Actual and Self-Assessed Performance on a Logical Reasoning Task after a Night of Total or Partial Sleep Deprivation

Melissa Vander wood
Clemson University, mvanderwood@gmail.com

Follow this and additional works at: https://tigerprints.clemson.edu/all_theses
Part of the Psychology Commons

Recommended Citation
https://tigerprints.clemson.edu/all_theses/318

This Thesis is brought to you for free and open access by the Theses at TigerPrints. It has been accepted for inclusion in All Theses by an authorized administrator of TigerPrints. For more information, please contact kokeefe@clemson.edu.
ACTUAL AND SELF-ASSESSED PERFORMANCE ON A LOGICAL REASONING TASK AFTER A NIGHT OF TOTAL OR PARTIAL SLEEP DEPRIVATION

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Applied Psychology

by
Melissa Ann Vander Wood
May 2008

Accepted by:
Dr. June J. Pilcher, Committee Chair
Dr. Fred S. Switzer, III
Dr. Richard Pak
ABSTRACT

The effect of sleep deprivation on cognitive task performance is becoming more important in today’s society. Because of this, how total and partial sleep deprivation affect performance in the workplace needs to be better understood to increase awareness of how employees are able to perform. In addition, employers need to know if employees are able to accurately judge how sleep deprivation is affecting their own performance. The purpose of the current study was to compare the effects of total and partial sleep deprivation on actual and self-assessed performance on a logical reasoning task. Two studies, one under total sleep deprivation and one under partial sleep deprivation, were conducted. Each study examined participant performance on a logical reasoning task. Upon completion of the task, participants indicated how many questions they thought they answered correctly and how confident they were in that assessment.

The results of this study suggest that while total sleep deprivation negatively affected performance on a logical reasoning task, partial sleep deprivation had no effect. Employers should be aware that employees who have experienced total sleep deprivation will be unable to maintain logical reasoning performance. When asked to estimate their own performance, participants consistently gave values that were higher than the actual values. Participants also remained very confident in their self-assessed performance estimations. In other words, if an employer asks employees to rate their performance, they will do so with a great level of confidence, even though their self-assessed performance values are likely to be higher than their actual performance values.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>v</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Sleep Deprivation and Performance</td>
<td>1</td>
</tr>
<tr>
<td>The Effect of Sleep Deprivation on Cognitive Task Performance</td>
<td>3</td>
</tr>
<tr>
<td>The Effect of Sleep Deprivation on Logical Reasoning Task Performance</td>
<td>6</td>
</tr>
<tr>
<td>Self-Assessment of Performance under Sleep Deprivation Conditions</td>
<td>8</td>
</tr>
<tr>
<td>Purpose and Hypotheses</td>
<td>11</td>
</tr>
<tr>
<td>II. METHOD</td>
<td>14</td>
</tr>
<tr>
<td>Study 1: Total Sleep Deprivation</td>
<td>14</td>
</tr>
<tr>
<td>Study 2: Partial Sleep Deprivation</td>
<td>20</td>
</tr>
<tr>
<td>Data Analyses</td>
<td>24</td>
</tr>
<tr>
<td>III. RESULTS</td>
<td>26</td>
</tr>
<tr>
<td>Sleep Log and Actiwatch Data</td>
<td>26</td>
</tr>
<tr>
<td>LSAT Performance</td>
<td>27</td>
</tr>
<tr>
<td>Confidence in Estimated LSAT Performance</td>
<td>34</td>
</tr>
<tr>
<td>IV. DISCUSSION</td>
<td>36</td>
</tr>
<tr>
<td>Limitations and Future Research</td>
<td>40</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>45</td>
</tr>
<tr>
<td>A: Background Information Completed by Potential Participants</td>
<td>46</td>
</tr>
</tbody>
</table>
# Table of Contents (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: Available Dates Information Completed by Potential Participants for Study 1</td>
<td>50</td>
</tr>
<tr>
<td>C: Sleep Log Completed by Participants</td>
<td>51</td>
</tr>
<tr>
<td>D: Meta-Cognition Survey Completed by Participants after Completing the LSAT in Study 1</td>
<td>52</td>
</tr>
<tr>
<td>E: Verbal Instructions Given to Participants in the Training Session for Study 1</td>
<td>54</td>
</tr>
<tr>
<td>F: Verbal Instructions Given to Participants in the Testing Sessions for Study 1</td>
<td>55</td>
</tr>
<tr>
<td>G: Study Description and Informed Consent Document Given to Participants for Study 1</td>
<td>56</td>
</tr>
<tr>
<td>H: Available Dates Information Completed by Potential Participants for Study 2</td>
<td>61</td>
</tr>
<tr>
<td>I: Meta-Cognition Survey Completed by Participants after Completing the LSAT in Study 2</td>
<td>62</td>
</tr>
<tr>
<td>J: Verbal Instructions Given to Participants in the Training Session for Study 2</td>
<td>63</td>
</tr>
<tr>
<td>K: Verbal Instructions Given to Participants in the Testing Sessions for Study 2</td>
<td>65</td>
</tr>
<tr>
<td>L: Study Description and Informed Consent Document Given to Participants for Study 2</td>
<td>66</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>71</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>The testing room in the research house</td>
<td>15</td>
</tr>
<tr>
<td>3.1</td>
<td>Actual LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.</td>
<td>29</td>
</tr>
<tr>
<td>3.2</td>
<td>Estimated LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.</td>
<td>30</td>
</tr>
<tr>
<td>3.3</td>
<td>Actual and estimated LSAT performance under total sleep deprivation conditions.</td>
<td>32</td>
</tr>
<tr>
<td>3.4</td>
<td>Actual and estimated LSAT performance under partial sleep deprivation conditions.</td>
<td>33</td>
</tr>
<tr>
<td>3.5</td>
<td>Difference in actual and estimated LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.</td>
<td>34</td>
</tr>
<tr>
<td>3.6</td>
<td>Participant confidence level in logical reasoning accuracy prediction under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.</td>
<td>35</td>
</tr>
</tbody>
</table>
CHAPTER ONE
INTRODUCTION

The pace of today’s society often prevents people from receiving enough sleep to become fully rested. A survey by the National Sleep Foundation (NSF) found that approximately 71% of adults in the United States do not sleep the recommended eight hours a night (2005). Furthermore, in an earlier study, 27% of adults reported feeling sleepy at work at least two days a week (NSF, 2000). To compound this problem, many employees are required to do shiftwork, further interrupting their regular sleep schedules and circadian rhythms. How shiftwork and sleep deprivation affect people in the workplace needs to be better understood to ensure that employees are able to work safely and efficiently. The current research should focus on how various types of tasks are affected by sleep deprivation to determine the potential effects on people in the workplace.

Sleep Deprivation and Performance

The current research has looked at the effects of two different types of sleep deprivation, total and partial, on performance for a variety of tasks. Sleep-deprived participants generally perform worse than those who are not sleep deprived, though the nature of the sleep deprivation also has an effect on performance (Harrison & Horne, 2000; Krueger, 1989; Pilcher & Huffcutt, 1996). In a meta-analytic review of 19 studies, Pilcher and Huffcutt found that for periods of sleep deprivation up to or equal to 45 hours, performance decreased more on cognitive tasks that were complex and long than
on those that were simple and short. For periods of sleep deprivation greater than 45
hours, performance decreased more on cognitive tasks that were short than on those that
were long. People also did slightly worse on simple tasks versus complex tasks. Their
results demonstrate that both the length of sleep deprivation involved and the type of task
being performed are important in determining the effects of sleep loss.

Most research has focused on the effects of total sleep deprivation (Durmer &
Dinges, 2005; Philibert, 2005), even though partial sleep deprivation may be more
representative of what occurs in today’s society. There is evidence that partial sleep
deprivation negatively affects performance on cognitive tasks (Durmer & Dinges, 2005;
Pilcher & Huffcutt, 1996). Other research indicates that performance on a variety of
vigilance and cognitive tasks is negatively affected by chronic partial sleep deprivation
(Belenky et al., 2003; Dinges et al., 1997; Van Dongen, Maislin, Mullington, & Dinges,
2003). In addition, there is limited research on whether partial and total sleep deprivation
affect performance differently. Van Dongen et al. (2003) determined that performance
under chronic partial sleep deprivation was comparable to performance after two nights
of total sleep deprivation. On the other hand, Blagrove, Alexander, and Horne (1995)
found no effect of chronic partial sleep deprivation for cognitive or vigilance tasks.
However, the same tasks were sensitive to one night of total sleep deprivation. Even
though partial sleep deprivation is more indicative of what occurs in today’s society, the
research examining how it affects performance is limited. In addition, the results are
mixed. Some studies indicate that participants who have experienced partial sleep
deprivation perform worse than those who have experienced total sleep deprivation, though other evidence does not support this.

An additional element that can affect performance is our endogenous circadian rhythm. Circadian rhythms, the daily cycles in both physiological and behavioral processes, are organized around the 24 hours of the day. Because humans are diurnal, circadian rhythms regulate an internal clock that causes people to want to be awake during the day and to sleep at night (Van Dongen & Dinges, 2005). People tend to perform better when these natural rhythms are left intact (Rouch, Wild, Anciau, & Marquie, 2005). Working at night can also prove to be especially harmful (Folkard, 1990). For example, a study done by Gunzelmann, Gluck, Kershner, Van Dongen, and Dinges (2007) found that accuracy on a serial addition and subtraction task decreased over the course of 88 hours of sleep deprivation and that there was a cyclical pattern to the decline corresponding to the circadian rhythm. Participants in this study slept for approximately eight hours for the three nights prior to the sleep deprivation period to stabilize their circadian rhythms. During the 88 hours of sleep deprivation, participants completed the addition and subtraction task every two hours. During this time period, participant accuracy decreased and response time increased. There was also a daily rise and fall that corresponded to the circadian rhythm. Previous research suggests that people tend to perform better when their circadian rhythms are left undisturbed.

The Effect of Sleep Deprivation on Cognitive Task Performance

Research has examined how total sleep deprivation, partial sleep deprivation, and circadian rhythms affect performance on a variety of tasks. For example, vigilance tasks
have been studied often and are consistently negatively affected by sleep deprivation (for example, Dorrian, Lamond, & Dawson, 2000; Dorrian et al., 2003; Gillberg, Kecklund, & Åkerstedt, 1994). On the other hand, research on the effects of sleep deprivation on cognitive tasks is much more limited. Cognitive tasks are often seen in the workplace when employees are required to complete complex and challenging assignments. Harrison and Horne (2000) conducted a review of the sleep deprivation literature that focused on how sleep deprivation affects complex tasks and, more specifically, decision-making. Their review examined how different types of cognitive tasks respond to sleep deprivation, but they acknowledge that the literature on more complex tasks is limited.

In their review, Harrison and Horne (2000) suggest that complex tasks are often assumed to be resistant to sleep deprivation; however, research does not always support this assumption. Harrison and Horne determined that rule-based and interesting complex tasks are not affected by sleep deprivation, while more divergent, open-ended tasks without a necessarily right or wrong answer are sensitive to sleep loss. However, Harrison and Horne go on to point out that if novel and interesting complex tasks, which may initially be resistant to sleep deprivation, are given many times, the novelty wears off and performance may then decline. Current research supports Harrison and Horne’s suggestion that different types of complex tasks are differentially affected by sleep deprivation.

