The Relationships Between Working Memory, Anxiety, Sleep, and Study Habits in College Students

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Abstract

The purpose of this study was to examine the relationships between anxiety levels, sleep, study habits and working memory performance in college students. There is overlap in brain regions associated with each of these regions so there is reason to believe that they impact each other. Participants (N = 36) were recruited to wear an actigraph for two consecutive nights and to self-report sleep times and study habits. They then completed the Beck Anxiety Inventory (BAI), the Pittsburgh Sleep Quality Index (PSQI), a study habits questionnaire and two working memory tasks. Participants who exhibited higher anxiety levels unexpectedly scored higher on the working memory tasks, however anxiety levels were negatively correlated with sleep efficiency. Additionally, students with higher anxiety levels exhibited poorer study habits than those with lower anxiety levels as expected. Small sample size was the major limitation of this study. However, the results suggest that study skills may be linked to anxiety, and consequently may also be linked to working memory. Additional studies are suggested to further investigate the relationships between working memory, sleep, anxiety and study habits in college students.

Introduction

The purpose of this study is to examine the relationships between working memory, anxiety, sleep and study habits. These factors have yet to be studied together in a single comprehensive experiment, even though they all play an important role in the average college student's experiences. Ross, Niebling, & Heckert (1999) reported that 81.1% of student stressors occur on a daily basis. These stressors come from many different origins, including class work, financial difficulties, environmental problems, and any variety of personal issues (Ross, Niebling, & Heckert, 1999). In addition to high amounts of stress, 71% of college students are dissatisfied with the amount of sleep they receive, and 48% get fewer than seven hours of sleep a night (Tsai & Li, 2004). Changes in sleeping habits and lack of time management skills may result in added stress on students (Ross, Niebling, & Heckert, 1999; Misra, McKean, West, & Russo, 2000). Stress is closely related to anxiety, because anxiety, in part, is defined as an inappropriate response to a stressor (Bear, Connors, & Paradiso, 2007). Anxiety and sleep deprivation have both been linked to working memory performance (Darke, 1988; Dutke & Stober, 2001; Alhola & Polo-Kantola, 2007; & Van Dongen, Maislin, Mullington, & Dinges, 2007). The study of working memory performance and the factors that affect it in college students is important because students are frequently processing information, or using their working memory, in order to learn course material, successfully complete assignments, papers and exams, and apply learned material to situations outside of the classroom.

Very little research has been published regarding study habits and their relationship to working memory, but as discussed in depth below, an individual's approach to studying can be indirectly related to the function of their working memory because some approaches to studying utilize attention and a component of working memory more than others (Cermakova, Moneta, &

Spada, 2010). Additionally, an approach to studying which does not efficiently exercise working memory is linked to higher levels of anxiety (Cermakova, Moneta, & Spada, 2010). Theories such as these support the need for research regarding how study habits affect working memory performance.

Working Memory

Researchers have classified memory in several categories: long-term memory, short-term memory, and working memory. After decades of research there is still no cohesive definition of working memory (Shah & Miyake, 1999). However, several models propose an explanation of what working memory does and how it works. Among educators and researchers there is often confusion and contradiction in distinguishing between short-term memory and working memory. However, working memory is not simply the storage of information. It is also the processing of recent information to complete a task at hand (Shah & Miyake, 1999). The multiple-component model, proposed by Baddeley and Logie (1999) explains working memory processes through three main characters: the central executive, the phonological loop, and the visuo-spatial sketch pad. According to this model, the central executive is the center for attentional control. The phonologoical loop and the visuo-spatial sketchpad function as the central executive's two slave systems. The phonological loop temporarily stores verbal and acoustic information. The visuo-spatial sketchpad holds visual and spatial information. Additionally, the model has evolved to include an episodic buffer. This buffer integrates information from multiple components of memory, across space and time, hence the episodic nature of the buffer (Baddeley, 2000). According to the multiple-component theory, working memory allows humans to retain

information regarding their immediate surroundings and experiences in order to solve problems and acquire new knowledge (Shah & Miyake, 1999).

The multiple-component model is supported with biological evidence. Baddeley and Logie (1999) discuss several studies supporting Baddeley's original claims regarding working memory. These studies identify different regions of activation in the brain for each the phonological loop, visuospatial sketchpad, and the central executive. The left hemisphere, specifically the lower part of the parietal lobe where it junctions with the posterior temporal lobe, and the supra-marginal gyrus are involved in the phonological loop. This evidence comes from information regarding brain lesions, and positron emission tomography (PET) scans (Baddeley & Logie, 1999). The visuospatial sketchpad is most strongly correlated with the right hemisphere, but the specific region is unclear (Baddeley & Logie, 1999). The occipital lobe, the parietal lobe, the prefrontal cortex, and the premotor areas show activation during visual and spatial tasks (Baddeley & Logie, 1999). The prefrontal cortex is highly active during tasks that utilize the central executive (Baddeley & Logie, 1999). Additionally, the episodic buffer is thought to be closely linked with the central executive (Baddeley & Logie, 1999). However, there is evidence that the buffer is found in the right frontal lobe. This evidence comes from an fMRI study regarding integrated and unintegrated verbal and spatial information. The study showed increased activity in the right frontal lobe when verbal and spatial information were integrated (Baddeley, 2000).

