within the recommended range of 6-8 hours, and spend a smaller percentage of time in deep sleep yet a greater percentage of time in REM sleep compared to the average population. An increase in average sleep quantity in this population yields an increase in average time spent in REM sleep. Furthermore, the more sleep an undergraduate student acquires over a period of time, the greater the likelihood of being able to acquire more sleep in the future, as well as more time spent in deep sleep and REM sleep. While these significant findings are important, what is more interesting is the direction of the relationship between total sleep length and time spent in deep sleep. Specifically, following the natural sleep cycle, individuals spend less time in deep sleep with an increase in overall sleep length, but there was a positive relationship found between time spent in deep sleep and overall sleep length. Aside from these findings, a negative relationship exists between average time spent in deep sleep and sleep quality. Students do not report poorer sleep quality compared to the average population, but students are more likely to report poor sleep quality when there is less time spent in deep sleep on average. Finally, students endorsed greater daytime sleepiness compared to the general population, but the average daytime sleepiness scores of college students are not in the clinical range.

The second implication of the present study is the effect of sleep patterns on cognitive functioning. It appears that more time spent in deep sleep the night prior to a performance evaluation relates to a decrease in concentration strength, yet other sleep variables do not have a significant impact on attention. Individuals who present with decreased time spent in deep sleep may utilize compensatory strategies to improve performance and in essence try harder than those who obtained a greater amount of deep sleep. Additionally, given the correlation between time spent in deep sleep and sleep quality, individuals may be better able to determine when additional attention needs allocation to a task following multiple nights of poor sleep. Individuals who spend more time in deep sleep may become bored and may experience less motivation to pay as close attention as those who experienced less time in deep sleep. This poor attention performance, however, is not clinically indicative of attention impairment. Therefore, attention may not be as affected by sleep variations as demonstrated in previous research, with previous research assuming that a measure of reaction time quantifies attention performance. If assessing clinical impairment of attention does not require a direct measure of reaction time, these results further suggest that the effect of sleep is not generalizable to all measures of attention.

There has been limited research concerning the effects of sleep on reading comprehension, therefore this study contributes uniquely to the literature. From the present study, more sleep acquired the night before a reading comprehension evaluation improves performance yet a higher average of acquired deep sleep hinders performance. Therefore, if an individual is able to acquire an adequate amount of sleep the night prior, cumulative effects of sleep debt appear to decrease. Additionally, the variation within the present study raise questions concerning the impact of time spent in the additional stages of NREM sleep, particularly stage 2.

The third implication of the present study involves the possible lack of motivation of college students to adjust sleep hygiene behaviors. There appears to be minimal effects of sleep deprivation on the cognitive functioning of college students, whether it is because of compensatory strategies or inter-individual differences or general youthfulness. Because of the lack of imposition that sleep deprivation is having on performance, achieving the buy in from college students to adjust their current sleep hygiene practices may be difficult, particularly if the primary reason for change is to improve academic performance.

Limitations and Suggestions for Future Research

There were several limitations to the present study, including limitations with the measures used, the design of the experiment, and statistical limitations. One primary limitation was the apparatus and measures used to identify the different levels of the independent variables. The Zeo device, which was used to identify time spent in different stages of sleep, was faulty in capturing the full night sleep for some participants because either the battery died or the sensors needed to be changed. Unfortunately, the company that manufactured the device went out of business and these particular devices were not returnable. Additionally, some participants reported problems with the device slipping up on their forehead, which could have affected the accuracy of marked times in different sleep stages. Although all reported problems were documented carefully, this experimenter relied on the participants' word regarding accuracy of the data and could not identify unreported problems with the sleep data. Another limitation was the measure chosen for identifying quality of sleep. There is limited research using the SQI as a measure of sleep quality in evaluating the effects of sleep quality on attention and reading comprehension, and the majority of the research used the PSQI to measure sleep quality. Both measures are valid, reliable measures of sleep quality, but the PSQI may be more sensitive to the effects of sleep deprivation and identifying individuals with good sleep quality versus poor sleep quality.