One study supporting the assertion that rule-based and interesting complex tasks are resistant to the effects of sleep deprivation indicated that performance on a complex real-life simulation task remained stable under total sleep deprivation conditions.
(Hockey, Wastell, & Sauer, 1998). In Hockey et al.’s study, participants had to monitor an automatically controlled process based on a life-support system and only respond when specific situations arose. Performance on this complex and cognitively-challenging task was found to be stable within two-hour testing sessions. In this study, which utilized a rule-based and interesting task, participants were able to maintain performance, supporting the idea that these types of tasks are resistant to sleep deprivation.

Other research has supported the findings that more divergent, open-ended tasks are susceptible to the effects of sleep deprivation. For example, performance on divergent creative thinking tasks was negatively affected by sleep deprivation in Horne’s 1988 study. Performance in other areas such as receptive speech, expressive speech, and memory have also been shown to decrease significantly with sleep deprivation (Kim et al., 2001). Another study found that a sleep-deprived group performed significantly worse than a control group on other kinds of open-ended tasks such as story-telling and object naming (Nilsson et al., 2005). In a different study that also supported the assertion that more divergent tasks are susceptible to the effects of sleep deprivation, May and Kline (1987) found that participants performed significantly worse after a night of sleep deprivation on several divergent tasks that required higher-level functioning, including maze-tracing, paper-folding, auditory digit span, card rotations, and letter sets tasks. All of these studies support the idea that complex tasks that are more divergent and open-ended are susceptible to sleep loss, even though their more rule-based counterparts are not.
To better understand how employees will perform in the workplace, the effects of sleep deprivation on various cognitive tasks needs to be determined. However, the current research specifically on how cognitive tasks are affected by sleep deprivation is limited. In addition, what exists indicates mixed results. The current evidence suggests that complex tasks that follow rules and are highly interesting may be resistant to the effects of sleep deprivation. On the other hand, complex tasks that are more divergent and open-ended tend to be negatively affected by sleep deprivation (Harrison & Horne, 2000).

The Effect of Sleep Deprivation on Logical Reasoning Task Performance

Logical reasoning tasks require participants to form a conclusion based on specific information. These types of tasks are one subset of complex tasks that have received only minimal attention in the sleep deprivation literature. Harrison and Horne (2000) classify logical reasoning tasks as rule-based, suggesting that they will be resistant to the effects of sleep deprivation. However, there is currently little research on this type of task. What exists focuses only on how total sleep deprivation affects performance, without examining the effects of partial sleep deprivation. In studies where participants were subjected to total sleep deprivation conditions, logical reasoning ability was generally found to decrease (Blagrove et al., 1995; Ryman, Naitoh, & Englund, 1985; Smith & Maben, 1993). These results contrast with what Harrison and Horne suggest, but all of these studies utilized a simple grammatical reasoning task (Baddeley, 1968) that only required participants to determine whether a statement was true or false. For this task, participants were shown a statement and a set of letters. Participants had to indicate
whether or not the statement accurately described the set of letters. For example, the participants might be given the statement “M is not preceded by C” and then given a set of letters “MC” to compare to the statement. In this case, the correct answer would be “True.” The studies did not examine how a more complex logical reasoning task would be affected by sleep deprivation.

Furthermore, the evidence using a grammatical-based logical reasoning task is mixed. Not all of the studies utilizing the same grammatical reasoning task have found the same results (e.g., Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2001). However, this is only one type of logical reasoning task. There are other, more complex ways to test for logical reasoning performance. For example, the Law School Admission Test (LSAT) contains two logical reasoning sections that ask inferential questions based on very short reading passages (The Very Best Coaching and Review Course, 2004). These questions are more complex than the simple grammatical reasoning questions used in previous studies.

To summarize, the existing research on the effects of sleep deprivation on cognitive-based tasks in general and specifically on logical reasoning tasks is limited and has produced mixed results. Although it has been suggested that complex tasks that are rule-based and interesting should be resistant to the effects of sleep deprivation (Harrison & Horne, 2000), not all evidence supports this assertion. One type of a rule-based task is a logical reasoning task. Research focused specifically on logical reasoning tasks and sleep deprivation is limited and those studies that exist concentrate on more simplistic reasoning tasks. The current study will focus on performance on a more complex logical
reasoning task and attempt to examine whether or not total and partial sleep deprivation affect participant performance.

**Self-Assessment of Performance under Sleep Deprivation Conditions**

One factor that could affect how participants perform under sleep deprivation conditions is their self-assessment of their performance. In most workplace settings, workers are not provided with real-time external feedback that can assist in self-assessment of performance. As such, workers can only depend on their personal assessment of ability to gauge their performance levels. Harrison and Horne (2000) make the argument that it is necessary for a person to have insight into his or her performance in order to avoid recurring errors. Because there is usually no immediate feedback in the field, people will be unable to avoid errors unless they are able to accurately self-assess how well they are doing.

There is currently minimal literature on whether people are able to accurately predict their performance levels when they are sleep deprived. Some evidence suggests that participants can accurately self-assess performance on cognitive tasks with up to 64 hours of sleep deprivation (Baranski, 2007; Baranski & Pigeau, 1997; Baranski, Pigeau, & Angus, 1994; Dinges & Kribbs, 1991). For example, participants in Baranski and Pigeau’s study were accurate in their self-assessment of performance on cognitively-challenging perceptual comparison and mental addition tasks. The authors noted that since the participants in their study did not have access to any external feedback, their ability to accurately assess their own performance had to be due to some sort of internal
feedback. However, they were unsure of exactly how participants were able to internally self-assess their performance without the benefit of any outside information.

Other studies, however, have not found a strong correlation between actual and predicted performance. Dorrian et al. (2003) did not find a significant correlation between predicted and actual performance on a grammatical reasoning task throughout a week of simulated night shifts. In another study, Dorrian et al. (2000) had participants complete several cognitive tasks. They found that participants’ self-ratings of performance either over or underestimated their actual performance and that there was a moderate correlation between predicted and actual performance only when task performance decreased significantly. These studies conflict with the work of other researchers (Baranski, 2007; Baranski & Pigeau, 1997; Baranski et al., 1994; Dinges & Kribbs, 1991) and suggest that participants are unable to accurately gauge their own performance levels when they are sleep deprived. To summarize, there is conflicting research on whether or not participants are able to accurately self-assess their own performance when sleep deprived. Some studies indicate that participants are accurate in their own performance estimates. Other studies have not found this correlation.

A few researchers have tried to examine what factors participants use to self-assess their performance. Studies have suggested that there is a possibility that participants rate their performance using only their level of alertness. Dorrian et al. (2003) found a significant correlation between participants’ self-rated levels of alertness and their performance ratings on a grammatical reasoning task. Research has also found that the longer participants are awake, the worse they rate their own performance on
cognitive tasks (Dorrian et al., 2000). In addition, the decreasing performance rating applied to all tasks and was not task-specific. Another study did not have participants self-assess their performance (Gillberg et al., 1994), but the authors did note that participants’ self-ratings of sleepiness correlated strongly with their performance. These studies indicate that it is possible that participants’ performance ratings may be related to alertness.

Another factor to be considered is a participant’s confidence rating of his or her own self-assessment. If people are highly confident in their self-assessments of performance, they will trust they know how well they are doing regardless of whether or not their assessment is accurate. Although no research to date has examined confidence ratings under sleep deprivation conditions, some studies have been completed under non-sleep deprivation conditions. A study investigating participants’ ability to answer general knowledge questions suggests that people are often wrong when they are certain they know an answer to a question (Fischkoff, Slovic, & Lichtenstein, 1977). Other research in this area indicates that people are, in general, overconfident in their judgments of accuracy, even across very different types of judgments. Dunning, Griffin, Milojkovic, and Ross (1990) had participants predict a peer’s response to a specific situation. They found that participants’ level of confidence was much higher than their accuracy rates warranted. In a similar study that asked participants to predict their own future actions instead of those of their peers, participants still proved to be overconfident (Dunning & Story, 1991). Other research has looked at both confidence in accuracy on specific test items and at confidence in cognitive task performance (Lundeberg, Fox, & Punčochar,
1994 and Pallier et al., 2002, respectively). These studies also indicated a consistent overconfidence among participants. Similarly, Dunning, Heath, and Suls (2004) found that people are overconfident in how insightful they are about their own predictions. Although there is a limited amount of literature on this topic, what exists indicates that people are overconfident in their judgments of accuracy.

In conclusion, whether sleep-deprived participants are able to accurately monitor their own performance on a complex logical reasoning task has not yet been clearly determined. In addition, there is little, if any, research examining whether partial sleep deprivation affects the ability to self-assess. The current literature examining self-assessment under sleep deprivation conditions has produced mixed results, with some evidence suggesting that participants are able to accurately assess and other studies finding the opposite outcome. Finally, it is not yet entirely clear how confident sleep-deprived participants are in their self-assessments of performance. No research has examined how sleep deprivation affects confidence levels, though the decision-making literature indicates that participants are generally highly confident in their assessments of accuracy.

**Purpose and Hypotheses**

The purpose of the current study was to compare the effects of total sleep deprivation and partial sleep deprivation on actual and self-assessed performance on a logical reasoning task. Two studies, one under total sleep deprivation conditions and the other under partial sleep deprivation conditions, were conducted that examined participant performance on a logical reasoning task. Upon completion of the logical
reasoning task, participants filled out a survey asking them how many questions they believed they answered correctly and how confident they were in that assessment.

Hypothesis 1: Because much of the previous research has indicated that sleep deprivation negatively affects performance on logical reasoning tasks, I expect participant performance to decrease on a complex logical reasoning task under both total and partial sleep deprivation.

Hypothesis 1a: Research indicates that even though partial sleep deprivation can have a negative effect on performance, the negative effects of total sleep deprivation are often greater because of circadian rhythms and the fact that participants have been awake for a greater number of hours. I expect that participant performance on a logical reasoning task will decrease more for the participants who experienced total sleep deprivation than for those who experienced partial sleep deprivation.

Hypothesis 2: The previous research on the accuracy of self-report ratings for cognitive tasks has produced mixed results. However, some evidence suggests that sleep-deprived participants are able to accurately gauge their performance. I expect participants’ self-assessed performance to accurately reflect their actual performance on the task.

Hypothesis 2a: Little research has examined whether the type of sleep deprivation (total or partial) has an effect on the ability of participants to accurately self-assess their own performance. However, since the current research does indicate that sleep-deprived participants are often able to accurately gauge their own performance, I do
not expect there to be any difference in accuracy between the total and partial sleep deprivation conditions.

Hypothesis 3: There is no information in the current literature examining how confident sleep-deprived participants are in the accuracy of their self-assessments. Existing studies in the decision-making literature indicate that people tend to be very confident in their predictions, even when this confidence is unwarranted. I expect that participants in both total and partial sleep deprivation conditions will exhibit a high level of confidence in the accuracy of their self-assessed performance.
CHAPTER TWO

METHOD

Two separate studies were conducted testing participant performance on a logical reasoning task. Following the completion of the logical reasoning task, participants completed a survey indicating how well they believed they performed on the task.