Smith and Jonides (1997) completed a thorough study on brain activity and working memory. Their findings support the multiple-component theory, by highlighting the similarities and differences in brain activity during working memory tasks that focus on spatial, object, and verbal memory. Spatial memory tasks activated the right posterior parietal, and the right anterior

occipital cortex. This activation in the right hemisphere correlates with the activated brain areas in the visuospatial sketchpad as discussed by Baddeley and Logie (1999). PET scans during the verbal task showed activity in the left hemisphere, particularly the posterior parietal cortex, Broca's area and the premotor area (Smith & Jonides, 1997). The involvement of the left hemisphere, particularly the left parietal cortex, is also consistent with the discussion on the phonological loop (Baddeley & Logie, 1999). The findings of Smith and Jonides (1997) support the multiple-component model by illustrating that different brain regions function during working memory tasks that activate different portions of working memory. However, they also find that the areas may be interconnected, and not independent. When they made the tasks more difficult, additional regions of the brain were activated as more processing became necessary. This could suggest that there are alternate or enhanced neural networks when the processing tasks become complex. Notably, PET scans during the spatial task showed that the left hemisphere was also involved, and the prefrontal cortex was activated in both the verbal and spatial tasks (Smith & Jonides, 1997).

In summary, working memory does not lay claim to any one specific definition; it has been discussed in terms of being the storage of memory in conjunction with the processing of information. The multiple component model of working memory as described by Baddeley and Logie (1999) includes the central executive, its two slave systems, the phonological loop and the visuo-spatial sketchpad, and the integrative episodic buffer. This model has been supported through studies that link the phonological loop with specific areas of the left hemisphere, the visuo-spatial sketchpad with the right hemisphere, the central executive with the prefrontal cortex, and the episodic buffer with the frontal region (Baddeley & Logie, 1999; Smith & Jonides, 1997).

Working Memory Measurement

Several working memory tasks reflect similar constructs, and all show good reliability and validity (Unsworth, Heitz, Schrock, & Engle, 2005). These tasks include the reading span task, automated reading span task, operation span task, automated reading span task, counting span task, and spatial span task. All require the participant to remember an item in the presence of a distracting task. The distracting tasks include, respectively, reading sentences, solving math problems, counting circles in different colors, and identifying mirror images of letters (Unsworth, Heitz, Schrock, & Engle, 2005). Due to the amount of time it takes to administer working memory tasks, Unsworth, Heitz, Schrock, and Engle (2005) created automated versions of the operation and reading span tasks. These automated versions allow the task to be completed without the experimenter present. This is important because it can eliminate confounding variables such as anxiety caused by the presence of the experimenter. It is also important because it allows the experimenter to test more than one subject at a time, therefore increasing the number of participants a study can include.

The tasks listed above are termed working memory tasks, which differ from short term memory tasks. Short term memory tasks include the n-back task and digit span task which require recalling an item without an interfering task (Kane & Engle, 2003). Working memory tasks correlate with intelligence, while short term memory tasks do not, thus suggesting that working memory tasks make greater demands on attentional control from the central executive (Kane & Engle, 2003).

Anxiety and Working Memory

Darke (1988) showed that people with high anxiety levels do not perform as well on memory tasks when compared to those with less anxiety. Researchers theorized that the central executive does not function to its full capacity in highly anxious individuals because they stay focused, or worried, on irrelevant information (Darke, 1988). Worry takes away from the ability of the central executive to focus on the processing needed for the task at hand (Darke, 1988). Darke (1988) found that individuals with high anxiety levels did poorly on both digit span tasks and reading span tasks, but the degree of poor performance was greater on the reading span task than the digit span task. This is thought to be due to the fact that the digit span task primarily measures storage, while the reading span encompasses both storage and processing capacities. Other studies have obtained the same results by using a memory load task (Dutke & Stober, 2001). The findings presented suggest that anxiety does interfere with working memory capabilities.

A more recent study examines anxiety and working memory from a biological perspective (Zhao et al., 2007). Functional neuroimaging studies support the theory that anxiety negatively affects working memory. Zhao et al. (2007) found activity in the posterior cingulate cortex (PCC) was less active in highly anxious individuals. The PCC is located in the posterior parietal lobe, which as stated earlier is linked to working memory. One theory suggests the working memory processes are focused on threat-related words in highly anxious individuals (Zhao et al., 2007). However, with the results showing a decrease in PCC activity it can be argued that there is a also a decrease in working memory processing, or that focus on threatening stimuli rather than the task causes the decrease in working memory processes.

Anxiety Measurement

Anxiety and depression have similar symptoms, and as a result some self reporting anxiety measures closely correlate with depression (Fydrich, 1992). The Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988) was designed to differentiate between anxiety and depression, unlike the measures that existed before the BAI (Fydrich, 1992). Over an 11 day period the BAI's test-retest reliability, internal consistency and validity were all shown to be strong (Fydrich, 1992). Other indices for measuring anxiety exist, including the State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970), the Self-Rating Anxiety Scale (SRAS; Zung 1971). However, these indexes do not differentiate between symptoms of depression and symptoms of anxiety (Beck, Epstein, Brown & Steer, 1988).

Sleep Deprivation and Working Memory

According to the literature, sleep deprivation has adverse effects on working memory (Alhola & Polo-Kantola, 2007). Sleep deprivation causes a decrease in the activity of the frontal regions of the brain, which are also regions involved in working memory, specifically the central executive and episodic buffer (Baddeley, 2000). While literature does support this claim, it differs in regards to how working memory is affected. Some studies show that working memory speed is negatively affected; others show that performance is negatively affected by total or partial sleep deprivation (Alhola & Polo-Kantola, 2007). In either instance, working memory performance is negatively impacted by sleep deprivation.