A second limitation to the present study involved measures of the dependent variables. The use of the TOSSA, rather than the highly utilized PVT, to measure vigilant attention may have contributed to the lack of significant findings. The PVT is more sensitive to sleep effects, so it is common in studies assessing the effect of sleep on cognitive functioning, whereas there were no studies found using the TOSSA to measure the effects of sleep on non-clinical populations. Even though there was no significance regarding the effect of sleep on vigilant attention for the present study, results were important in that sleep deficits are not generalizable to all measures of attention. The primary difference between the attention index for the TOSSA and that of the PVT is the inclusion of reaction time to assess behavioral alertness. Therefore, choosing an index on the TOSSA more sensitive to mental fatigue may have yielded comparable effects as the PVT. The Flesch-Kincaid reading level for the reading comprehension component may have also contributed to limited significance. The Flesch-Kincaid reading level for the present studied registered at 10.6, yet the assumed Flesch-Kincaid reading level for college students is 12.0 or higher. This lower reading level may have allowed individuals to utilize compensatory reading strategies, even though strict time limitations were present to prevent the use of these compensatory strategies. This may have decreased the sensitivity of the measure in detecting effects of sleep on reading comprehension performance, which resulted in limited significant findings.

A third limitation of the present study was the overall design measuring the effect of sleep on cognitive functioning. Individuals wore the Zeo device for three consecutive nights yet were testing for cognitive functioning only following the third night, which made it difficult to determine what specifically influenced performance. By measuring performance each day, a reflection of change in performance with variations in sleep architecture and subjective reporting may have provided greater insight into the role of sleep on cognitive functioning. An additional design limitation with the present study is the failure to assess for possible covariates, such as motivation and anxiety. Counterbalancing helped to control for possible fatigue or practice effects, but both the TOSSA and the SVT failed to measure participant motivation while completing the task. Furthermore, anxiety may have accounted for a greater amount of variance in differences in performance as well as differences in sleep variables.

In conjunction with design limitations, there were also statistical limitations with the present study. One primary statistical limitation was the small sample size. Even though 80 participants completed the experiment, only data from 46 individuals was used because of technical difficulties. This likely contributed to the lack of statistical significance, yet the computed effect sizes for all variables, which are resilient to the adjustments of sample size, were relatively small except for one – a moderate effect was found for sleep length on the final night and reading comprehension performance. Similarly, the median split of levels for the independent variables, rather than the clinically determined levels, may have failed to represent the true categories of good and poor sleep quality, high and low daytime sleepiness, and short versus long sleepers. An additional statistical limitation may also be the possibility of curvilinear relationships between some of the sleep variables and cognitive functioning. For example, the unexpected negative trends in deep sleep and performance on both attention and reading comprehension measures may be due to a curvilinear bend in the data. Finally, the alpha levels from the self-reported measures in the present study were significantly lower than the recommended .70 for the validation of internal consistency. The response style of the sample was not similar to response styles of previous samples, which may have lowered statistical significance for the self-reporting of daytime sleepiness and sleep quality and its effects on performance.

Based on these observed limitations and implications of the present study, there are multiple suggestions for future research. One suggestion is to examine the effects of sleep debt on college students with a reading comprehension task of longer duration than the present study. For the present study, participants were able to utilize compensatory strategies for a task of short duration, but it is unclear what detriment would occur if the task duration doubled. Additionally, comparing various task durations across multiple nights of observed sleep may assist in identifying a critical time period of task duration in which cognitive deficits from sleep debt become clinically evident. It would also be helpful to measure daily daytime sleepiness and sleep quality to assess specific factors of sleep architecture that may contribute to these self-reports as well as how these self-reports are reflected in task performance.

Another suggestion for future research is to evaluate the effect of sleep on mental fatigue by using the SADS index of the TOSSA, which is a measure of the influence of speed on detection strength, to determine whether mental fatigue explains impaired attention associated with sleep debt better than clinical attention deficits. Because the PVT indices are highly sensitive to response time, the use of another index that is affected similarly by response may help ascertain whether reaction time is more impaired following sleep debt rather than ability to attend sufficiently to stimuli. Finally, future research should focus on testing the statistical procedure recommended by Van Dongen et al. (2003) to account for inter-individual differences in sleep architecture and how that affects cognitive functioning.

Summary

This study evaluated the effects of sleep on cognitive functioning in college students and determined which sleep characteristics (i.e., time spent in REM sleep, time spent in deep sleep, total sleep length, sleep quality, and daytime sleepiness) best predicted cognitive performance. It was hypothesized that students would have impaired vigilant attention and reading comprehension following consecutive nights of partial sleep deprivation, along with negative self-reports of sleep quality and daytime sleepiness because of the consistent findings of poor sleep habits in the college student population and the associated effects of sleep on cognitive functioning. An additive aspect of this study was the evaluation of specific stages of sleep among a healthy, non-clinical, college population and the effects of time spent in deep and REM sleep on cognitive performance.