Study 1: Total Sleep Deprivation

Participants

Twenty-three students (15 males and 8 females) completed the total sleep deprivation study. The average age was 21.2 years (standard deviation [SD] = 2.7). Flyers were posted around the Clemson University campus to recruit participants. All participants who completed the study were compensated with $150. If a participant decided to leave the study early, a graduated scale was used to determine the dollar amount he or she would receive. People interested in participating in the study either phoned or emailed the on-campus laboratory and then completed screening questionnaires. Each potential participant completed two surveys designed to gather background information and personal and family health history (see Appendix A). In addition, participants completed a form listing which dates they were available for the study (see Appendix B). Participants were selected to complete the study based on their responses to the questionnaires. To participate, volunteers had to be Clemson University students, could not use drugs or drink alcohol excessively, could not smoke, had to be in
good health, had to be native English speakers, and could not have any sleep disorders. Participants were also required to be between the ages of 18 and 35.

Setting/Apparatus

The study was conducted at a research house approximately 15 minutes from the Clemson University campus. The house contained, on the upstairs level, four bedrooms and two bathrooms, and, on the downstairs level, a master bedroom and bathroom, a dining and living room area, a kitchen, a half-bath, and a group “testing” room. Figure 1.1 is a photograph of the testing room with four of the five computer desks and chairs visible. Each of the five desks contained a PC, flat-screen monitor, keyboard, mouse, and set of headphones.

Figure 1.1: The testing room in the research house.
Materials

Actiwatches and Sleep Logs

The Tuesday before the beginning of the study, participants met with a researcher at the on-campus laboratory. At this time they were given an Actiwatch and three copies of the sleep log (see Appendix C). Actiwatches are wristwatch-like devices that measure wrist accelerations as an objective measure of body activity. Participants were instructed to wear the Actiwatches for the three days prior to the study and then through the completion of the study. Participants were only allowed to remove the Actiwatches when there was a possibility that the watch might get wet, such as when the participant was bathing, swimming, or exercising. Participants also completed a sleep log reporting how much they slept, how much they napped, and the quality of their sleep for each of the three nights prior to the study. The Actiwatch data was used to compare to the sleep log data to ensure that the participants had correctly completed all aspects of the logs. In addition, the Actiwatches and sleep logs were used to confirm that participants slept the required eight hours the night before the study and did not nap during the day leading up to the study.

Law School Admission Test

The logical reasoning portion of the Law School Admission Test (LSAT) was used. All American Bar Association (ABA)-approved law schools, most Canadian law schools, and many non-ABA-approved law schools require this test for admission. The test is designed to provide a standardized way to measure verbal reasoning and reading abilities (About the LSAT, n.d.). Participants had 30 minutes to complete as many
questions as they could. Each participant was scored on the number of questions attempted, the number of questions answered correctly out of the number of questions attempted, and the number of questions answered correctly out of the total number of questions presented.

Meta-Cog Survey

After completing the LSAT, participants filled out a meta-cognition survey. Meta-cognition, or meta-cog, refers to an assessment of one’s own knowledge (Koriat, Ma’ayan, & Nussinson, 2006). The survey (see Appendix D) was designed to assess participants’ ability to accurately gauge their performance on the LSAT. Participants were asked how many questions they answered and what percentage of those questions they believe they answered correctly. Participants were then asked to indicate how confident they were in this answer. In addition, if participants did not feel 100% confident in their answer to the question, they were asked to rank the factors that could have affected their ability to correctly answer the questions. Participants were also asked a series of questions concerning the questions they were certain they answered correctly, the questions they thought they might have answered correctly, and the questions they had to just guess on. For the purposes of this study, only self-assessed accuracy and participant confidence level were examined.

Other Tasks

The data used in the current study was a portion of a larger study. The participants completed a battery of tasks during each testing session that included many tasks in addition to the LSAT. Participants took several standardized tests, including the
Graduate Record Examination (GRE) Verbal, the GRE Quantitative, and the Dental Admission Test (DAT). Participants also completed two reaction time tasks that either required them to react as quickly as possible to a specified stimulus or to engage their working memory to indicate whether or not a given display was equivalent to a target display. Two listening tasks were also used. In these tasks, participants had to listen to a reading and then respond to questions at the reading’s conclusion. The final task participants completed was a reasoning task examining decision policies.

Each participant took the series of tasks in the same order during every session. The tasks were also counterbalanced across participants. In addition, participants had their blood pressure and oral temperature recorded during each session and completed several Fitness-For-Duty Impairment tests (FIT). The FIT machine measured involuntary eye movements to identify central nervous system changes.

Design

Study 1 used a within-subjects repeated measures design. Participants first completed a training session upon arrival at the research house to become familiarized with the tasks and to establish a baseline. This was the only opportunity participants had to ask questions about the tasks. Following this, each participant completed different versions of the same set of tasks during four testing sessions. To help control for order effects, the test materials were counterbalanced across participants and sessions.

The research staff, undergraduate research assistants, and graduate research assistants served as the researchers for this study. Everyone involved was first trained on the study procedures. Either a staff member or a graduate student was present at all times
during the study to serve as a supervisor. Notes were taken as the study progressed to document any problems that occurred. To ensure that all participants received the same information, instructions for the participants were developed prior to the study. All researchers read the appropriate set of instructions for tasks in both the training (see Appendix E) and testing (see Appendix F) sessions.

The independent variable in this study was the participants’ level of fatigue as measured by testing session. There were four testing sessions during the study. The dependent variables were the participants’ logical reasoning ability, their self-awareness of performance, and their confidence in that self-awareness. Actual and self-assessed performance on the LSAT over the testing sessions was recorded.

Procedure

This study was approved by Clemson University’s Institutional Review Board before it began. Volunteers who were selected to participate visited the on-campus laboratory on the Tuesday prior to the study to read over the study description document (see Appendix G) and sign the informed consent form (see Appendix G). This was also the participants’ opportunity to ask questions and receive their Actiwatches and sleep logs. Participants were required to wear the Actiwatches and complete the logs for the three days prior to the onset of the study. Participants were asked to sleep approximately eight hours the night before the study and to not consume alcohol, caffeine, or excessive sugar during the day before the onset of the study.

The study began at 10:00 am on Day 1. Participants met with a member of the research staff on campus and were transported via a Clemson University van to the
testing location. Participants had their oral temperature and blood pressure taken and then completed two training sessions, interspersed with breaks and meals, until 6:15 pm. To train for the LSAT, participants were given 15 minutes to read over a set of instructions and a selection of LSAT sample problems. Participants also completed some personality and critical thinking surveys during Day 1. Food and drinks were provided to participants during the study, with no caffeine or excess sugar allowed.

The first testing session began at 6:15 pm. Every participant completed the same set of tasks four times over the course of the study. Each session lasted approximately four hours: 6:15-10:30 pm, 11:00 pm-3:00 am, 3:30-7:30 am, and 8:00 am-12:00 pm. Participants were given a 30-minute break between the sessions. The study concluded at approximately 1:30 pm on Day 2. Participants were then driven to their residences in a Clemson University van; they were reminded that they were sleep deprived and not to drive or operate equipment until they had had the opportunity to sleep and become fully rested.

Study 2: Partial Sleep Deprivation

Participants

Thirty-two students (17 males and 15 females) participated in Study 2. Their average age was 20.3 years (SD = 1.9). Participants were recruited in the same manner as in Study 1 but were offered $100 for a partial sleep deprivation study. Participants had to complete the entire study to receive the $100. The same procedure was followed for recruiting volunteers as in Study 1 (see Appendix A and Appendix H for forms).
Participants were required to have the same basic qualifications as in the first study. However, they could only be between the ages of 18 and 30.

Setting/Apparatus

The same setting was used for Study 2 as in Study 1. The only difference was that four computer desks and chairs were set up in the testing room (see Figure 1.1), since only four participants were scheduled for each session during Study 2.

Materials

Actiwatches and Sleep Logs

Participants followed the same procedure as in Study 1 to receive their Actiwatches and sleep logs (see Appendix C). Participants in this study completed a sleep log for each of the three nights prior to the study and the one night of the study.

Law School Admission Test

To test for logical reasoning performance, the LSAT was again used. In this study participants were allowed only 15 minutes to take the test to allow adequate time for other tasks to be completed in each testing session.

Meta-Cog Survey

At the end of the 15-minute time period, participants filled out a short survey, similar to the survey used in Study 1, created by members of the research team. The survey (see Appendix I) was a shortened version of the one used previously.

Other Tasks

The current study was part of a more extensive study where the participants completed a large battery of tasks in each session. Several of the tasks were similar to
those used in Study 1, but the shortened testing sessions did not allow for the same
number of tasks to be completed. Participants in this study worked on several
standardized tests, including the SAT Verbal and Quantitative sections. Participants also
took a series of reaction time and vigilance tasks requiring them to either react as quickly
as possible or to indicate if the display on the screen was equivalent to a target display. A
listening task was also used; participants first listened to a passage being read to them and
then listed the main points of the passage. Participants also took a stress-inducing math
task. Finally, the participants completed a picture-rating task. The tasks were
counterbalanced across participants. Each participant took the series of tasks in the same
order during every session. In addition, each participant had his or her blood pressure
and oral temperature recorded during each session.

Design

Study 2 also used a within-subjects repeated measures design. Before beginning
the study, participants were trained on the tasks they were to complete. Each participant
then completed four different versions of the same series of tasks over the course of four
sessions during the study. The tasks were counterbalanced across the participants and
sessions to help control for order effects.

To ensure partial sleep deprivation, participants were only given a five-hour
period in which to sleep during the night of the study, though they might not necessarily
have slept the entire time. Actiwatches and sleep logs were used to determine how much
participants actually slept. Participants were required to stay in their rooms with the
lights off and try to sleep during this five-hour period.
The researchers for this study were the research staff, a graduate research assistant, and undergraduate research assistants. Pre-written instructions were read to the participants for the training (see Appendix J) and testing (see Appendix K) sessions to ensure that all participants received the same set of instructions. The independent and dependent variables for this study were the same as those in Study 1.

Procedure

The Institutional Review Board at Clemson University approved this study before it began. The basic study procedure was very similar to that used in Study 1. Selected participants reported to the on-campus laboratory three days before the study began to read the study description document (see Appendix L), sign the informed consent form (see Appendix L), be given the opportunity to ask questions, and receive their Actiwatches and sleep logs.

The study began at 5:30 pm on Day 1. Participants met with a research team member at the on-campus laboratory and were transported to the research house in a Clemson University van. Participants first had their height, weight, oral temperature, and blood pressure taken. Next, all participants completed some brief personality and critical thinking surveys and participated in two hour-long training sessions. Training for the LSAT was done the same way as in Study 1. Participants then had a break before going to bed at 1:00 am. Participants were given five hours in which to sleep.

Participants were awakened at 6:00 am and had their oral temperature and blood pressure taken. The first testing session began at 7:00 am. Each participant completed the same set of tasks four times over the course of the day. The sessions lasted 2 hours.
and 30 minutes: 7:00-9:30 am, 9:45 am-12:15 pm, 1:15-3:45 pm, and 4:00-6:30 pm. Each testing session also contained an oral temperature reading and numerous blood pressure readings.

