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PARTIAL-SLEEP DEPRIVATION DIFFERENTIALLY AFFECTS SEMANTIC MEMORY ACCORDING TO WORD CLASS

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ABSTRACT

Sleep deprivation is a major health and safety concern to our society. The purpose of this study was to examine how partial sleep deprivation (PSD) differentially affects semantic memory according to three word classes: function, concrete content, and abstract content. This study extends a previous study that showed PSD giving rise to impaired semantic memory. The previous study lacked several controls that were implemented in this study in order to generalize the findings. Ninety-one participants (74 females, mean age 20) performed an immediate serial recall task involving the three classes of words, which differ in their semantic representations. Participants were grouped as PSD, intermediate, or well rested based on their hours of sleep from the night before testing, with the respective guidelines as followed: 6.5 hours or less (PSD), greater than 6.5 hours but less than 8 hours (intermediate), and 8 hours or great (well-rested). The word classes were grouped in word sequences that balance out any position effects. The PSD group recalled fewer abstract words, that have weak semantic representations, as compared to more well rested groups. It also had lower recall for the word sequence with the least semantic representations—abstract and function—as compared to more well-rested groups. Concrete words, when in the last sequence position, were recalled more frequently than function words in the last position. These results supported the prior study that PSD apparently impairs semantic memory.

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Chapter 1

Introduction

Sleep Deprivation

Adequate sleep has long been emphasized as vital to our health and wellbeing. However, sleep deprivation, the condition of not getting sufficient sleep to feel rested, has continued to remain a widespread health and safety concern in our society. Sleep deprivation can range from *acute total sleep deprivation* (TSD)—which is defined as “no sleep […] in the usual total sleep time over a period of 1-2 days” —to the more commonly practiced *chronic partial sleep deprivation* (PSD) (Kelly & Nisynboim, 2015, p. 81). PSD is defined as “. . . the reduction in the total sleep time relative to one's usual baseline […] for a prolonged period of time” (Doghramji, 2005, p. 2).

Even though the precise baseline for optimal sleep duration varies between individuals, the National Institute of Health recommends 7-8 hours of sleep daily for the average adult (U.S. Centers for Disease Control and Prevention, 2015). For college students, however, 9 hours may be more appropriate, as recommended by the American Academy of Sleep Medicine (2015). In addition, one theory has defined the duration of core sleep to be 6 hours for most adults, which is the amount of sleep necessary to “. . . repair the effects of waking wear and tear on the cerebrum,” (Dinges, Rogers, & Baynard, 2005, p. 68). Unfortunately, the U.S. Centers for Disease Control and Prevention (2015) reports that nearly one-third of the adult population does not meet these guidelines, obtaining an average of only six hours or less of sleep per night.

Many factors can contribute to sleep restriction, including work-related demands (e.g. long working shifts), family responsibilities (e.g. rearing young children), and health conditions (e.g. sleep disorders). Regardless of the cause, sleep loss can have detrimental effects on cognitive functions. An ample amount of studies has demonstrated consequent impairments to various domains of cognition, including attention, visuomotor functions, verbal functions, reasoning ability, decision-making, divergent thinking, creativity, working memory, and long-term memory (Raidy & Scharff, 2005; Boca & Denise, 2006; Harrison & Horne, 1999; McCarthy & Waters, 1997; Linde, Edland, & Bergstrom, 1999; Alhola & Polo-Kantola, 2007). The two most extensively researched domains are attention and working memory (Alhola & Polo-Kantola, 2007).