This notion of total or partial sleep deprivation is important to consider. While total sleep deprivation does happen, partial sleep deprivation is more common in college students, as well as members of the workforce, parents of young children, etc. Van Dongen et al (2007) showed that

impairment on working memory was the same for short term total sleep deprivation and chronic partial sleep deprivation groups. Since college students have a mixture of total sleep deprivation, chronic partial sleep deprivation, and healthy sleep it is of importance to study how their working memory is affected with such fluctuating sleep habits. One study reported that 73% of its participants suffered from some sort of sleep deprivation (Buboltz, Brown, & Soper, 2001). Tsai and Li (2004) reported that 71% of college students are dissatisfied with their sleep, and 48% slept fewer than 7 hours a night. Additionally, more than 60% of college students in another study were labeled as poor quality sleepers by the Pittsburgh Sleep Quality Index (PSQI) (Lund, Reider, Whiting, & Prichard, 2010).

Sleep Deprivation and Anxiety

Sleep deprivation has also been linked to increased levels of anxiety. Sagaspe et al. (2006) found that total sleep deprivation increased self reported anxiety. McEwen (2006) found constant stress in animal models caused remodeling of specific brain structures, specifically the prefrontal cortex which is involved in memory and anxiety. The neurons of the prefrontal cortex exhibit atrophy due to chronic stress (McEwen, 2006). Lund, Reider, Whiting, and Prichard (2010) found that self reported stress accounted for the largest variance in sleep quality score.

Sleep Measurement

Polysomnography (PSG) is a diagnostic tool that measures sleep onset, sleep duration, sleep state parameters, electroencephalography (EEG), electrooculography (EOG), electromyography (EMG), electrocardiography (ECG), respiratory effort, airflow and gas exchange (Hoban & Chervin, 2001; Weaver, Kapur, Yueh, 2004). The subject is typically

connected to several leads in a laboratory setting. While PSG is very useful as a diagnostic tool it is impractical for this study. PSG is expensive and considered more invasive than actigraphy, an alternative sleep measurement tool (Siversten et al., 2006). PSG has long been considered the gold standard of sleep measurement, however it has limitations. It is difficult to do long term sleep studies with PSG as it disrupts participant's schedules and is not completely objective as the participant may be affected by the laboratory setting (Souza et al., 2003).

According to the Academy of Sleep Medicine, actigraphy is a useful tool in diagnosing sleep disorders (Kushida et al., 2001). An actigraph measures sleep, wakefulness, sleep latency, and sleep efficiency based on an algorithm and the activity of a monitor worn either on the wrist or the ankle. Unlike PSG, measurement by means of an actigraph does not require the participant to sleep in a laboratory. Rather he or she simply wears a watch-like device for a given period of time. This is less expensive and less invasive than PSG. Studies have been done to compare actigraphy and PSG and it has been found that they have an agreement rate between 78-95% in terms of distinguishing sleep from wakefulness (Kushida et al., 2001; Souza et al., 2003).

The PSQI is a questionnaire designed to measure sleep quality, sleep latency, and the depth of sleep (Buysse, Reynolds, Monk, Berman, & Kupfer, 1988). An eighteen month field study was completed to test the usefulness and validity of the index. The items on the index were selected based on the findings of the field study, a review of previous sleep questionnaires, and clinical experience with sleep disorders (Buysse, et al., 1988). Nineteen items on the questionnaire are grouped into seven components: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction. The field testing found the PSQI is simple and understandable to subjects, and the

index scores in the field study had a reliability coefficient of 0.83, meaning that the test is reliable and has internal consistency (Buysse, et al., 1988). The scores also could differentiate between the patients and the controls, which supports the validity of the PSQI (Buysse, et al., 1988). Higher scores equate to lower sleep quality, and any score greater than five are qualified as poor sleepers (Buysse et al., 1988).

Study Habits

Little research has been completed regarding productive and unproductive study habits and their relationship to working memory. However, Cermakova, Moneta, and Spada (2010) published a useful article about approaches to studying. Their explanation can be linked to the multiple component model of working memory. The authors proposed three approaches to studying, deep, strategic, and surface. A deep approach to studying requires the studier to have undivided and focused attention on the task at hand. The individual is processing the information with the intent to understand and find meaning in the material. A strategic approach is very similar to the deep approach. The difference is the studier is motivated by wanting to achieve the highest grade possible. In a surface approach to studying the individual has no intent to learn and understand the material; rather they simply want to memorize the material to do well on the examination. This approach uses much less processing. Additionally, when the deep approach is used information is retained, while in a surface approach the information is easily forgotten.

This focus on attention can be directly related to the central executive, as the central executive's role in the multiple component model is to focus the attention of the two slave systems on the task at hand. An individual's control over their attention has a positive

correlation with a deep or strategic approach to studying (Cermakova, Moneta, & Spada, 2010). In terms of the multiple component model, an individual studies more effectively if they have an efficient central executive.

Anxiety is a meaningful indicator of a surface approach to studying (Cermakova, Moneta, & Spada, 2010). As previously discussed, working memory is adversely affected by anxiety (Zhao et al., 2007). Therefore, when an individual is anxious their central executive will not process properly. As a result attention will be unfocused, and deep approaches will be impossible to achieve. The individual will engage in minimal processing, and therefore working memory will not be exercised.