At the conclusion of the fourth testing session, participants again had their blood pressure and oral temperature taken. They also completed another version of the critical thinking survey they took during the previous night’s training session. The study ended at approximately 7:30 pm. Participants were then transported home in a Clemson University van and were reminded to sleep before attempting to drive or operate equipment.

Data Analyses

The data analyses were done in the same manner for both Study 1 and Study 2. As soon as each study was completed, the LSAT exams were scored and entered into Microsoft Excel. All of the reported LSAT data are based on the percent correct out of the number of questions attempted, since participants did not have an equal amount of time to answer questions in both studies. A researcher also entered all of the data for the self-assessment questionnaires into an Excel spreadsheet. The data were then double-checked for accuracy. In addition, the sleep log and Actiwatch data for each participant in each study were examined to ensure that participants were well-rested prior to the onset of the studies.

All data were imported into SPSS (SPSS, Inc., Chicago, IL) for analyses. The means and standard deviations were first calculated in Microsoft Excel and then recalculated using SPSS to check for accuracy. The first step in the analyses was a 2 x 2
A 4-repeated-measures analysis of variance (ANOVA). The first two levels referred to
the two different studies (total sleep deprivation and partial sleep deprivation), the second
two levels referred to either actual or estimated performance, and the four levels referred
to the four different testing sessions within each study. The Wilks-Lambda Multivariate
test was used to report all within-subjects effects. To further examine any main and
interaction effects, 2 x 4 ANOVAs, univariate ANOVAs, and individual repeated-
measures ANOVAs were run. Any necessary post-hoc tests were used to examine
significant results from the individual repeated-measures ANOVAs. In addition, a 2 x 4
repeated-measures ANOVA was used to determine if there was any significant difference
in the amount by which participants over or underestimated their own performance across
the testing periods. For this ANOVA, the two levels referred to the two different studies
(total or partial sleep deprivation) and the four levels referred to the four different testing
sessions. Finally, another 2 x 4 repeated-measures ANOVA was used to examine
participant confidence levels in estimated performance. In this ANOVA, the two levels
again referred to the two different studies (total or partial sleep deprivation) and the four
levels again referred to the four different testing sessions. A $p$-value of 0.05 was used as
the cut-off for significance.
CHAPTER THREE

RESULTS

Sleep Log and Actiwatch Data

Sleep log and Actiwatch data from each study indicated that participants were well-rested at the start of the experiment. In the total sleep deprivation study, participants reported sleeping an average of 7 hours and 21 minutes (SD = 54 minutes) for the three nights prior to the onset of the study and an average of 8 hours and 4 minutes (SD = 1 hour, 17 minutes) the night before the study. The Actiwatch data indicated similar sleeping patterns, with participants sleeping an average of 6 hours and 30 minutes (SD = 1 hour, 2 minutes) for the three nights prior to the study and 6 hours and 50 minutes (SD = 1 hour, 50 minutes) the night before the onset of the study. In the partial sleep deprivation study, participants reported sleeping an average of 7 hours and 2 minutes (SD = 1 hour, 7 minutes) for the three nights prior to the study and 7 hours and 34 minutes (SD = 1 hour, 26 minutes) the night before the study began. The Actiwatch data supported the reported sleeping patterns. Participants slept an average of 7 hours and 5 minutes (SD = 1 hour, 33 minutes) the three nights before the study and an average of 7 hours and 12 minutes (SD = 1 hour, 16 minutes) the night before the onset of the study. In this study, participants also completed a sleep log and wore the Actiwatch for the night of partial sleep deprivation. For this night, participants reported sleeping an average of 4 hours and 26 minutes (SD = 29 minutes). The Actiwatch data supported this, indicating that participants slept an average of 4 hours and 24 minutes (SD = 24 minutes).
LSAT Performance

A 2 x 2 x 4 repeated-measures ANOVA on the actual and estimated LSAT performance revealed a main effect for actual versus estimated performance, $F(1, 52) = 86.004, p < .001$, a main effect for session, $F(3, 50) = 4.339, p = .009$, and no main effect for total versus partial sleep deprivation. There were also interaction effects for total versus partial sleep deprivation and actual versus estimated performance, $F(1, 52) = 7.494, p = .008$, and total versus partial sleep deprivation and session, $F(3, 50) = 4.820, p = .005$. There was no interaction effect for actual versus estimated performance and session and no three-way interaction effect for total versus partial sleep deprivation, actual versus estimated performance, and session. The remainder of the actual and estimated LSAT performance results are follow-ups to the 2 x 2 x 4 repeated-measures ANOVA.

Actual LSAT Performance

As shown in Figure 3.1, there was a trend for participants to perform worse on the LSAT under total sleep deprivation conditions than under partial sleep deprivation conditions. A 2 x 4 repeated-measures ANOVA on the actual LSAT performance data revealed a main effect for total versus partial sleep deprivation, $F(1, 53) = 6.665, p = .013$, and no main effect for session. There was also an interaction effect for session and total versus partial sleep deprivation, $F(3, 51) = 4.633, p = .006$.

To probe into the main and interaction effects, a repeated-measures ANOVA was run on each study. As evidenced by the trend shown in Figure 3.1, a significant decrease in performance scores was found for the total sleep deprivation condition, $F(3, 20) =$
5.093, \( p = .009 \). There was no significant difference in performance over the course of the study for the partial sleep deprivation condition. Post-hoc tests on the total sleep deprivation condition data revealed significant differences between Sessions 1 and 3 (\( p = .036 \)), Sessions 1 and 4 (\( p = .001 \)), and Sessions 2 and 4 (\( p = .034 \)).

A univariate ANOVA was conducted on each testing session to see if there were any differences in actual performance between the two study conditions. There was no significant difference in actual performance between the total and partial sleep deprivation conditions for Session 1, indicating that in both studies participants began at the same level of performance. There was also no significant difference between performance levels for Session 3. However, significant differences in performance were found for Session 2, \( F(1, 53) = 4.691, p = .035 \), and Session 4, \( F(1, 53) = 19.822, p < .001 \), with the partial sleep deprivation participants scoring higher than the total sleep deprivation participants in both sessions.
Figure 3.1: Actual LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.

Estimated LSAT Performance

As seen in Figure 3.2, participants in the total sleep deprivation condition indicated a decreasing trend in estimated LSAT performance. Participants in the partial sleep deprivation condition indicated unchanging LSAT performance across the four testing sessions. A 2 x 4 repeated-measures ANOVA conducted on the estimated LSAT performance data revealed a main effect for session, $F(3, 50) = 5.165, p = .003$, and no main effect for total versus partial sleep deprivation. There was also an interaction effect for session and total versus partial sleep deprivation, $F(3, 50) = 3.208, p = .031$. 
To examine the main and interaction effects, individual repeated-measures ANOVAs were conducted on each study. A significant decrease in estimated performance across the four testing sessions of the total sleep deprivation study was found, \( F(3, 19) = 5.448, p = .007 \). However, there was no change in estimated performance across the four testing sessions of the partial sleep deprivation study. Post-hoc tests on the total sleep deprivation study data revealed significant differences between Sessions 1 and 4 (\( p = .045 \)), Sessions 2 and 3 (\( p = .002 \)), and Sessions 2 and 4 (\( p = .007 \)).

![Figure 3.2: Estimated LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.](image)
Actual versus Estimated LSAT Performance

Participants in the total sleep deprivation condition consistently estimated their LSAT performance higher than their actual level of performance (Figure 3.3). A 2 x 4 repeated-measures ANOVA revealed main effects for actual versus estimated performance, $F(1, 43) = 39.605, p < .001$, and session, $F(3, 41) = 8.060, p < .001$. There was no interaction effect. Univariate ANOVAs were run on each session to determine if there were any significant differences between actual and estimated performance. For the total sleep deprivation condition, there was a significant difference between actual and estimated performance for each testing session: Session 1, $F(1, 44) = 13.961, p = .001$; Session 2, $F(1, 44) = 36.059, p < .001$; Session 3, $F(1, 44) = 11.973, p = .001$; and Session 4, $F(1, 43) = 15.094, p < .001$. The results indicated that for every session in the total sleep deprivation condition, estimated performance was significantly greater than actual performance.
Figure 3.4 indicates that participants in the partial sleep deprivation condition consistently estimated their LSAT performance to be higher than their actual LSAT performance. A 2 x 4 repeated-measures ANOVA was conducted on the partial sleep deprivation data, revealing a main effect for actual versus estimated performance, $F(1, 62) = 12.313, p = .001$. There was no main effect for session and no interaction effect. Univariate ANOVAs were run on each session of the partial sleep deprivation data to determine if there were significant differences between actual and estimated performance. Results revealed a significant difference between actual and estimated performance for each testing session: Session 1, $F(1, 62) = 9.650, p = .003$; Session 2, $F(1, 62) = 8.136, p = .006$; Session 3, $F(1, 62) = 7.928, p = .007$; and Session 4, $F(1, 62)$.
The results indicated that for every session in the partial sleep deprivation condition, estimated performance was significantly greater than actual performance.

![Figure 3.4: Actual and estimated LSAT performance under partial sleep deprivation conditions.](image)

Figure 3.5 illustrates the discrepancy between actual and estimated LSAT performance for each session in each study. For every session, participants in the total sleep deprivation condition overestimated their own performance by a greater amount than the participants in the partial sleep deprivation condition. A 2 x 4 repeated-measures ANOVA revealed a main effect for total versus partial sleep deprivation, $F(1, 53) = 7.152$, $p = .010$, and no main effect for session. There was no interaction effect. To
examine the study main effect, univariate ANOVAs revealed a significant difference in the overestimation amounts for Session 2 only, $F(1, 53) = 10.504, p = .002$.

![Figure 3.5: Difference in actual and estimated LSAT performance under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.](image)

**Confidence in Estimated LSAT Performance**

Figure 3.6 indicates that participants in both studies did not exhibit a change in their confidence of their estimates of LSAT performance accuracy over the course of the sessions. Participants were, on average, 77% confident in their ability to self-assess their performance. A 2 x 4 repeated-measures ANOVA did not reveal any main effects or
interaction effect. These results indicate that participant confidence level remained high and stable for both sleep deprivation conditions.

Figure 3.6: Participant confidence level in logical reasoning accuracy prediction under total and partial sleep deprivation conditions. For total sleep deprivation, S1: 6:30-10:30 pm, S2: 11:00 pm-3:00 am, S3: 3:30-7:30 am, S4: 8:00 am-12:00 pm. For partial sleep deprivation, S1: 7:00-9:30 am, S2: 9:45 am-12:15 pm, S3: 1:15-3:45 pm, S4: 4:00-6:30 pm.
CHAPTER FOUR
DISCUSSION

The current results indicate that performance on a complex logical reasoning task decreased across four testing sessions under total sleep deprivation conditions. However, participants who experienced partial sleep deprivation were able to maintain performance on the same task. When asked to estimate their performance, both groups of participants consistently overestimated their performance levels. The trends within this overestimation followed actual performance, in that participants in the total sleep deprivation condition estimated a decrease in performance, while participants in the partial sleep deprivation condition did not estimate a decrease in performance. The amount by which the participants overestimated their performance was greater for those experiencing total sleep deprivation than for those experiencing partial sleep deprivation. Finally, participant confidence level in estimated performance remained stable for both studies.