Attention is referred to as "…the process that, at a given moment, enhances some information and inhibits other information, and it serves as a basic foundation to higher level cognition (Smith & Kosslyn, 2006, p. 103). Thus, it has been a focus of many sleep deprivation studies. The Psychomotor Vigilance Test (PVT), a simple reaction-time test, is the most widely employed task in assessing alertness and vigilance (Dinges & Powell, 1985). The overall reaction time on the PVT increases according to the length of the SD period (Lim & Dinges, 2008). Furthermore, in a study using fMRI, Drummond et al. (2005) demonstrated that fast reaction times on the PVT were associated with neural reactions in the sustained-attention network of the cortex. Sleep deprivation also leads to increase in attentional lapses (i.e. failure to respond to cue in a timely fashion, defined as response time exceeding 500 ms in length) and increase in errors of commission or false alarms (i.e. responding when no cue is present or incorrect responses (Killgore, 2010). However, it has been argued that the effect of SD is stronger on simpler, less engaging tasks (i.e. the PVT), and is not adequate to predict performance on other traditionally more complex tasks, such as those assessing working-memory (Lo et al., 2012).

A number of studies have also demonstrated compromised effects of working memory from SD. Since frontal brain areas—responsible for working memory—are susceptible to SD, it can be hypothesized that working memory is affected by SD (Harrison & Horne, 2000; Thomas et al., 2000; Alhola & Polo-Kantola, 2007). Indeed, in a study by Van Dongen, Maislin, Mullington, and Dinges (2003), working memory performances progressively declined after sleep durations were chronically restricted to four and six hours per night. Results from another study as well (Lo et al., 2012) confirmed that the effect of PSD on working memory is significant, but the effect seems to be greater on sustained attention for acute TSD.

As a result of these cognitive deficits, sleep deprivation can significantly increase the risk of human-error-related accidents. The National Highway Traffic Safety Administration (2016) conservatively estimated that between the years 2005 and 2009 an average of 83,000 motor vehicle crashes each year was related to drowsy (i.e. a symptom of SD) driving. In fact, sleepiness-related crashes have fatality rates and injury severity comparable to that of alcohol-related crashes (Durmer & Dinges, 2005). Moreover, an epidemiological study revealed that disturbed sleep increases the risk of fatal occupational accidents by 50% (Akerstedt, Fredlund, Gillberg, & Jansson, 2002). Sleep loss has also contributed to several major human disasters, most notably the Space Shuttle Challenger Accident (Mitler et al., 1988), as well as the Three Mile Island, PA and Chernobyl, Russia, atomic power plant damages, and Bhopal, India chemical factory poisoning catastrophes. These types of accidents also put a financial burden on the economy, which estimated a cost of $43 to $56 billion every year (Goel, Rao, Durmer, & Dinges, 2009).

Semantic Memory

Semantic memory—a part of the declarative memory system of the human brain — consists of all acquired facts and conceptual knowledge about the world, including people, objects, actions, states, and events (Binder & Desai, 2011). For example, the knowledge that a car has four wheels, a trunk, and a hood would be considered part of the semantic memory; whereas the knowledge of when and where you first learned how to drive a car would be referred to as part of the *episodic memory* (i.e. autobiographical information) (Alhola & Polo-Kantola, 2007). Humans have the unique ability to represent symbolically concepts in the form of language (Binder & Desai, 2011). Semantic memory, thus, plays a critical role in language comprehension, such as ascribing meanings to words (Binder, Desai, Graves, & Conant, 2009; Saumier & Chertkow, 2002).

Memory is modeled as being divided into three discrete stages: encoding (i.e. learning information), storage (i.e. organizing the information), and retrieval (i.e. accessing stored information). When a word is perceived or written, the semantic knowledge network is activated and retrieval occurs (Saumier & Chertkow, 2002). In the Level of Processing Model, Craik and Lockhart (1972) proposed a hierarchy of processing—referred to as “depth of processing”—where the “deeper” the processing, the greater the degree of semantic analysis. In turn, greater semantic complexity (i.e. more semantic features associated) has been implicated with faster retrieval processing (Hofmeister, 2011). In addition, a meta-analysis of imaging studies demonstrated that semantic processing underlying word comprehension is associated with seven different regions of the brain, all of which have been implicated with high-level integrative processes. These include 1) posterior inferior parietal lobe, 2) lateral temporal, 3) ventral temporal cortex (mid-fusiform and adjacent parahippocampal gyrus), 4) dorsomedial prefrontal cortex, 5) the inferior frontal gyrus, 6) ventromedial prefrontal cortex, and 7) posterior cingulate gyrus (Binder, Desai, Graves, & Conant, 2009).