Hypotheses

(1) College students who exhibit high levels of anxiety will perform worse on the working memory task than those who do not exhibit high levels of anxiety (Darke, 1988; Dutke & Stober, 2001; Zhao et al., 2007). (2) Students whose sleeping habits include total and/or partial sleep deprivation will have lower working memory performance than those who are not deprived of sleep in any way (Alhola & Polo-Kantola, 2007). (3) The greater the sleep deprivation the worse subjects will perform on the working memory task (Van Dongen et al., 2007). (4) Individuals who score high on the anxiety scale will also exhibit poorer study habits as indicated by the questionnaire (Cermakova, Moneta, & Spada, 2010). (5) Individuals who exhibit better study habits will also score higher on the working memory task than those that do not study well (Cermakova, Moneta, & Spada, 2010; Zhao et al., 2007).

Methods

Participants

Thirty six participants were recruited from a small liberal arts college in northwestern Pennsylvania. The study was approved by the College Ethics Committee. Bonus points for participation were rewarded per professor's discretion. Participant demographics can be found in Table 1.

Measures

Sleep was measured through the use of an actigraph (Actigraph, Pensacola, Florida), as well as self report through use of a sleep journal and the Pittsburgh Sleep Quality Index (PSQI; Buysse, et al., 1988). Participants self-reported their sleep time and study habits by recording in a sleep/study journal (Appendix A). Subjects also completed a questionnaire regarding study habits (Appendix B) and anxiety was measured by the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988).

Actigraphy

For over 20 years actigraphy has been an accepted, useful, and cost effective way of collecting information on individual sleep patterns (Ancoli-Israel et. al., 2003; Kushida et al., 2001; Souza et al., 2003) Based on the time the participant lays down in and gets out of bed, the actigraph will estimate time of sleep onset, latency to sleep onset, final awake time, sleep duration, number and duration of awakenings, sleep efficiency or time asleep divided by time in bed expressed as a percentage, and average awake time (Actigraph, Pensacola, Florida). The actigraph is able to do this through the use of the Sadeh algorithm (Actigraph, Pensacola,

Florida). An eleven minute time period is applied to the algorithm, and it is determined whether or not the subject was asleep based on self-report time in bed and time out of bed by the participant (Actigraph, Pensacola, Florida).

Participants wore a GT3X Actigraph (Actigraph, Pensacola, Florida). The device was worn on the participant's wrist for two consecutive weeknights. The participant picked up the actigraph on either Monday or Wednesday, and returned it on Wednesday or Friday, respectively. Members of the swimming and diving team were not eligible for participation. These individuals would have to frequently take off their actigraphs, which would disrupt the algorithm and therefore lead to inaccurate measurements by the actigraphs. All participants were instructed to only remove the actigraph when they shower or swim. Additionally, participants were instructed to record the time they lay down in bed, the time they woke up, and how many nighttime awakenings they remember.

Pittsburgh Sleep Quality Index (PSQI)

Nineteen items on the questionnaire are grouped into seven components: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction. The component scores are weighted and used to generate an overall score which can range from 0 to 21. Higher scores equate to lower sleep quality, and any score greater than five are qualified as poor sleepers (Buysse, et al., 1988).

Beck Anxiety Inventory (BAI)

There are 21 items on the BAI. Each item is given a score of zero to three, zero meaning "not bothered at all" and three meaning "severely bothered" (Maruish, 2004). Scores can range

from 0-63. Scores of 0-7 indicate minimal anxiety, 8-15 indicate mild anxiety, and 16-63 indicate moderate-severe anxiety to severe anxiety (Beck & Steer, 1993).

Working Memory Tasks

Working memory performance was measured by using two tasks, the automated operation span task (Aospan) and the automated reading span task (Rspn) (Unsworth, Heitz, Schrock, & Engle, 2005). The Aospan is a completely mouse driven task that does not require the experimenter to be in the same room. It starts with a practice session which includes three sections. The first section is letter span practice. A letter shows on the screen for 800 msec. After all of the letters show a 4 x 3 letter matrix appears. Only the letters F, H, J, K, L N, P, Q, R, S, T and Y are used due to research suggesting that results in span tasks and reading comprehension tasks are due to knowledge of common words and the letters that comprise them (Unsworth, Heitz, Schrock, & Engle, 2005). The participant clicks on the letters in the order that they appeared.

Math operations are the second section of the practice session. A math operation, such as (1*2) +1 = ? appears on the screen. The participant is instructed to solve the problem as quickly as they can and to click on the screen once they have finished. A number appears on the screen and the participant is to click true if the number is the correct answer, and false if it is the incorrect answer. The program will calculate the participants' average time to solve the 15 math problems.

The third section of the practice session is the math operations paired with the letter span task. The participant is to solve a math problem as before, and after they answer true or false a letter appears. If the participant takes longer than their average time plus 2.5SD to answer the

math problem the screen automatically moves onto the letter, and the trial will be counted as an error. After the set is done the matrix letters appears and the participant answer just as in the first section.

In the real test there are sets of problems ranging from three to seven. There are three sets of each set size, which total 75 letters and 75 math problems. The order of the set sizes are random for each participant. Additionally, to make sure participants are trying to solve the math problems an 85% accuracy rate is encouraged, and the accuracy rate is shown during letter recall. The Aospan yields five scores. The Ospan score - the sum of all perfectly answered sets, the total number correct - the total number of letters recalled in the correct order, math errors - total number of task errors, speed errors - the total number of times the participant ran over time to solve a math problem, and accuracy errors - the total number of math problems solved incorrectly.