The current results demonstrate that logical reasoning tasks are susceptible to the effects of total sleep deprivation, but not to the effects of partial sleep deprivation. These results support the current literature that suggests that total sleep deprivation has a negative effect on performance on logical reasoning tasks (Blagrove et al., 1995; Ryman et al., 1985; Smith & Maben, 1993). These previous studies examined performance on a fairly simple grammatical reasoning task, so it is interesting to note that participants working on a more complex reasoning task also experienced a decrease in performance under total sleep deprivation conditions. However, previous research has not examined
how partial sleep deprivation affects logical reasoning task performance, though there is some evidence that partial sleep deprivation negatively affects performance on cognitive tasks (Durmer & Dinges, 2005; Pilcher & Huffcutt, 1996). Conversely, a recent study by Stenuit and Kerkhofs (2008) found that participants whose sleep had been partially restricted for three consecutive nights did not experience a decrement in performance on complex tasks. Though Stenuit and Kerkhofs did not specifically examine logical reasoning tasks, their results suggest that some complex tasks may be resistant to the effects of partial sleep deprivation. This finding is replicated in the current study, with participants maintaining performance on logical reasoning tasks when subjected to partial sleep deprivation.

Our endogenous circadian rhythms are another potential reason why participant performance on the logical reasoning task decreased only under total sleep deprivation conditions. Research has indicated that people tend to perform better when their circadian rhythms are left intact (Rouch et al., 2005). In addition, working at night can be especially harmful to performance (Folkard, 1990). This could have come into play with the participants in the total sleep deprivation condition because they were required to work overnight. Another potential effect of circadian rhythms can be seen in the performance for participants in the partial sleep deprivation study. Participants in this condition experienced a slight post-lunch dip in performance. This dip is likely due to the diurnal nature of our circadian rhythms (Bakoff, Zukerman, Fostick, & Ben-Artzi, 2005). Participants in Babkoff et al.’s study also experienced a decrease in performance during the early- to mid-afternoon hours when completing an auditory temporal order task.
judgment task. Another study done by Owens et al. (2000) found that participants experienced significant post-lunch dips in performance for both vigilance and cognitive tasks while spending six to seven days in a controlled environment. As evidenced by Figure 3.1, participants in the partial sleep deprivation condition also experienced a slight post-lunch dip in performance, even though their performance was stable overall.

As expected, the current data indicate that participants were aware of the general trend in their performance. Participants in the total sleep deprivation condition, whose performance was actually decreasing, estimated this decrease. Participants in the partial sleep deprivation condition, whose performance was staying the same, estimated this stability. At first glance it appears that participants were accurate in their self-estimation of logical reasoning performance, a trend seen in some literature suggesting that sleep-deprived participants are accurate in their self-assessments of performance on a cognitive task (Baransi, 2007; Baransi & Pigeau, 1997; Baransi et al., 1994; Dinges & Kribbs, 1991). However, upon further examination of the data, it becomes clear that while participants were aware of the general trend of their performance, they still overestimated just how well they were doing.

Participants in both the total and partial sleep deprivation conditions thought they were doing better than they were. This trend coincides with research outside of the field of sleep deprivation that indicates that people tend to overestimate their own performance levels (Ehrlinger & Dunning, 2003; Ehrlinger, Johnson, Banner, Dunning, & Kruger, 2008; Mabe & West, 1982). However, there is limited and mixed literature on self-assessment of performance for cognitive tasks while under sleep deprivation conditions.
Some research, as mentioned previously, suggests that participants are able to accurately assess their own performance on a cognitive task (Baranski, 2007; Baranski & Pigeau, 1997; Baranski et al., 1994; Dinges & Kribbs, 1991). Other research, however, does not find this correlation (Blagrove & Akehurst, 2000; Dorrian et al., 2000; Dorrian et al., 2003), with participants either over or underestimating their performance. The results of the current study suggest that, as seen in using non-sleep deprivation testing conditions, people tend to overestimate their performance levels.

It is important to note that in addition to finding that the participants overestimated their performance levels, the results from the current study suggest that total sleep deprivation could potentially exaggerate this overestimation. The current results found that participants in the total sleep deprivation condition overestimated their performance more so than participants in the partial sleep deprivation condition. To date there is no literature comparing self-assessment under these two sleep deprivation conditions. This is the first study that found that participants subjected to total sleep deprivation seem to be vulnerable to logical reasoning performance decrements and overestimations of their own performance in comparison to partially sleep-deprived participants.

There is a possibility that self-assessed ratings of performance could be at least partially due to internal states that are largely separate from actual performance. Previous sleep deprivation research has indicated that participants potentially base their estimated performance solely on their level of alertness (Dorrian et al., 2000; Dorrian et al., 2003; Gillberg et al., 1994). Since participants in the total sleep deprivation study were
experiencing increasing fatigue as the day progressed, perhaps that explains why they rated their level of performance as decreasing. On the other hand, participants in the partial sleep deprivation condition likely did not feel that their level of alertness was decreasing throughout the day and therefore did not estimate that their performance was decreasing. Although we are unable to separate the possible effects of increasing sleepiness versus actual performance on estimated performance in the current study, the idea that participants use their level of alertness to rate their own performance does not account for the fact that participants in the total sleep deprivation condition overestimated their performance by a greater amount than those in the partial sleep deprivation condition.

When participants were asked how confident they were in their self-assessments, they remained highly confident, even when sleep deprived. This indicates that participants will say they are confident in their ability to perform well, even though this confidence is unjustified. There is currently no research that has specifically looked at a participant’s confidence level under sleep deprivation conditions, but the results of this study support the literature demonstrating that people are, in general, overconfident in their judgments (e.g., Dunning et al., 2004; Dunning & Story, 1991; Lundeberg et al., 1994; Pallier et al., 2002). In other words, neither total nor partial sleep deprivation had an effect on overconfidence in performance ability.

**Limitations and Future Research**

One limitation of the current study is the use of college students as participants. College students tend to have sleeping patterns that differ from the rest of the population...
(Buboltz, Jr., Brown, & Soper, 2001; Coren, 1994; Tsai & Li, 2004), so it is possible that they might be more accustomed to receiving less sleep. Because of this, college students could potentially perform better under sleep-deprivation conditions than non-college students. However, this limitation actually strengthens the results because we might expect older workers to be even more sensitive to the effects of total sleep deprivation. Future research should examine the performance of typical employees under similar sleep deprivation conditions to determine if their pattern of results is comparable.

Another limitation of the current study is the fact that there was no control situation. Participants in both studies were subjected to some form of sleep deprivation. A possible control study could have participants sleep a full seven to eight hours and then complete the logical reasoning task over the course of the day. However, because participants in the partial sleep deprivation condition were able to maintain performance, it seems unlikely that participants who received a full night of sleep would perform any worse. For the participants who experienced total sleep deprivation, they had the additional issue of having to work overnight. One way to help control for circadian rhythm effects would be to subject participants to total sleep deprivation and then have them complete the task during the following day. This could potentially help to separate the effects of the circadian rhythm and total sleep deprivation. However, this scenario would not control for the increasing number of hours without sleep which would potentially result in a different confound. Unfortunately, creating a true control condition for a sleep deprivation and sustained operations paradigm is problematical. Nonetheless, the current research design allows us to compare performance between well-rested and
increasingly-fatigued states, allowing us to draw conclusions about the effects of our fatigue-inducing procedure on actual and estimated performance.

Another avenue that future research could explore is whether or not some sort of “calibration” could help participants more accurately estimate their performance. Studies should examine whether or not participants informed of their actual performance after completion of a task at the beginning of a study would be more accurate during the rest of the testing sessions. In the current study, participants were correct in their estimation of the trends of their performance; a “calibration” to establish accuracy at the beginning of the study could potentially alert them to their actual levels of performance and subsequently make them more accurate throughout the remaining sessions.

Future research should also continue to examine how other types of logical reasoning tasks are affected by both total and partial sleep deprivation. The current study utilized one type of logical reasoning task, while most previous research has focused on a simple grammatical reasoning task. In addition, research still has not definitively determined which types of cognitive tasks are susceptible to the effects of sleep deprivation and which are not. Future studies should continue to examine these differences. Another area that has received limited attention in the literature is how partial sleep deprivation specifically affects performance. Since this type of sleep deprivation is probably more common than total sleep deprivation in today’s society, it is important that we continue to expand our knowledge of how it affects performance on a variety of tasks.
Finally, there is very little literature to date on how participants are able to self-assess their own performance while sleep deprived. Future research should continue to study how well sleep-deprived participants are able to self-monitor their performance. These studies should examine both total and partial sleep deprivation conditions and the self-assessment of performance on a variety of tasks. In addition, research should continue to examine participant confidence levels in self-assessed performance to determine whether or not the level of confidence is justified. Specifically, studies should further examine the findings of this research that total sleep deprivation brings about higher levels of performance overestimation, even though there is a trend for decreasing performance across the sleep deprivation period.

To summarize, total sleep deprivation negatively affects performance on a logical reasoning task, though people are able to maintain performance when experiencing partial sleep deprivation. Employers should be aware that employees who have experienced total sleep deprivation will be unable to maintain logical reasoning performance. However, if an employee has only experienced partial sleep deprivation (receiving approximately five hours of sleep), he or she should be able to perform adequately throughout the workday. When asked to rate their own levels of performance, participants gave values that were higher than the actual values for every session of the study. This overestimation persisted, even though participants were accurate in their self-assessment of performance trends. Participants also remained very confident in their self-assessed performance estimations. In other words, if an employer asks employees to rate their performance, they will do so with a great level of confidence, even though their
self-assessed performance will be greater than their actual performance. Employees who have been subjected to total sleep deprivation will not only experience significant decrements in logical reasoning performance, but they will also overestimate their level of performance more so than their better-rested, and better-performing, counterparts.
APPENDICES
Appendix A

Background Information Completed by Potential Participants

Participant Number:                Name:
Home number:                      Cell Number:              Email:

Screening Questionnaire

Marital Status:       Age:        Sex:  
Height: feet inches  Weight: lbs

1. What is your native (mother) language?
   If appropriate, please provide a dialect.

2. How would you rate your overall physical health?
   [ ] Poor             [ ] Good
   [ ] Fair             [ ] Excellent
   [ ] Average

3. How would you rate your overall mental health?
   [ ] Poor             [ ] Good
   [ ] Fair             [ ] Excellent
   [ ] Average

4. Do you take any medications regularly?
   [ ] Yes             [ ] No
   If yes, please list the medications and why you take them:

5. Have you ever been diagnosed with high blood pressure or diabetes?
   [ ] Yes             [ ] No

6. Have you ever been diagnosed with or hospitalized for a psychiatric or seizure disorder?
   [ ] Yes             [ ] No

7. Has anyone in your immediate family been diagnosed with or hospitalized for a psychiatric or seizure disorder?
   [ ] Yes             [ ] No