A number of studies have cited the negative impact of sleep deprivation on semantic memory. In a study by Harrison and Horne (1998), two linguistic tasks were used to measure the effects of TSD. The first was the Haylings test, which is a sentence completion task. The second was a word generation task, where subjects were presented orally with a noun and then prompted to list as many associated verbs as possible within one minute. Results from the study showed that, after 36 hours of TSD, performance was observed to have deteriorated in both tasks. Specifically, the SD group produced more errors on the Haylings test and generating about two words less per minute as compared to the control group (Harrison & Horne, 1998). Additionally, in a laboratory-controlled study by Pilcher et al. (2007), performance on the reading comprehension subsection of the verbal section of the Graduate Record Exam significantly worsened after 28 hours of TSD. Kim et al. (2001) used the Luria-Nebraska Neuropsychological Battery to assess the effect of total sleep deprivation on functions measured on different clinical scales. This is a series of tests sensitive to brain lesioning. These included motor function, visual function, and expressive and receptive speech. While some clinical subscales did not show any difference after TSD, score of the subscale containing expressive and receptive speech did show decline (Kim et al., 2001).

Effects on Immediate Serial Recall

Several variables have been established to affect the performance of immediate serial recall (ISR). One of them is *word length*, which states that lists that contain short words are better recalled than those that contain longer words (Baddeley, Thomson, & Buchanan, 1975; Cowan, Baddeley, Elliott, & Norris, 2003). Another variable is serial position. The serial position effect is the tendency that first-presented items and the last few items in a list are better remembered as compared with the middle items (due to the primacy and recency effects, respectively). This effect has been shown to influence recall in ISR tasks as well (Neath & Crowder, 1996; Glenberg et al., 1980; Garcea, 2009).

The effects described above are attributed to verbal short-term memory (STM). However, other studies have revealed the contribution of long-term memory (LTM) in ISR (Baddeley, 1986; Baddeley & Hitch, 1974; Gregg, Freedman, & Smith, 1989; Hulme, Maughan, & Brown, 1991; Hulme, Roodenrys, Brown, & Mercer, 1995; Saint-Aubin & Poirier, 2000). The *retrieval-based hypothesis*, proposed and confirmed in a study conducted by Saint-Aubin and Poirier (2000), describes the interaction of STM and LTM in the following manner. Upon presentation of a list, a phonological representation (STM) is formed, but is subjected to degradation at recall. The degraded phonological representation, in turn, serves as a retrieval cue for accessing long-term knowledge, including that stored in the semantic memory (LTM) (Saint-Aubin & Poirier, 2000).

Present Study

The present study serves as an extension to a previous study by Derise (2015) that investigated the effects of chronic partial sleep deprivation (PSD) on semantic memory. Although its results were statistically significant, its limits include its small sample size and lack of balance in the order of presentation of the word classes. To correct these deficiencies, modifications were made in the current study to further examine the effects of PSD on semantic memory.

Function words, concrete content words, and abstract content words are three classes of words that differ by their semantic representation. Function words, which have little to no imaginable meanings, are closed-class words and serve as syntactic connectors (Münte et al., 2001). They include conjunctions, prepositions, pronouns, and articles (e.g. the, and, of).

In contrast, content words have definable semantic content and are open-class words; they include nouns, adjectives, and adverbs (Rijkhoff, 2007). Content words are divided into 1) *concrete* content words and 2) *abstract* content words. Concrete content words are concepts that can be experienced through the senses and strong semantic representation (Jefferies, Patterson, Jones, & Ralph, 2009). On the other hand, abstract content words are concepts that refer to ideas or mental states (e.g. hope, happiness); they do not readily evoke mental images and thus have weaker semantic representations than compared to content concrete words (Jefferies et al., 2009).