The Rspn task is very similar to the Aospan, but in place of math problems the Rpsn includes sentences. Each sentence either makes sense or is nonsense. The participant clicks on the screen after they have read the sentence, just as after they solved the math problem. The next screen will say, "This sentence makes sense." The participant then either clicks on "True" or "False". Just as in the Aospan task the program calculates the average time it takes the participant to read the sentences in the practice section. Then, in the real test if the participant does not click on the screen within 2.5SD of their average time the screen moves directly onto the letter and the trial will be recorded as an error. There are 75 sentences and 75 letters, and set sizes vary between three and seven sentences. Five scores are reported at the end of the task; Rspan score, total number correct, total number of errors, accuracy errors, and speed errors. The Rspan score is the number of perfect trials, the total number correct is the total number of letters

recalled in the correct order, the total number of errors is the total number of task errors, the accuracy error is the number of sentences the subject verified incorrectly, and the speed error is the number of sentences the participant did not respond to within 2.5SD of their average time.

Results

Forty participants were recruited from psychology courses at a small liberal arts college. Four participants did not properly complete the questionnaires and/or actigraphy and were therefore removed from data analyses. BAI scores were sorted into three groups. Scores of 0-7 points equate to minimal anxiety, 8-15 reflect mild anxiety, 16-63 indicate moderate-severe anxiety (Beck & Steer, 1993). Demographics of the remaining 36 participants are shown in Table 1 and descriptives if sleep and anxiety findings are shown in Table 2.

Table 1

Participant Demographics

	Frequency	Percent
Male	6	16.7
Female	30	83.3
First Year	14	38.9
Second Year	11	30.6
Third Year	4	11.1
Fourth Year	7	19.4

Table 2

Sleep and Anxiety Descriptives

	Percent
Poor sleep efficiency*	61.1
Sleep deprived**	63.9
Minimal anxiety	50.0
Mild anxiety	27.8
Moderate-severe anxiety	22.2

*Less than 85% sleep efficiency (Buysse et al., 1988)

**Less than 7 hours of sleep per night (Durmer & Dinges, 2005; Weinger & Ancoli-Israel, 2002).

Two-tailed bivariate Pearson correlations were run between the BAI scores, PSQI scores, working memory scores of both the Aospan task and the Rspn task, an average of the two, all twelve study skills questions, and sleep efficiency as calculated by the actigraph on the first night, second night, and an average of both nights. All significant correlations are reported in Ta

Table 3

Pearson Correlations

Measure	1	2	3	4	5	6	7
1. BAI	—	0.471**	-0.051	-0.395*	-0.564**	-0.452**	0.384*
2. PSQI		—	-0.041	-0.252	-0.069	0.074	0.050
3. Working Memory Average			—	-0.365*	0.280	0.042	-0.068
4. Sleep Efficiency Night Two				—	0.155	0.122	-0.338*
5. Study Question 3					—	0.365*	-0.503**
6. Study Question 5						—	-0.547**
7. Study Question 11							—

Note. BAI = total score on the Beck Anxiety Inventory; PSQI = global score on the Pittsburgh Sleep Quality Index; Working Memory Average = the average of the participant's Aospan and Rspan scores; Sleep Efficiency Night Two = sleep efficiency for night two as calculated by the actigraph; Study Questions 3, 5, 11 = questions 3, 5, and 11 from the study habits questionnaire.

*significant at $p<0.05$, **significant at $p<0.01$

Four one-way between subjects ANOVAs were conducted to compare the effects of anxiety as indicated by the BAI on PSQI scores, sleep efficiency on night two, and questions three and five on the study habits questionnaire.

Anxiety level had a significant effect on sleep quality, $F(2,33) = 4.152$, $p = .025$. Tukey post hoc comparisons indicated that the mean score for the minimal anxiety condition ($M = 5.50$, $SD = 3.22$) was significantly different than the moderate-severe anxiety condition ($M = 9.38$, $SD = 3.99$). However, the mild anxiety condition ($M = 7.10$, $SD = 2.28$) did not differ significantly from either the minimal or moderate-severe conditions.

There was a significant effect of anxiety level on sleep efficiency, $F(2.33) = 3.75$, $p = .034$. Tukey post hoc comparisons indicated that the mean score for mild anxiety ($M = 85.29$, $SD = 6.65$) was significantly different than the moderate-severe anxiety condition ($M = 75.10$, $SD = 8.86$). However, the minimal anxiety condition ($M = 83.07$, $SD = 8.18$) did not differ significantly from either the mild or moderate-severe conditions.

Question three on the study habits questionnaire was significantly impacted by anxiety level, $F(2,33) = 6.03$, $p = .006$. Tukey post hoc comparisons indicated that the mean score for minimal anxiety ($M = 3.89$, $SD = 0.58$) was significantly different than the mild anxiety condition ($M = 3.20$, $SD = 0.32$). There was also a significant difference in the mean for the minimal anxiety level and the moderate-severe anxiety level ($M = 3.00$, $SD = 0.93$).

Finally, anxiety level had a significant effect on responses to question five level, $F(2,33) = 3.29$, $p = .05$. Tukey post hoc comparisons indicated that the mean score for minimal anxiety ($M = 3.78$, $SD = 0.81$) was significantly different than the moderate-severe condition ($M = 2.88$, $SD = 0.84$). However, the mild anxiety condition ($M = 3.30$, $SD = 0.95$) did not differ significantly from either the minimal or moderate-severe conditions.

Discussion

The purpose of this study was to examine the relationships between working memory, anxiety levels, sleep quality and study skills in college students. Results supported the hypothesis that individuals who score high on the anxiety scale will also exhibit poorer study habits as indicated by the questionnaire. However, results did not support the remaining four hypotheses.