Results of this study did not reveal any significant effects of time spent in REM sleep, deep sleep, overall sleep length, sleep quality, or daytime sleepiness on vigilant attention. Similarly, there were no significant effects of time spent in REM sleep, deep sleep, sleep quality, or daytime sleepiness on reading comprehension, yet acquiring less sleep the night before a reading comprehension task negatively affected performance. When assessing which variables best predict vigilant attention performance, time spent in deep sleep the night before the task was the best predictor, although all variables combined explained a significant amount of the variance. The best predictor of reading comprehension was total sleep length the night before the task and average time spent in deep sleep for three consecutive nights before the task.

In summation of the findings, there is no significant deficit in vigilant attention in college students with poor sleep habits compared to those with better sleep habits. Furthermore, students who experience partial sleep deprivation the night prior to a task measuring reading comprehension may perform worse than if more sleep was acquired. This study contributes to the literature on the effects of sleep and vigilant attention in that it demonstrates a lack of generalizability to overt deficits in vigilant attention comparable to that of the clinical population following partial sleep deprivation. Additionally, it provides evidence against a causal explanation of clinically significant attention deficits from sleep deprivation. This study also contributes to the limited research on the effects of sleep on reading comprehension and demonstrates that sleep reparations following consecutive nights of sleep deprivation may prevent poor reading comprehension performance.

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APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

#____________

*****Please provide the following information by filing in the blank or circling the appropriate answer.**

A. Age in years_______

B. Gender M F

C. Current year/status in school?

Freshman Sophomore Junior Senior Graduate Student Other

D. With which ethnic group do you **most** identify?

1. African American	2. Asian American	3. Caucasian American
4. Hispanic/Latino	5. Native American	6. Other

E. Current Major (if any) or Undecided_____________________________________

F. Grade Point Average (G.P.A.) for the last year of school you completed _________

G. Is your vision corrected with glasses or contact lenses? Y N

H. Do you have any hearing difficulties? Y N

*If yes, do you wear hearing aids? Y N

I. Have you ever been diagnosed with a learning disability and/or a reading disorder? Y N

J. Have you ever been diagnosed with a sleep disorder and/or a breathing disorder? Y N

K. Is English your second language? Y N

L. Please provide your preferred contact information. The contact information you provide will be used only to remind you of the different phases of the experiment as well as to inform you of your winnings, should your name be drawn. Please provide only one of the following and be aware that standard text messaging charges will apply :

Email:

Cell phone (for text message reminders):

APPENDIX B

SLEEP QUALITY INDEX

Please answer the following questions to the best of your ability by circling the response that best fits you. If unsure, please give your best guess.

1. Time to fall asleep

   <10 min   11-30 min   >30 min

2. Suffered from insomnia during the past 3 months

   No   < 3 days/week   3-7 days/week

3. Difficulties falling asleep during the past 3 months

   No   < 3 days/week   3-7 days/week

4. Disturbed night sleep during the past 3 months

   No   <3 days/week   3-7 days/week

5. Nocturnal awakenings during the past 3 months

   No   <3 days/week   3-7 days/week

6. Tiredness in the morning

   Very or Mostly Alert   Don't Know   Very or Mostly Tired

7. Wake up too early in the morning during the past 3 months

   No   <3 days/week   3-7 days/week

8. Use of sleeping medication during the past 3 months

   No   Occasionally   At least once per week

APPENDIX C

EPWORTH SLEEPINESS SCALE

How likely are you to doze off or fall asleep in the following situations? You should rate your chances of dozing off, not just feeling tired. Even if you have not done some of these things recently try to determine how they would have affected you. For each situation, decide whether or not you would have:

- No chance of dozing =0
- Slight chance of dozing =1
- Moderate chance of dozing =2
- High chance of dozing =3

Write down the number corresponding to your choice in the right hand column.

Situation	**Chance of Dozing**
Sitting and reading	
Watching tv	
Sitting inactive in a public place (e.g., a theater or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in traffic	

TOTAL SCORE: ____________

APPENDIX D

READING COMPREHENSION PASSAGES

You will be asked to read carefully four passages and respond to test sentences over each passage from memory. You will not be allowed to refer back to the passages in responding to the test items. A practice passage follows then a sample memory test to familiarize you with the procedure. Please follow all instructions and do not turn the pages until instructed to do so.