Recall performance was compared according to word class in ISR. As stated in the earlier studies, because of their rich and strong semantic representations, concrete words succumb less to impairment to semantic memory than words with weaker semantic representation (i.e. function words and abstract words). This has been observed in both cognitive normal individuals and semantic dementia patients (Caza & Belleville, 1999; Hoffman, Jones, Ralph, 2013; Derise, 2015). In the study by Derise (2015), PSD indeed appears to contribute to the impairment of semantic memory. However, the position, ratio (within a sequence), and length of words for each word class were not balanced. Thus, questions remained as to how much the effect was fully attributed to word class effect. In this present study, those factors were controlled and balanced. Thus, it is hypothesized that PSD (i.e. 6.5 hours or less of sleep the night before) individuals, as compared with well-rested individuals, would 1) have a lower recall for all three word classes, 2) with the lowest recall for function words; and 3) have the lowest recall for sequences containing more function and abstract content words than concrete words (i.e. 2F1C2A sequence).

Unlike the previous study, in this current study the single testing session was limited to a narrow time of the day to control for possible influence of circadian rhythm effect. In other words, differences in circadian arousal across the daytime were controlled for and not predicted to play a role in this study.

Chapter 2

Methods

Participants

Participants included 91 (74 females, 17 males) Pennsylvania State University undergraduate student volunteers from an introductory psychology course at the University Park campus. They took part in this study to fulfill a requirement for their psychology course. The mean age was 20 years. Information about the study was posted on the course management system where it was freely accessed by students of the course. Participants were then able to sign up for one session via an online scheduling tool. Informed consent was obtained from all participants in compliance with the Pennsylvania State University Institutional Review Board for human subject research study. A demographic of the participants is shown in Table 1 in the Appendix.

Materials

Data were collected using the following tasks: Immediate Serial Recall (ISR) Task, Stanford Sleepiness Scale (SSS) (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), Karolinska Sleepiness Scale (KSS) (Johns, 2009), Pittsburgh Sleep Diary (Smith & Wegener, 2003), and Mood Scale II (MSII) (Paterson, Dorrian, Furguson, Jay, & Dawson, 2013). The ISR Task consists of 30 trials of five-word sequences, presented visually on a computer screen to be recalled in order immediately following their presentation. Each ISR sequence contains words from three classes of words: concrete content words (C), abstract words (A), and function words

(F). A secondary distractor task was also included within the ISR Task to prevent deliberate rehearsal of the words. This required counting the number of seconds that elapsed during the five-word sequence presentation. The SSS and the KSS were two self-rating scales used to subjectively score participants' degree of sleepiness. The SSS is on a Likert-type scale ranging from 1 ("Feeling active, vital, alert, or wide awake") to 7 ("No longer fighting sleep, sleep onset soon; having dream-like thoughts"). The KSS ranges from 1 ("Extremely alert") to 9 ("Extremely sleepy, fighting sleep") is a comprehensive self-report questionnaire used to gather information about participant's activities (e.g. exercise, food and beverages consumed) on the day of the session, and about participant's sleep routine (e.g. sleep and wake times) and quality of the night before. The MSII uses 36 mood-related adjectives (i.e. content, frustrated) measuring various mood dimensions, including activation, and fatigue. Participants rated their current of each adjective on a three-point Likert scale (1 = not at all, 2 = somewhat/sometimes, 3 = mostly/generally). E-prime software was used to collect all computer-presented tasks, which were the ISR task, MSII, SSS, and KSS.

Immediate Serial Recall Task

Fifty of the concrete content words (C), 50 of the abstract content words (A), and 50 of the function words (F) were selected mostly from a compilation of the top 10,000 most frequently used words in American English (Davies, 2012). This was to control for a possible word frequency effect of recalling words of higher frequency with more ease, and thus producing faster times, as compared with words of lower frequency. Only nouns were chosen for the C words. This class names objects that can generally be detected by the five physical senses (e.g.