8. If you are a female, are you pregnant or think that you may be pregnant?
   [ ] Yes             [ ] No
9. Do you classify yourself as a “normal” sleeper for someone your age?  
   [ ] Yes  [ ] No

10. Do you normally sleep at night (versus normally working at night and sleeping during the day)?  
    [ ] Yes  [ ] No

11. If you have a diagnosed sleep disorder, briefly describe and indicate how long you have had the problem.

12. On average, how long do you usually sleep at night?        hours        minutes

13. How would you rate your overall sleep habits?  
    [ ] Poor        [ ] Good
    [ ] Fair        [ ] Excellent
    [ ] Average

14. Write in the average number of each of these beverages that you drink each day.  
    Caffeinated coffee        cups/day
    Decaffeinated coffee      cups/day
    Tea                       cups or glasses/day
    Carbonated soft drinks with caffeine    cans or bottles/day
    Other carbonated soft drinks    cans or bottles/day

15. Do you drink alcohol at all?  [ ] Yes  [ ] No

16. If yes, do you feel you are a normal drinker for someone your age?  
    [ ] Yes  [ ] No

17. If yes, do friends and relatives think you are a normal drinker?  
    [ ] Yes  [ ] No

18. Do you smoke or use any type of tobacco?  [ ] Yes  [ ] No
    If yes, how much per day?

19. Do you think you have a problem with drug use?  [ ] Yes  [ ] No

20. Do you think that you have normal hearing?  [ ] Yes  [ ] No

21. Do you think you have normal vision (either corrected or uncorrected)?  
    [ ] Yes  [ ] No

22. Handedness:
**Personal and Family Health History**

Date__ / _____/____  Participant Number: ____________

Date of Birth____/_____/_________  Age__________

Ethnic Background: White___Black___Asian___Hispanic___Native American___Other___

Gender (sex)  Male___ Female _____

Are you currently under a doctor’s care?  
Yes____ No____ What for?________________

Are you currently taking any prescription medication? Yes____ No____  
If so, please list name of medication and why you take it________________________

Females only: Date of onset of last menstrual period  / /  
Are you currently taking birth control pills? Yes_____ No_____
How many days usually pass between two menstrual cycles?________

Have any of your family members ever been treated for the following?  
Please indicate the number of affected relatives and which side of the family the affected grandparent is on (mother or father's side). If you indicate that siblings are affected, please indicate if they are step or half-siblings by writing this in the corresponding block.

<table>
<thead>
<tr>
<th></th>
<th>Siblings</th>
<th>Parents</th>
<th>Grandparents</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney Disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness or Fainting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating Disorders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic Depression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizophrenia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Traumatic Stress Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

48
Here is a list of chronic health conditions. Please check any that apply to you.

Have you ever had or do you presently have:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberculosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Attack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angina (chest pain)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal Heart Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emphysema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Illness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitalized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Outs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gout</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nervousness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint Problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney Disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness/Fainting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convulsions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paralysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headaches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shortness of Breath</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulcers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hernia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Cramps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insomnia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating Disorders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizophrenia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Traumatic Stress Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (Explain)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you answered "yes" to any of the conditions above, or if you have additional comments, please write a brief explanation below:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Appendix B

Available Dates Information Completed by Potential Participants for Study 1

Available Dates:

Please select all of the following dates for which you would be available for testing. Simply click inside the grey box to select that date (an X will appear inside the box). If you are selected for testing, you will only be required to be here for one set of dates (e.g. Fri/Sat or Sat/Sun). We are asking for available dates so that we may schedule participants to effectively conduct our study. While we will conduct a maximum of one set of experiments on any weekend, it may vary whether we test Fri/Sat or Sat/Sun). Thank you for your time.

Note: The first day is the day the test begins and the second day is when it ends. (i.e. Fri/Sat Feb. 24/25 begins on Friday February 25 and ends on Saturday February 26.)

<table>
<thead>
<tr>
<th>Fri/Sat Dates</th>
<th>Sat/Sunday Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 24/25</td>
<td>February 25/26</td>
</tr>
<tr>
<td>March 3/4</td>
<td>March 4/5</td>
</tr>
<tr>
<td>March 10/11</td>
<td>March 11/12</td>
</tr>
<tr>
<td>March 17/18</td>
<td>March 18/19</td>
</tr>
<tr>
<td>March 24/25</td>
<td>March 25/26</td>
</tr>
<tr>
<td>March 31/April 1</td>
<td>April 1/2</td>
</tr>
<tr>
<td>April 7/8</td>
<td>April 8/9</td>
</tr>
<tr>
<td>April 14/15</td>
<td>April 15/16</td>
</tr>
<tr>
<td>April 21/22</td>
<td>April 22/23</td>
</tr>
<tr>
<td>April 28/29</td>
<td>April 29/30</td>
</tr>
</tbody>
</table>
Appendix C

Sleep Log Completed by Participants

Sleep Log

Instructions: Please complete the following sleep log regarding your sleep last night.
1. Estimate your total time in bed last night with the intention of sleeping. Give hours and minutes. (for example: 7 hrs 15 mins): ___________
2. Estimate your total time asleep last night (hrs and mins): ___________
3. Estimate the total number of awakenings that you experienced during the night: ____
4. Estimate the time in minutes that you napped or dozed yesterday: __________
5. Estimate the time you went to bed with the intention of sleeping last night: ________
6. Estimate the time you got out of bed this morning: __________

Instructions: For each of the following scales please make a vertical mark on the scale to indicate how you would answer the question.

For example, if you feel very hungry, you might make the following mark:

not hungry          hungry

7. Rate how well you slept last night:

very poorly           very well

8. Rate how easily you fell asleep last night:

very difficult              very easy

9. Rate how easily you woke up this morning:

very difficult           very easy

10. Rate how calm your sleep was last night:

very restless           very calm

11. Rate how refreshed you felt upon awakening this morning:

not at all refreshed       completely refreshed
Appendix D

Meta-Cognition Survey Completed by Participants after Completing the LSAT in Study 1

The following questions refer to the logic task that you just completed and the answers you provided.

1. How many out of the 24 total questions did you answer?  ________

2. How many of the questions that you answered do you think you answered correctly (0% = none to 100% = all questions)? ________ %

3. How confident are you in your answer to number 2 above (0% = not confident at all to 100% = totally confident)? ________ %

4. How many of the questions that you answered would you say you had NO idea of the correct answer and just guessed (0% = none to 100% = all questions)? ________ %
   If you answered 0%, please skip to number 5 below.
   4a. How many of these questions do you think you got correct (0% = none to 100% = all questions)? ________ %
   4b. How many of these questions do you think you got wrong (0% = none to 100% = all questions)? ________ %

5. How many of the questions that you answered would you say you had SOME idea of the answer but you weren’t sure (0% = none to 100% = all questions)? ________ %
   If you answered 0%, please skip to number 6 below.
   5a. How many of these questions do you think you got correct (0% = none to 100% = all questions)? ________ %
   5b. How many of these questions do you think you got wrong (0% = none to 100% = all questions)? ________ %

6. How many of the questions that you answered would you say you KNEW the answer (0% = none to 100% = all questions)? ________ %
   If you answered 0%, please skip to number 7 below.
   6a. How many of these questions do you think you got correct (0% = none to 100% = all questions)? ________ %
   6b. How many of these questions do you think you got wrong (0% = none to 100% = all questions)? ________ %

7. If you answered less than 100% on question 2 above, please rank order the following factors according to how you think each factor may have affected your ability to answer correctly. Please assign the numbers 1, 2, 3, 4, and 5 where the number 1 indicates the
most important factor and number 5 indicates the least important factor. If you think that two or more of the factors were equally important, please assign them the same number.

- Difficulty paying attention to the material
- Difficulty remembering the material
- Difficulty understanding the material
- Lack of interest in the material
- Lack of time to complete the task

8. Did something other than the five factors listed above affect your ability to answer correctly?
   - [ ] Yes  
   - [ ] No

If so, what? _____________________________________________________________
Appendix E

Verbal Instructions Given to Participants in the Training Session for Study 1

Verbal Instructions for the Training Session

“We are now going to start training. The schedule for the day includes an hour of training this morning followed by lunch. Then, we have a paper-pencil task, a short break, and then a second training session, which is approximately 2 hours long. Afterwards is a break followed by a series of surveys, and then dinner.”

Standardized Test Training Block:
“‘You will now take several minutes to look over three standardized tests. Included are a verbal, quantitative and logic task. Please let a researcher know once you are finished.’”
Appendix F

Verbal Instructions Given to Participants in the Testing Sessions for Study 1

Verbal Instructions for Testing:

LSAT—Logic
“Now you are going to take the standardized logic task. You have 30 minutes to complete this task, and you must take at least 20 minutes to complete this task. Please let an experimenter know when you have finished. Afterwards, you will be given time to complete the questionnaire that is attached to the back of your answer sheet.”

<<Researcher: Use the appropriate color stopwatch to time the task>>
Appendix G

Study Description and Informed Consent Document Given to Participants for Study 1

Consent Form for Participation in a Research Study
Clemson University

Stress, Fatigue, and Language Abilities: Effects of Sleep Deprivation on Prolonged Performance and Subjective Assessments

Description of the research and your participation

You are invited to participate in a research study conducted by Dr. June J. Pilcher. The purpose of this research is to examine the effects of sleep deprivation on a variety of performance tasks and subjective measures. Approximately 30 volunteers will complete the research procedures described below.

Your participation will involve the following procedures:

♦ Potential participants will initially complete a screening survey that includes questions on their current health, family history of health problems, drug use, alcohol use, native language speaker, and sleep habits. This survey will be used for screening volunteers for participation. The survey will take approximately 15 minutes to complete.

♦ Volunteers that meet the criteria for participation will meet with a research associate 3 days before the start of the experiment to pick up an acti-watch (a device that provides an objective measure of body activity) and a self-report sleep log. The volunteers will wear the acti-watch for the 3 days prior to the onset of the experiment. Concurrently, the volunteers will complete a self-report sleep/activity log.

♦ Volunteers will agree to allow us to access your TOEFL scores from Admissions at Clemson University. Signing this consent form indicates your willingness to allow us to access your TOEFL scores.

♦ Volunteers will sleep for approximately 8 hours the night before the experiment. They will go to bed between 11:30 PM and 1 AM and get up between 7:30 and 9 AM.

♦ Volunteers will report to the sleep lab (Brackett 316A) at 9:30 AM and will be transported to the Sustained Operations Lab (1924 Shiloh Rd., Seneca, SC  29678).

♦ Volunteers will turn in their acti-watches and completed sleep logs upon arrival at the Sustained Operations Lab. Between about 10 AM and the start of the experiment at 6:30 PM, volunteers will complete several self-report measures on subjective concepts such as mood, health, emotions, anxiety, and personality, will be trained on the tasks that will be completed during the experimental period, and will complete a one hour cognitive task.
There will be regular breaks during the day when participants can watch TV shows, movies, study, or play board games. Lunch and dinner will be provided during the day as well as snacks and non-caffeinated drinks.