PRACTICE PASSAGE

The Communication of War

Communication is the common factor in the initiation and termination of wars. Wars begin when two entities display disagreement. These disagreements can be displayed verbally through speech or nonverbally through behavior. Without the communication of these disagreements, either verbally or nonverbally, the other entity is not made aware that an enemy exists. If there is no known enemy, the need for defending a belief or way of life is unnecessary. Wars end through communication as well. Specifically, wars end when the other entity displays defeat or when both entities come to a mutual agreement. These displays can also be conveyed verbally or nonverbally.

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

The Insanity of Defining Sanity

If insanity and sanity exist, how shall we know them? The question is neither capricious nor itself insane. However much we may be personally convinced that we can tell the normal from the abnormal, the evidence is simply compelling. It is commonplace, for example, to read about murder trials wherein eminent psychiatrists for the defense are contradicted by equally eminent psychiatrists for the prosecution on the matter of the defendant's sanity. More generally, there are a great deal of conflicting data on the reliability, utility, and meaning of such terms as insanity, sanity, mental illness, and schizophrenia. Finally, as early as 1934, Benedict suggested that normality and abnormality are not universal. What is viewed as normal in one culture may be seen as quite aberrant in another. Thus, notions of normality and abnormality may not be quite as accurate as people believe they are. To raise questions regarding normality and abnormality is in no way to question the fact that some behaviors are deviant or odd. Murder and hallucinations are both deviant. Nor does raising such questions deny the existence of personal anguish that is often associated with mental illness. Anxiety and depression exist, along with psychological suffering.

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

The Theory Behind Theories

Many scientists have intellectual curiosity as their primary motivation. They seek knowledge in order to satisfy that curiosity, whether or not any practical benefits result from the effort. This is one reason why academicians are sometimes viewed as existing in a world that is remote from everyday experiences of the rest of society. In their never-ending quest to gain new knowledge, scientists sometimes study things that appear trivial to others. The first use of theory, then, is not a use at all in the practical sense of the word. Theory helps to satisfy intellectual curiosity. This is a trait often considered in the Western world as a major hallmark of our species. However, the money that supports scientists and scientific enterprises comes largely from government and industry. Moreover, in many sciences, including sociology, a substantial proportion of practitioners have practical motives which guide their work. For instance, many sociologists explicitly wish to understand their society better in order to change it in some manner. Theories help us to understand why things occur as they do. Thus, sooner or later most theories can have practical utility for someone.

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

Checks and Balances of Government Power

The struggle between liberty and authority is the most conspicuous feature of the history with which we are familiar, including Roman and Greek history. In old times this was between subjects and the government. By liberty was meant protection against the tyranny of political rules. The rulers were conceived, except in some of the popular governments of Greece, as in a necessary antagonistic position to the people whom they ruled. They consisted of a governing One, or a governing tribe or caste, who derived their authority from inheritance or conquest. Their power was regarded as necessary, but also as highly dangerous. The aim of patriots was to set limits on the power which the rule was allowed to exercise over the community. This limitation is what they meant by liberty. To protect this liberty, citizens obtained a recognition of certain immunities, called political liberties or rights, which the ruler could not infringe upon. Later, constitutional limits were placed on the power of the rule. If the ruler violated these conditions, rebellion was justified. In ancient Rome, rules were often ousted this way.

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

Measuring Emotions and Intellect

IQ and emotional intelligence are not opposing competencies, but rather separate ones. We all mix up intellect and emotional acuity. Individuals with high IQ but low emotional intelligence (or low IQ and high emotional intelligence) are, despite the stereotypes, rare. Indeed, there is a slight correlation between IQ and some aspects of emotional intelligence. Still, it is clear that they are largely separate entities. Unlike the familiar tests of IQ, there is, as yet, no single paper-and-pencil test that yields an emotional intelligence score. Although there is ample research on each of its components, constructs such as empathy are best tested by observing an individual's actual ability to listen. Another test is to measure how well someone can infer the feelings of others from their facial expressions. It has been shown that women do this better than men. They are more intuitive, one might say. Still, men can be trained to read the feelings of others. However, they are usually not socialized in childhood to do so.

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

APPENDIX E

SENTENCE VERIFICATION TECHNIQUE

PRACTICE TEST ITEMS

READ EACH SENTENCE BELOW AND INDICATE WHETHER OR NOT IT HAS THE SAME MEANING, EVEN IF EXPRESSED IN DIFFERENT WORDS, AS A SENTENCE YOU READ IN THE PASSAGE BY CIRCLING YES IF IT DOES OR NO IF IT DOES NOT.