“bird” or “tree”), whereas A-class words cannot—they generally only exist in the mind (e.g. “hope” or “law”). In contrast, F words have no meaningful content, instead serve to express grammatical relationship between other words within a sentence (e.g. prepositions, conjunctions). All the words selected were monosyllabic, with half of each word class (i.e. 25 words) three characters in length, and the other half four characters in length. These criteria were used in order to control for word length effect, which reduces the effect of lists with short words being recalled better than lists with longer words (Cowan, Baddeley, Elliott, & Norris, 2003). To ensure that each word class was balanced for each experiment, 10 trials of each of the following ratios of word classes were used for sequences: 2F:2A:1C, 2F:1A:2C, 1F:2A:2C. The *serial position effect* is the tendency for people to remember the first words in a series best, followed by the last words in a series remembered next best. Thus, to control for this effect, 10 occurrences of each word class were the first word of each trial; and 10 occurrences of each word class were the last word of each trial. Each participant underwent a total of 30 short-term memory trials.

In addition, a secondary distractor task occurred at the same time of the word presentation to prevent deliberate rehearsal of the words. A red cross appeared at the beginning of each trial, at which time participants were instructed to begin counting silently the number of seconds that pass until a green cross appeared. Word presentation would occur a few seconds after the red cross appeared, and would end before the green cross appeared. Participants were then instructed to first type in the number of seconds they counted, and then type in the words in the order they were remembered as being presented.

Procedure

All testing sessions took place between 3-7pm daily, during the highest part of the circadian rhythm (i.e. peak alertness) that occurs in the late afternoon for day active and night sleeping persons (Endo, Kobayashi, Yamamoto, Fukuda, Sasaki, & Ohta, 1981). Each participant reported to the Human Performance Rhythms Laboratory for one 60-minute session, were signed in, and then escorted to an assigned computer. Unlimited time was given for participants to read the written consent form, ask questions regarding it, and then sign two duplicate copies. One was returned to the participant, the other kept for lab records. For the tasks, due to their complexity, general instructions about the study and specific instructions were read to participants before administering the four computer-based tasks and two written questionnaires. In specific order, participants first completed the computer tasks—ISR Task, Mood Scale II, Stanford Sleepiness Scale, Karolinska Sleepiness Scale—followed by the Pittsburgh Sleep Diary, a written questionnaire. Upon completion of the study, participants were given a written Debriefing Statement and answers to any remaining questions they may have had. The approximate time allocated to each task was as follows: ISR Task, 30 minutes; Mood Scale II, 5 minutes; Stanford Sleepiness Scale, 1 minute; Karolinska Sleepiness, 1 minute; Pittsburgh Sleep Diary, 5 minutes. Also, additional demographic information was collected, including age, gender, usual bedtime and awakening, and average length of nightly sleep.

Chapter 3

Results

Mean Proportion of Correct Recall

Participants were categorized into three groups based on their sleep duration the night before. Those who obtained 6.5 hours or less are considered partially sleep deprived (PSD); those who obtained greater than 6.5 hours but less than 8 hours are considered intermediate; and those who obtained greater than 8 hours are considered well-rested. Tables of means and standard deviations, as well as an ANOVA table for analyses, are included in the Appendix and discussed below.

A repeated-measures of analysis of variance (ANOVA) was performed on the proportion of items correctly recalled. The analysis confirmed that in addition to significant main effects for word class ($F_{(2,176)}=9.657$, $p<0.001$) and sequence type ($F_{(2,176)}=6.847$, $p=0.001$), there were significant interaction effects between sleep duration and word class ($F_{(4, 176)}=3.668$, $p=0.007$), and sleep duration and sequence type ($F_{(4,176)}=4.097$, $p=0.003$). Interaction effects were investigated further using post hoc unadjusted t-tests.