The experimental night will start at 6:30 PM. There will be 4 four-hour testing sessions with 30 minute breaks between the sessions during the night. Participants will complete a series of computer and paper/pencil tasks during each testing session. A final one hour cognitive task will be completed at the end of the four testing sessions. All tasks will be completed by 1:30 PM the next day. Sandwiches, snacks, and non-caffeinated drinks will be provided during the testing periods. Participants will be provided with transportation from the Sustained Operations Lab to their homes at the conclusion of the experiment.

While at the lab, some non-invasive physiological measures will be taken: oral temperature, blood pressure, and eye activity. Oral temperature will be taken with a digital thermometer using a disposable sheath. Blood pressure will be taken with an automated vital signs device. Eye activity will be monitored for brief periods of time (less than 1 minute) in response to light flashes. Most of the tasks and surveys will be either computer-generated or paper/pencil. Your responses on all tasks and surveys will be identified only with your participant number. One task will require a verbal response (naming a picture). This verbal response will be recorded onto a cassette tape and will be identified only with your participant number.

Wireless cameras will be used at the lab to help the research associates monitor the volunteers activity during the study. No permanent recordings of this activity will be made. Cameras are only mounted in the testing areas and in the “social” areas at the lab (living room, kitchen).

Numerous times throughout the sleep deprivation period, participants will be asked to complete surveys that assess their experiences during the testing period. For example, participants will be asked to assess the amount of effort, motivation, sleepiness, or enjoyment they are experiencing while completing tasks. In addition, participants will be asked to subjectively assess their ability to perform a task.

Volunteers are urged to nap during the day following sleep deprivation and to sleep 8 to 9 hours that night. Please remember not to drive or operate any power equipment until after sleeping.

Volunteers will be expected to do their best when training for the tasks and when completing all tasks. Volunteers who are obviously not trying to successfully complete the tasks will be removed from the study at the discretion of the principle investigator or the research associates. Volunteers may also choose to remove themselves from the study at any time.

The amount of time required for your participation will be a total of 28 hours. During those 28 hours, you will complete tasks and surveys for 21.5 hours.
Exclusion criteria

You may not take part in this study if you:

1. are less than 18 or greater than 35 years old.
2. are a native English speaker.
3. report excessive drug or alcohol use.
4. have ongoing medical conditions that require chronic medication (women on birth control pills may participate).
5. have ongoing use of psychoactive medication for depression, bipolar illness, anxiety, or ADD/ADHD.
6. have ever been a patient in a psychiatric hospital.
7. have a seizure disorder.
8. have a family history of psychiatric disorders of seizure disorders.
9. are pregnant.
10. have a documented sleep disorder.
11. use tobacco in any form.
12. report abnormalities with vision or audition.

Risks and discomforts

There are certain risks or discomforts associated with this research. They include the following:

♦ Some people react negatively to sleep deprivation. To minimize this risk, each volunteer will be assessed for known health-related risks as well as pre-existing sleep disorders. Volunteers at risk due to health-related conditions will be excluded from the study. If at any time you believe you are experiencing a negative reaction the sleep deprivation procedure, please inform the research associate and remove yourself from the study.

♦ Most people experience some level of fatigue following a night of sleep deprivation. To minimize this risk, volunteers are urged to only participate in the night of sleep deprivation if they do not have a class or other major obligation the next day. In addition, the study has been extended until the early afternoon. At that time, most participants will start to feel more alert independent of the sleep-deprived state. In addition, volunteers will be informed at the onset of the study about the dangers of driving a car or operating power equipment following a night of sleep deprivation without sleeping first. Participants will be urged to go home and nap for several hours as soon as possible after the conclusion of the study. In addition, the participants will be urged to sleep at least 8 hours the following night. A nap and 8 hours of sleep will provide enough rebound sleep in insure that the participants have recovered sufficiently from the night of sleep deprivation to return to classes and their other obligations.

♦ Some people dislike or find it uncomfortable to respond to some self-report surveys such as mood (depression, anxiety), personality, or health. If you feel uncomfortable
about the idea of honestly completing surveys on these types of topics, please inform
the research associate and remove yourself from the study.

- Participation in this study will require prolonged effort in completing the self-report
surveys and the different types of tasks. Completing the surveys and tasks will take
approximately 21.5 hours during the 28 hour period at the Sustained Operations Lab.
Some people may find this to be too much work and decide that they are unwilling to
complete the study. If you decide not to complete the study, please inform the
research associate and remove yourself from the study. If you choose to do this, you
will not receive any monetary compensation. If you choose to stay at the lab but
simply rest, the research associate will allow you to use one of the bedrooms at the
lab to rest and relax. You would then be transported home with the other participants
at the conclusion of the study. You can also choose to leave the lab if you quit and
can use the lab phone to arrange transportation home.

Potential benefits

The current study has many benefits. The data collected in this study will contribute to
our growing understanding of the effects of short-term sleep deprivation. This is a
particularly pertinent topic in our society where many people, including college students,
voluntarily stay awake at night. In addition, these data will be useful in work
environments where workers are required to stay awake at night to work on the night
shift.

The participants’ personal benefits include the opportunity to earn $150 for completing
the entire study including: completing the sleep log for 3 days prior to the study, wearing
the Actiwatch to monitor body activity for 3 days prior to the study, sleeping about 8
hours the night before the study, reporting to the campus lab by 9:30 AM the day of the
study, staying awake for about 30 hours, being at the Sustained Operations Lab for about
28 hours, and successfully completing tasks and surveys for about 21.5 hours.

It is not possible to predict whether or not any personal benefit will result from your
participation in this study. You understand that the information that is obtained from this
study may be used scientifically and may be helpful to others.

Protection of confidentiality

We will do everything we can to protect your privacy. Your performance and subjective
data will only be entered into data sets by your unique participant number. Your identity
will not be revealed in any publication that might result from this study.)

In rare cases, a research study will be evaluated by an oversight agency, such as the
Clemson University Institutional Review Board or the federal Office for Human
Research Protections, that would require that we share the information we collect from
you. If this happens, the information would only be used to determine if we conducted this study properly and adequately protected your rights as a participant.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. If you choose to withdraw, the research associates will either help make you comfortable and allow you to rest in a bedroom at the lab or will let you use the lab phone to call someone and make transportation arrangements home. However, the monetary compensation ($150) will only be paid to those who complete the entire study.

Participants may be removed from the study at any time at the discretion of the principle investigator and the research associates. The most likely reasons for being removed from the study include:

1. Not completing and returning the daily sleep log as directed.
2. Not wearing the acti-watch as directed or not returning the acti-watch at the start of the experiment.
3. Not sleeping on the night before sleep deprivation.
4. Drinking alcohol the day before the study.
5. Not working on and/or focusing on the tasks as directed during the night of sleep deprivation.
6. Not cooperating with the research associates during the night of sleep deprivation.

You will be informed of any significant new information regarding this study that may affect your willingness to continue in this study.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Dr. June J. Pilcher at 864-656-4985. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Institutional Review Board at 864.656.6460.

Consent

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant’s signature: ________________________________ Date: ______________

A copy of this consent form should be given to you.
## Appendix H

### Available Dates Information Completed by Potential Participants for Study 2

Please select all of the following dates for which you would be available for testing. Simply click inside the grey box to select that date (an X will appear inside the box). If you are selected for testing, you will only be required to be here for one set of dates (ex Fri/Sat or Sat/Sun). We are asking for available dates so that we may schedule participants to effectively conduct our study. While we will conduct a maximum of one set of experiments on any weekend, it may vary whether we test Fri/Sat or Sat/Sun). Remember an “X” inside a box means that you are available on those dates for testing. Thank you for your time.

### Available Dates:

<table>
<thead>
<tr>
<th>Fri/Sat Dates</th>
<th>Sat/Sunday Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feb 23/24</td>
</tr>
<tr>
<td></td>
<td>Feb 24/25</td>
</tr>
<tr>
<td>March</td>
<td></td>
</tr>
<tr>
<td></td>
<td>March 2/3</td>
</tr>
<tr>
<td></td>
<td>March 3/4</td>
</tr>
<tr>
<td></td>
<td>March 9/10</td>
</tr>
<tr>
<td></td>
<td>March 10/11</td>
</tr>
<tr>
<td></td>
<td>March 16/17</td>
</tr>
<tr>
<td></td>
<td>March 17/18</td>
</tr>
<tr>
<td></td>
<td>March 17/18</td>
</tr>
<tr>
<td></td>
<td>March 23/24</td>
</tr>
<tr>
<td></td>
<td>March 24/25</td>
</tr>
<tr>
<td></td>
<td>March 30/31</td>
</tr>
<tr>
<td>April</td>
<td></td>
</tr>
<tr>
<td></td>
<td>April 13/14</td>
</tr>
<tr>
<td></td>
<td>April 14/15</td>
</tr>
<tr>
<td></td>
<td>April 20/21</td>
</tr>
<tr>
<td></td>
<td>April 21/22</td>
</tr>
<tr>
<td></td>
<td>April 27/28</td>
</tr>
<tr>
<td></td>
<td>April 28/29</td>
</tr>
</tbody>
</table>
Appendix I

Meta-Cognition Survey Completed by Participants after Completing the LSAT in Study 2

The following questions refer to the logic task that you just completed and the answers you provided.

1. How many out of the 24 total questions did you answer? ________

2. How many of the questions that you answered do you think you answered correctly (0% = none to 100% = all questions)? ________ %

3. How confident are you in your answer to number 2 above (0% = not confident at all to 100% = totally confident)? ________ %

4. If you answered less than 100% on question 2 above, please rank order the following factors according to how you think each factor may have affected your ability to answer correctly. Please assign the numbers 1, 2, 3, 4, and 5 where the number 1 indicates the most important factor and number 5 indicates the least important factor. If you think that two or more of the factors were equally important, please assign them the same number.
   Difficulty paying attention to the material ________
   Difficulty remembering the material ________
   Difficulty understanding the material ________
   Lack of interest in the material ________
   Lack of time to complete the task ________

5. Did something other than the five factors listed above affect your ability to answer correctly?
   □ Yes    □ No
   If so, what? ____________________________________________________
Appendix J

Verbal Instructions Given to Participants in the Training Session for Study 2

Verbal Instructions for the Training Session

First read the following instructions for the sleeping period and for how participants will be awakened.

Rules for the sleeping period:
- If you would like to shower at night, you may go upstairs 15-20 minutes early
- At 1 a.m. you must be in your room, in bed, with the lights out
- The only reason you should get out of bed during the night is to use the bathroom
- You may only come downstairs for something to drink or if there is a problem and you need to speak with a researcher
- We will make sure each alarm clock is set for 6:00 a.m. and to ALARM

How you will be awakened:
- If you are not downstairs by 6:05 a.m., one of us will knock on your door and tell you to wake up
- Please come downstairs as soon as you wake up (you may use the bathroom first), and then you will have until 7 a.m. to shower and eat breakfast
- Do not fall asleep during this hour; we will ensure that you don’t!

The following instructions are for the actual training session.