The Communication of War

1	If there is no known enemy, the need for defending a belief or way of life is unnecessary.	YES NO
2	Individuals do not know that they are in a disagreement with someone unless this information is communicated to them.	YES NO
3	Wars begin through miscommunication as well.	YES NO
4	Specifically, relationships require a fair amount of verbal and nonverbal communication to relay information accurately.	YES NO
5	Communication is the common factor in the initiation and termination of wars.	YES NO
6	Individuals know that someone disagrees with them when they either hear it or see it.	YES NO
7	Wars end when two entities avoid agreement.	YES NO
8	These relationships can be portrayed as good or bad.	YES NO

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READ EACH SENTENCE BELOW AND INDICATE WHETHER OR NOT IT HAS THE SAME MEANING, EVEN IF EXPRESSED IN DIFFERENT WORDS, AS A SENTENCE YOU READ IN THE PASSAGE BY CIRCLING YES IF IT DOES OR NO IF IT DOES NOT.

The Insanity of Defining Sanity

1	The question of whether the sane can be distinguished from the insane is a simple matter.	YES NO
2	Multiple personality disorders are a rare type of mental illness.	YES NO
3	The question is neither capricious nor itself insane.	YES NO
4	It is rare, for example, to read about murder trials wherein eminent psychiatrists for the defense are supported by equally eminent psychiatrists for the prosecution on the matter of the defendant's sanity.	YES NO
5	It was suggested several decades ago by Benedict that sanity and insanity are not known all over the world.	YES NO
6	How can we know what the defining characteristics of normality and abnormality are?	YES NO
7	More generally, there are a great deal of conflicting data on the reliability, utility, and meaning of such terms as insanity, sanity, mental illness, and schizophrenia.	YES NO
8	However little we may personally doubt that we can tell the normal from the abnormal, the evidence is complexly compelling.	YES NO
9	To raise questions regarding normality and abnormality challenges the fact that some behaviors are normal.	YES NO
10	We can only hope that in the future there is a clearer distinction between the terms normal and abnormal mental health.	YES NO
11	Thus, notions of normality and abnormality may not be quite as accurate as people believe they are.	YES NO
12	Nor does raising such questions deny the existence of personal anguish that is often associated with mental illness.	YES NO
13	Abnormal conditions like anxiety and depression may accompany mental suffering.	YES NO
14	Psychiatrists are often questioned by their patients about their own personal view of the patients' sanity.	YES NO
15	Multiple personalities is deviant.	YES NO
16	What one culture believes to be normal another culture may consider to be a breach of sanity.	YES NO

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

READ EACH SENTENCE BELOW AND INDICATE WHETHER OR NOT IT HAS THE SAME MEANING, EVEN IF EXPRESSED IN DIFFERENT WORDS, AS A SENTENCE YOU READ IN THE PASSAGE BY CIRCLING YES IF IT DOES OR NO IF IT DOES NOT.

The Theory Behind Theories

1	Few scientists have intellectual curiosity as their secondary motivation.	YES NO
2	The most popular usage for theories isn't really considered a use at all, at least in the most real sense of the word.	YES NO
3	For example, an understanding of why children in schools do not read well, can help in identifying workable strategies for improvement.	YES NO
4	In their brief quest to gain knowledge, scientists seldom study things that appear trivial to others.	YES NO
5	Although there may be few to no real benefits to seeking knowledge, scientists do it anyway to try to fill their curiosity hunger.	YES NO
6	Theory helps to satisfy intellectual curiosity.	YES NO
7	This is one reason why academicians are sometimes viewed as existing in a world that is remote from everyday experiences of the rest of society.	YES NO
8	Americans are heirs to a long cultural tradition, which values knowledge and learning for its own sake.	YES NO
9	Furthermore, among the many sciences, even in sociology, a considerable number of professionals are guided by legitimate intentions.	YES NO
10	However, the money that supports scientists and scientific enterprises comes largely from government and industry.	YES NO
11	Psychologists are probably most well noted for their use of theories to guide their work.	YES NO
12	Thus, sooner or later most theories can have practical utility for someone.	YES NO
13	Theories can prevent us from understanding why things occur.	YES NO
14	In the case of sociologists, it is a desire to comprehend society at an advanced level so that beneficial changes can be made.	YES NO
15	Theories help to pull ideas together in an understandable fashion.	YES NO
16	This is a trait often considered in the European world as a minor hallmark in our species.	YES NO

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READ EACH SENTENCE BELOW AND INDICATE WHETHER OR NOT IT HAS THE SAME MEANING, EVEN IF EXPRESSED IN DIFFERENT WORDS, AS A SENTENCE YOU READ IN THE PASSAGE BY CIRCLING YES IF IT DOES OR NO IF IT DOES NOT.