Anxiety and Working Memory

The first hypothesis predicted that college students who exhibit high levels of anxiety would perform worse on the working memory tasks than those who do not exhibit high levels of anxiety. This hypothesis was not statistically supported by the results. The lack of support for this claim is most likely due to small sample size, as anxiety's negative impact on cognitive functions, including working memory have been found repeatedly (Darke, 1988; Miller & Bichsel, 2004; Zhao et al., 2007).

However, it is possible that there were no significant findings because this study did not account for different types of anxiety. Those who experience trait anxiety tend to feel anxious in many different scenarios, while those who exhibit state anxiety feel anxious during very specific situations (Miller & Bichsel, 2004). Both state and trait anxieties affect task performance (Miller & Bichsel, 2004). In terms of working memory performance, it has been shown that participants with high trait anxiety performed poorly on working memory tasks when they placed under high state anxiety conditions (Miller & Bichsel, 2004). Interestingly, those who had low state anxiety and were placed in a low state anxiety condition also exhibited low working memory performance and those who were placed in intermediate conditions performed the best (Miller &

Bichsel, 2004). These findings suggest a nonlinear relationship between anxiety and working memory performance, which the hypothesis in this study did not account for.

Additionally, some studies that support the broad claim that anxiety negatively impacts cognitive performances, including working memory, contradict each other in terms of whether anxiety negatively impacts the verbal or visuo-spatial component of working memory (Miller & Bichsel, 2004). Miller and Bichsel (2004) assert that most research has found that anxiety negatively affects the phonological loop. However, it was found that the system impacted by anxiety depends on the type of anxiety (Miller and Bichsel, 2004). The working memory tasks used in this study were not verbal tasks, which would utilize the phonological loop, and this study did not account for different types of anxiety. These are both limitations of the study and possible explanations as to why no significant results were found between anxiety and working memory performance.

Sleep and Working Memory

The second and third hypotheses predicted that students exhibiting sleep deprivation would have lower scores on the working memory tasks than those who did not exhibit sleep deprivation. These expectations were not supported as time spent asleep did not correlate with scores on the working memory tasks. However, it was found that as sleep efficiency on night two of the study increased, working memory performance decreased and vice versa. This result was not expected and is not supported by other research, which has repeatedly found that sleep deprivation has adverse effects on cognitive abilities including working memory (Alhola & Polo-Kantola, 2007; Durmer & Dinges, 2005; Pilcher & Walters, 1997). Neurophysiological and functional imaging studies theorize working memory utilizes a network which includes the

prefrontal cortex, anterior cingulate, and basal ganglia and in conjunction with this sleep deprivation appears to affect performance of tasks which involve the prefrontal cortex (Durmer & Dinges, 2005). This evidence suggesting that sleep deprivation interrupts the neural network utilized by working memory brings the lack of support in this study into questioning.

There are a few explanations as to why this study found sleep efficiency negatively correlated with scores on the working memory tasks. The first is simply that the sample size was too small and therefore the significant result is not valid. However, it is also possible that there was intersubject and/or intrasubject variability (Durmer & Dinges, 2005). In this study intersubject variability may have occurred if a sleep deprived participant's worst performance on the working memory tasks is better than the best performance of another non-sleep deprived participant. Intrasubject variability may have occurred if a participant was sleep deprived, but as they completed the task they continued to improve because they were learning.

Additionally, there is a possible physiological explanation for why sleep deprivation did not adversely affect working memory performance. Functional neuroimaging studies showed that after 35 hours of total sleep deprivation verbal working memory tasks resulted in increased parietal lobe activation, while temporal lobe activation, which is usually associated with verbal working memory tasks, was decreased (Durmer & Dinges, 2005). This finding suggests that the brain has a compensatory response to sleep deprivation and that an alternate neural network can be used for working memory. This is a very intriguing argument which should be further researched. However, it is unlikely the cause of unexpected results in this study as no participants experienced total sleep deprivation.

No participants experienced total sleep deprivation, but more than 60% experienced partial sleep deprivation, which was defined as less than seven hours of sleep in one night

(Durmer & Dinges, 2005; Weinger & Ancoli-Israel, 2002). Previous studies have found that four or more days of sleep deprivation result in compromised neurobehavioral functions (Durmer & Dinges, 2005). A limitation of this study is that it measured only two nights of sleep, so it is possible that participant's who experienced sleep deprivation were not necessarily subject to chronic sleep deprivation and therefore the lack of sleep was not yet severe enough to impact on their cognitive abilities, including working memory.

Study Habits, Anxiety, and Working Memory

It was found, as expected, that individuals who exhibit high anxiety levels exhibit worse study skills. Participants with higher anxiety did not classify themselves as self-motivated and they did not begin to study two or more days before an exam, and tended to "cram" more for exams and to complete assignments on time. There exists little research of study habits, but these findings support the theory regarding surface and deep approaches to studying which was discussed in the introduction (Cermakova, Moneta, & Spada, 2010). It was not found that study habits correlated with working memory, but the correlation between anxiety and study habits is promising, in particular because it has been found that anxiety typically has adverse effects on working memory performance (Miller & Bichsel, 2005; Zhao et al., 2007).

Sleep and Anxiety

The results suggest that those who experience less anxiety have better sleep quality and efficiency than those who experience moderate-severe anxiety. Although not hypothesized, this particular result was not unexpected. As stated in the introduction Sagaspe et al. (2006) found that sleep deprivation increased self-reported anxiety. This study supported the findings of

Sagaspe et al. (2006) by finding that those with low anxiety had higher self-reported sleep quality as well as higher sleep efficiency as calculated by actigraphy.