“Okay, we are now going to start training. You will have about an hour of training followed by a half-hour break. We will then take your oral temperature and your blood pressure. Next you will complete a second hour-long training session. Afterwards you will complete a series of surveys and we will take your oral temperature and blood pressure again. You will then have a break until 1 a.m., although we will take your oral temperature and blood pressure at 12:30 a.m. At 1 a.m., you will go to bed. An alarm clock will wake you up at 6 a.m. and you will have an hour to shower and eat breakfast. Your first testing session will begin at 7 a.m. tomorrow morning.”

“We will be taking your blood pressure, using your non-dominant arm, several times during the study. You should rest your arm on the armrest of your chair and not move it unnecessarily during the measurements. During the resting periods, try not to speak or move around.”
Standardized Test Training Block:
“Now you will look at three standardized test sections. For each of these tasks, you will use a standard fill-in-the-bubble answer sheet. During the testing sessions tomorrow you will be allowed 15 minutes on each of the three tasks. If you have not finished after the allotted time, the researchers will ask you to stop and move on to the next task.”

Verbal
“First look over the instructions and sample problems in your verbal packet. Remember you must take the full 15 minutes to complete this task during the testing sessions tomorrow. If you finish the test in less than 15 minutes, please check your answers. Also take a moment to look over the answer sheet.”

“During the testing sessions tomorrow, we will take your blood pressure several times while you are taking the standardized verbal task. While you take this task, your non-dominant arm, wearing the blood pressure cuff, should remain on the armrest of your chair. Continue working as normal while we take your blood pressure.”

Quantitative
“Next look over the instructions and sample problems in your quantitative packet. Remember you must take the full 15 minutes to complete this task during the testing sessions tomorrow. If you finish the test in less than 15 minutes, please check your answers. Also take a moment to look over the answer sheet.”

“During the testing sessions tomorrow, we will take your blood pressure several times while you are taking the standardized quantitative task. While you take this task, your non-dominant arm, wearing the blood pressure cuff, should remain on the armrest of your chair. Continue working as normal while we take your blood pressure.”

Logic
“Next look over the instructions and sample problems in your logic packet. Remember you must take the full 15 minutes to complete this task during the testing sessions tomorrow. If you finish the test in less than 15 minutes, please check your answers. Also take a moment to look over the answer sheet.”

“During testing, when you finish this task, please tell a researcher that you are done. You will then be asked to complete a short survey about your answers on this task.”

“We will not be taking your blood pressure during the task, but you will have to continue to wear the cuff.”

“Please take a moment to look over all of the documents in your packet. Let me know if you have any questions.”
Appendix K

Verbal Instructions Given to Participants in the Testing Sessions for Study 2

Verbal Instructions for Testing:

**LSAT—Logic:**
“Now you are going to take the standardized logic task. You have 15 minutes to complete this task. Please let an experimenter know when you have finished. Afterwards, you will be given time to complete the questionnaire that is attached to the back of your answer sheet.”

<<Researcher: Use the appropriate color stopwatch to time the task>>
Appendix L

Study Description and Informed Consent Document Given to Participants for Study 2

Consent Form for Participation in a Research Study
Clemson University

Stress and Fatigue in the Workplace: Effects of Sustained Operations and Sleep Deprivation on Performance and Subjective Assessments

Description of the research and your participation

You are invited to participate in a research study conducted by Dr. June J. Pilcher. The purpose of this research is to examine the effects of sustained operations and sleep deprivation on a variety of performance tasks and subjective measures. Approximately 30 volunteers will complete the research procedures described below.

Your participation will involve the following procedures:
♦ Potential participants will initially complete a screening survey that includes questions on their current health, family history of health problems, drug use, alcohol use, native language speaker, and sleep habits. This survey will be used for screening volunteers for participation. The survey will take approximately 15 minutes to complete.
♦ Volunteers that meet the criteria for participation will meet with a research associate 3 days before the start of the experiment to pick up an acti-watch (a device that provides an objective measure of body activity) and a self-report sleep log. The volunteers will wear the acti-watch for the 3 days prior to the onset of the experiment. Concurrently, the volunteers will complete a self-report sleep/activity log.
♦ Volunteers will sleep for approximately 8 hours the night before the experiment. They will go to bed between 11:30 PM and 1 AM and get up between 7:30 and 9 AM.
♦ Volunteers will report to the sleep lab (Brackett 316A) at 5:30 PM and will be transported to the Sustained Operations Lab (1924 Shiloh Rd., Seneca, SC  29678). Volunteers will turn in their acti-watches and completed sleep logs upon arrival at the Sustained Operations Lab.
♦ Between about 6 and 10:30 PM, participants will complete a cognitive task, several self-report measures on subjective concepts such as mood, emotions, personality, and health and will be trained on the tasks that will be completed during the experimental period.
♦ Participants will have free time between 10:30 PM and 1 AM when they can watch TV shows, movies, study, or play board games. They will then have a 5 hour time
period to sleep between 1 and 6 AM. Participants will be awakened at 6 AM and will have time for showers and breakfast before starting the experimental period.

♦ The experimental period will begin at 7 AM and will end at about 7:15 PM. There will be 4 two and a half hour testing sessions with 30 minute breaks between the testing sessions. Participants will complete a series of computer and paper/pencil tasks during each testing session. A final cognitive task will be completed at the end of the four testing sessions.

♦ Food and non-caffeinated drinks will be provided during the study. Participants will be provided with transportation from the Sustained Operations Lab to their homes at the conclusion of the experiment.

♦ While at the lab, some non-invasive physiological measures will be taken: oral temperature, blood pressure, and eye activity. Oral temperature will be taken with a digital thermometer using a disposable sheath. Blood pressure will be taken with an automated vital signs device. Eye activity will be monitored for brief periods of time (less than 1 minute) in response to light flashes.

♦ The tasks and surveys will be either computer-generated or paper/pencil. Your responses on all tasks and surveys will be identified only with your participant number.

♦ Wireless cameras will be used at the lab to help the research associates monitor the volunteers activity during the study. No permanent recordings of this activity will be made. Cameras are only mounted in the testing areas and in the “social” areas at the lab (living room, kitchen).

♦ Participants will be asked to complete surveys that assess their experiences during the testing period. For example, participants will be asked to assess the amount of effort, motivation, sleepiness, or enjoyment they are experiencing while completing tasks. In addition, participants will be asked to subjectively assess their ability to perform a task.

♦ Volunteers are urged to sleep 8 to 9 hours the night after the experiment. Please remember not to drive or operate any power equipment (including a car) until after sleeping.

♦ Volunteers will be expected to do their best when training for the tasks and when completing all tasks. Volunteers who are obviously not trying to successfully complete the tasks will be removed from the study at the discretion of the principle investigator or the research associates. Volunteers may also choose to remove themselves from the study at any time.

The amount of time required for your participation will be a total of 26 hours. During those 26 hours, you will complete tasks and surveys for 16 hours.

**Exclusion criteria**

You may not take part in this study if you:

1. are less than 18 or greater than 30 years old.
2. are a non-native English speaker.
3. report excessive drug or alcohol use.
4. have ongoing medical conditions that require chronic medication (women on birth control pills may participate).
5. have ongoing use of psychoactive medication for depression, bipolar illness, anxiety, or ADD/ADHD.
6. have ever been a patient in a psychiatric hospital.
7. have a seizure disorder.
8. have a family history of psychiatric disorders or seizure disorders.
9. are pregnant.
10. have a documented sleep disorder.
11. use tobacco in any form.
12. report abnormalities with vision or audition.

**Risks and discomforts**

There are certain risks or discomforts associated with this research. They include the following:

♦ Some people react negatively to sleep deprivation. To minimize this risk, each volunteer will be assessed for known health-related risks as well as pre-existing sleep disorders. Volunteers at risk due to health-related conditions will be excluded from the study. If at any time you believe you are experiencing a negative reaction the sleep deprivation procedure, please inform the research associate and remove yourself from the study.

♦ Most people experience some level of fatigue following a study of this type. To minimize this risk, volunteers are urged to only participate in the study if they do not have a class or other major obligation the next day. Participants will be provided with transportation home will be urged to sleep at least 8 hours that night. In addition, volunteers will be informed at the onset of the study about the dangers of driving a car or operating power equipment following the study without sleeping first.

♦ Some people dislike or find it uncomfortable to respond to some self-report surveys such as mood (depression, anxiety), personality, or health. If you feel uncomfortable about the idea of honestly completing surveys on these types of topics, please inform the research associate and remove yourself from the study.

♦ Participation in this study will require prolonged effort in completing the self-report surveys and the different types of tasks. Completing the surveys and tasks will take approximately 16 hours during the 26 hour period at the Sustained Operations Lab. Some people may find this to be too much work and decide that they are unwilling to complete the study. If you decide not to complete the study, please inform the research associate and remove yourself from the study. If you choose to do this, you will not receive any monetary compensation. If you choose to stay at the lab but simply rest, the research associate will allow you to use one of the bedrooms at the lab to rest and relax. You would then be transported home with the other participants.
at the conclusion of the study. You can also choose to leave the lab if you quit and can use the lab phone to arrange transportation home.

**Potential benefits**

The current study has many benefits. The data collected in this study will contribute to our growing understanding of the effects of sustained operations and partial sleep deprivation. This is a particularly pertinent topic in our society where many people, including college students, voluntarily deprive themselves of sleep. In addition, these data will be useful in work environments where 12-hour work days have become increasingly common.

The participants’ personal benefits include the opportunity to earn $100 for completing the entire study including: completing the sleep log for 3 days prior to the study, wearing the Actiwatch to monitor body activity for 3 days prior to the study, sleeping about 8 hours the night before the study, reporting to the campus lab by 5:30 PM the day of the study, being at the Sustained Operations Lab for about 26 hours, and successfully completing the study protocol. Participants will be paid $100 upon successful completion of all parts of the study.

It is not possible to predict whether or not any personal benefit will result from your participation in this study. You understand that the information that is obtained from this study may be used scientifically and may be helpful to others.

**Protection of confidentiality**

We will do everything we can to protect your privacy. Your performance and subjective data will only be entered into data sets by your unique participant number. Your identity will not be revealed in any publication that might result from this study.

In rare cases, a research study will be evaluated by an oversight agency, such as the Clemson University Institutional Review Board or the federal Office for Human Research Protections, that would require that we share the information we collect from you. If this happens, the information would only be used to determine if we conducted this study properly and adequately protected your rights as a participant.

**Voluntary participation**

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. If you choose to withdraw, the research associates will either help make you comfortable and allow you to rest in a bedroom at the lab or will allow you to use the lab phone to call someone and make transportation arrangements.
Participants may be removed from the study at any time at the discretion of the principle investigator and the research associates. The most likely reasons for being removed from the study include:

1. Not completing and returning the daily sleep log as directed.
2. Not wearing the acti-watch as directed or not returning the acti-watch at the start of the experiment.
3. Not sleeping on the night before the study.
4. Drinking alcohol the day before or the day of the study.
5. Not working on and/or focusing on the tasks as directed during the study.
6. Not cooperating with the research associates during the study.

You will be informed of any significant new information regarding this study that may affect your willingness to continue in this study.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Dr. June J. Pilcher at 864-656-4985. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Institutional Review Board at 864.656.6460.

Consent

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant’s signature: ________________________________ Date: ______________

A copy of this consent form should be given to you.
REFERENCES