Checks and Balances of Government Power

1	The rulers were conceived, except in some of the popular governments of Greece, as in a necessary friendly position to the people whom they ruled.	YES NO
2	They consisted of a governing One, or a governing tribe or caste, who derived their authority from inheritance or conquest.	YES NO
3	The struggle between liberty and authority is the most conspicuous feature of the history with which we are familiar, including Roman and Greek history.	YES NO
4	Most rulers of the time were respectful of the rights of their citizens.	YES NO
5	Power was seen as deriving from the people.	YES NO
6	Liberty used to mean protecting the people against the abuse of power of their rulers.	YES NO
7	In old times this was between the ruling class and the government.	YES NO
8	It was necessary to give power to the ruler, despite the obvious danger.	YES NO
9	Liberty came to mean limits on this power.	YES NO
10	Rulers these days are often regarded as servants of the people, not antagonists.	YES NO
11	In ancient Rome, rules were seldom ousted this way.	YES NO
12	To protect this liberty, citizens obtained a recognition of certain immunities, called political liberties or rights, which the rule could not infringe upon.	YES NO
13	The citizenry was justified in overthrowing a leader who violated their rights.	YES NO
14	Revolution during the early times often occurred violently, with much bloodshed.	YES NO
15	The aim of patriots was to support the use of power, which the ruler was allowed to exercise over the community.	YES NO
16	Later, constitutional limits were placed on the power of the rule.	YES NO

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READ EACH SENTENCE BELOW AND INDICATE WHETHER OR NOT IT HAS THE SAME MEANING, EVEN IF EXPRESSED IN DIFFERENT WORDS, AS A SENTENCE YOU READ IN THE PASSAGE BY CIRCLING YES IF IT DOES OR NO IF IT DOES NOT.

Measuring Emotions and Intellect

1	People with high IQ but low emotional intelligence (or low IQ and high emotional intelligence) are, despite the stereotypes rare.	YES NO
2	Emotional intelligence and IQ are not really antagonistic, but are distinct.	YES NO
3	However, it is evident that the two are distinguishable.	YES NO
4	We all distinguish between intellect and emotional acuity.	YES NO
5	Indeed, there is a slight correlation between IQ and some aspects of emotional intelligence.	YES NO
6	One's emotional intelligence has been shown to predict job performance as much as IQ.	YES NO
7	Emotional intelligence is a form of thinking not well reflected on most tests of intelligence.	YES NO
8	Like the familiar tests of IQ, there is a paper-and-pencil test of that yields an emotional intelligence score.	YES NO
9	It is hard to train men to read the feelings of others.	YES NO
10	Women are more intuitive, one might say.	YES NO
11	It has been shown that women are no better than men.	YES NO
12	Men, though, generally are not socialized from an early age to do so.	YES NO
13	Another way to assess empathy would be to determine his or her ability to interpret from a video the facial expressions of another.	YES NO
14	Although there is ample research on each of its components, things such as empathy are best tested by observing the individual's actual ability to listen.	YES NO
15	Men tend to view the world in quite different ways from how women do.	YES NO
16	A paper-and-pencil test of emotional intelligence would prove an asset to society.	YES NO

DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

APPENDIX F

HUMAN USE COMMITTEE APPROVAL

LOUISIANA TECH
UNIVERSITY

MEMORANDUM

OFFICE OF UNIVERSITY RESEARCH

TO:	Ms. Jennifer Thibodeaux and Dr. Walter Buboltz
FROM:	Barbara Talbot, University Research
SUBJECT:	HUMAN USE COMMITTEE REVIEW
DATE:	January 13, 2014

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

"Objectively Measuring the Effects of Sleep on Reading Comprehension and Sustained Selective Attention"

HUC 1159

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 10, 2014 and this project will need to receive a continuation review by the IRB if the project, including data analysis, continues beyond January 10, 2015.*** 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. Mary Livingston at 257-2292 or 257-5066.