Furthermore, sleep deprivation has appeared to affect performance of tasks which involve the prefrontal cortex (Durmer & Dinges, 2005; Yoo, Gujar, Hu, Jolesz & Walker, 2007), and as previously stated, the prefrontal cortex is also involved in anxiety (Engel, Bandelow, & Gruber, 2009; McEwen, 2006). Therefore, it makes sense that individuals with higher anxiety levels exhibited poorer sleep quality. Gregory et al. (2005) found that sleep problems during childhood is a strong predictor of anxiety in adulthood. The authors of the study give three reasons for this finding: that sleep difficulties and anxiety have the same underlying risk factors, that childhood sleep problems cause adulthood anxiety, and thirdly, sleep problems are a prodrome of anxiety. Gregory et al. (2005) does not go into a neurobiological explanation of the findings, but McEwen (2006) found that chronic stress is associated with atrophy of neurons in the prefrontal cortex. The findings of Gregory et al. (2005) in conjunction with those of McEwen (2006) support the claim that sleep deprivation and anxiety are related, however they suggest the opposite causal relationship. While it is usually stated that sleep deprivation results in higher levels of anxiety (Durmer & Dinges, 2005; Yoo, Gujar, Hu, Jolesz & Walker, 2007), this proposes the idea that sleep problems cause the atrophy of prefrontal neurons which leads to anxiety.

Future Research

Future studies, which take into consideration the limitations of this study, should be designed to further and refute the findings. A study which takes into account state and trait anxiety when looking at working memory would be useful (Miller & Bichsel, 2004). The majority of sleep deprivation studies focus on total sleep deprivation, even though partial sleep

deprivation is much more common (Durmesr & Dinges, 2005). This being said, a longitudinal study or a study which spans at least four nights of partial sleep deprivation is also warranted (Durmer & Dinges, 2005) to examine more closely the relationship between sleep deprivation, anxiety, working memory, and study skills. Neuroimaging studies which further the literature on anxiety causing atrophy to neurons in the prefrontal cortex will also be useful in looking at causal relationships between anxiety and other factors which involve the prefrontal cortex (McEwen, 2006).

It is also suggested that further research be conducted regarding study skills, anxiety and working memory. With the amount research in support of the relationship between anxiety and working memory (Darke, 1988; Miller & Bichsel, 2004; Zhao et al., 2007), and the current experiment's findings that anxiety is correlated with study skills it is evident that more studies should examine the relationship between working memory and study skills. A standardized test to measure study skills and study habits would be very useful in this research. Additionally, neuroimaging of students when presented with study material would be helpful in advancing theories of study habits and their relationship with working memory and anxiety.

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Appendix A

Allegheny College



Sleep and Study Journal

Instructions

- Record the time you lay down in bed and the time you wake up each day that you wear the Actigraph.
- If you remember anytime you wake up at night, please record this as well.
- Also indicate if you slept alone or with a partner.
- **Please remove the Actigraph before you shower or swim!**

IMPORTANT

If the Actigraph is lost please notify me or Dr. Conklin IMMEDIATELY. Please do your best to take care of the Actigraph. It is an expensive and valuable device.

Thank you for participating in my Senior Comprehensive Project!

Contact Information

If you have any questions or concerns regarding your participation in this experiment, please feel free to contact either me or my advisor, Sarah Conklin.

Katherine Bowser
bowserk@allegheny.edu
724-216-3834

Sarah Conklin
sconklin@allegheny.edu
814-332-2392
009 Carnegie Hall

Day 1
(first night wearing the Actigraph)

Any daytime sleep? Yes No

If yes, how many? _____

Duration? _____

How many hours did you study? _____

Between what hours did you study? _____

Time in bed: _____

Time you woke up: _____

Any night time awakenings? Yes No

If yes, how many? _____

Duration? _____

Did you sleep alone? Yes No

Day 2
(second night wearing the Actigraph)

Any daytime sleep? Yes No

If yes, how many? _____

Duration? _____

How many hours did you study? _____

Between what hours did you study? _____

Time in bed: _____

Time you woke up: _____

Any night time awakenings? Yes No

If yes, how many? _____

Duration? _____

Did you sleep alone? Yes No

Day 3
(day you turn in the Actigraph)

Any daytime sleep? Yes No

If yes, how many? _____

Duration? _____

How many hours did you study? _____

Between what hours did you study? _____

Thank you for participating in my
Senior Comprehensive Project!

Please bring this journal and the Actigraph with you when you return for your test session.
If you feel uncomfortable at any point in the experiment feel free to discontinue your participation without penalty.

If after completing all of the tasks you feel comfortable with any of the information the Allegheny College Counseling Center is available should you need to talk to someone. The Counseling Center is in Reiss Hall, and can be reached at 814-332-4368.

Appendix B

Demographics and Study Habits Questionnaire

Demographic Information

Sex: Male Female

Class year: First-year Second-year Third-year Fourth-year Fifth-year

GPA: _____ **First-years only:** High School GPA: _____

Have you ever been on academic probation? No Yes

Please answer each of the following questions. Answers should pertain to your typical study habits of the current semester.

1. I am done with homework and studying by approximately 10:00 p.m. every day.

Always Most Often Sometimes Rarely Never

2. I keep a schedule of due dates and/or a to-do list.

Always Most Often Sometimes Rarely Never

3. I start my assignments/studying for an exam two or more days in advance of due date or exam date.

Always Most Often Sometimes Rarely Never

4. I use study tools, such as flashcards, study guides, graphics, etc...

Always Most Often Sometimes Rarely Never

5. I set deadlines for myself to complete work, and I meet those deadlines.

Always Most Often Sometimes Rarely Never

6. I take thorough notes in class.

Always Most Often Sometimes Rarely Never

7. I complete all reading assignments before class.

Always Most Often Sometimes Rarely Never

8. I attend every class, unless I am very ill.

Always Most Often Sometimes Rarely Never

9. I work in a quiet atmosphere (i.e., first or third floor of the library, alone in my room, or alone in an academic building, etc).

Always Most Often Sometimes Rarely Never

10. I work in a noisy atmosphere (i.e., main floor of the library, McKinley's, in front of the TV, etc).

Always Most Often Sometimes Rarely Never

11. I tend to "cram" to get my work/studying done.

Always Most Often Sometimes Rarely Never

12. I day dream or fall asleep in my classes.

Always Most Often Sometimes Rarely Never

Appendix C

RESEARCH PARTICIPANT CONSENT FORM

Working Memory, Anxiety, Sleep, and Study Habits in College Students

Katherine Bowser
Allegheny College
Department of Neuroscience

Purpose of Research:

The purpose of this research study is to increase the scientific understanding of a student's working memory performance, anxiety levels, sleep patterns and study habits.

Specific Procedures:

I understand that I will be asked to wear an Actigraph for approximately 48 hours, and to concurrently keep track of my sleep in a sleep journal that will be provided to me. I understand that I will return the Actigraph during my second appointment with the researcher. **I understand that if I loose or misplace the Actigraph that I will contact Katherine Bowser or Professor Conklin immediately and try to locate the Actigraph.** I understand that I will be asked to complete a questionnaire regarding demographic information and my typical study habits. I understand that I will also complete questionnaires about my sleep patterns and my anxiety levels. I understand that I will complete two working memory tasks, one of which involves simple mathematical computations. I understand that my first appointment will take about 5 minutes. I understand that my second appointment will take place about 48 hours after the first appointment, and will take about 45 minutes.

Risks to the Individual:

I understand that the risks of participating in this study are no more than I would experience in everyday life.

Benefits to the Individual or Others:

I understand that the primary potential benefit of this research study will be obtained by other researchers studying working memory, sleep, anxiety, and study habits and the benefit to me is minimal.

Confidentiality:

I understand that the data I provide today are completely confidential and that my name never will be associated with the data I provide. I understand that the researcher is not interested in any single person's data and will combine the data I provide with all other participants' data to look for general patterns. Any reports made based on this study's data will focus only on general patterns.

I understand that my data and consent form will be stored separately under lock and key in the Department of Psychology at Allegheny College. I understand that the data I provide today will be destroyed when they are no longer needed.

Voluntary Nature of Participation:

I understand that I am at NO time required to participate in this study. I understand that if I

agree to participate, I may withdraw my participation at any time with no penalty. I understand that I may skip any and all parts of today's procedures that I wish and that I may skip any questions that I wish not to answer.

Contact Information:
For any questions or concerns about this research project, please call **Katherine Bowser** at **724-216-3834** or email her at **bowserk@allegheny.edu**. You also may contact **Dr. Sarah Conklin** at **814-332-2392** or email her at **sconklin@allegheny.edu**. For any questions or concerns about the treatment of research participants, including yourself, please call **Dr. James Lombardi**, Chair of the Allegheny College Institutional Review Board (IRB) at **(814) 332-2975** or email him at **jalombar@allegheny.edu.**

Participant's Signature_____ Date_____

Researcher's Signature_____ Date_____

Appendix D

RESEARCH PARTICIPANT DEBRIEFING FORM

Working Memory, Anxiety, Sleep, and Study Habits in College Students

Katherine Bowser
Allegheny College
Department of Neuroscience

Thank you very much for your participation in this study!
Your participation is greatly appreciated!

Purpose of Research:

The purpose of this research study is to increase the scientific understanding of the interaction between student's working memory performance, anxiety levels, sleep patterns and study habits. The hypotheses were that those who had high anxiety levels would have lower performance on the working memory tasks; those who exhibited total and/or partial sleep deprivation would have lower performance on the working memory tasks, and the greater the sleep deprivation the worse participants will perform on the working memory task, and those who had poor study habits would have lower performance on the working memory tasks. Additionally, it was hypothesized that individuals who score high on the anxiety scale will exhibit poorer study habits as indicated by the questionnaire.

Confidentiality:

The data provided by all participants are completely confidential and participants' names never will be associated with the data they provide. The data and consent form are stored separately and under lock and key in the Department of Psychology at Allegheny College. The entries in the drawing never will be connected with any data or consent forms. The data will be destroyed when they are no longer needed.

Additional Sources of Information:

Baddeley, A.D. & Logie, R.H. (1999). The Multiple Compenent Model. In Miyake, A. & Shah, P. (Eds.) *Models of Working Memory* (pp. 28-61). Cambridge: Cambridge University Press.

Contact Information:

Please feel free to contact any of the following people.

- For any questions or concerns about this research project, please call **Katherine Bowser** at **724-216-3834** or email her at **bowserk@allegheny.edu**. You also may call **Dr. Sarah Conklin** at **814-332-2392** or email her at sconklin@allegheny.edu.
- For any psychological concerns, please visit or call the Allegheny College Counseling Center at **814-332-4368.**
- For any questions or concerns about the treatment of research participants, including yourself, please call **Dr. James Lombardi**, Chair of the Allegheny College Institutional Review Board (IRB), at **(814) 332-2975** or email him at **jalombar@allegheny.edu.**
- For any health concerns, please visit or call the Allegheny College Health Center (Winslow Health Center) at **814-332-4355** or visit your personal physician.

THANK YOU AGAIN FOR YOUR PARTICIPATION.