Figure 1 illustrates the mean proportion (± SE) of words correctly recalled by the three groups. Post-hoc comparisons revealed a significant difference ($p=0.009$) in mean proportion correct for abstract words recalled between the PSD group and the well-rested group. Specifically, the PSD group demonstrated a significantly lower mean proportion correct for abstract words ($M=0.57$, $SD=0.16$) as compared to the well-rested group ($M=0.67$, $SD=0.13$), but was not significantly different from the intermediate group (M=0.63, SD=0.16). Also, the PSD group remembered significantly fewer function (M=0.60, SD=0.14) than concrete words (M=0.64, SD=0.14) words (p=0.008), and fewer abstract (M=0.57, SD=0.16) than concrete words (p<0.001) as shown in Figure 1. Although the intermediate group did not differ in the proportion correct for each word class, the well-rested group remembered more concrete (M=0.69, SD=0.15) words than either function (M=0.64, SD=0.16) words (p<0.001) or abstract (M=0.67, SD=0.13) words (p=0.038).

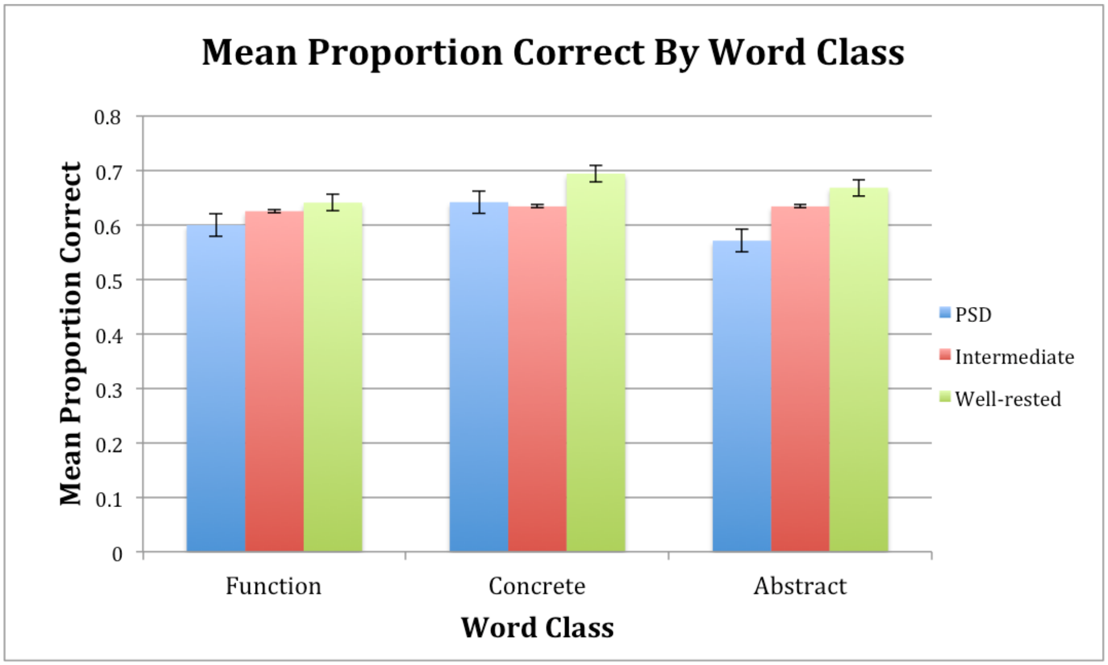

Figure 1. The effect of word class on proportion correct on ISR Task for the each group.

Figure 2 illustrates the mean proportion (± SE) of types of sequences correctly recalled by the three sleep groups. Post-hoc comparisons showed a significant difference in mean proportion of correctly recalled words for the sequence 2F1C2A between the PSD group and the intermediate group (p=0.015), as well as between the SD group and well-rested group (p=0.018).

Specifically, the PSD group recalled fewer 2F1C2A sequences (M=0.57, SD=0.16) as compared with the intermediate group (M=0.68, SD=0.16). The PSD group also recalled fewer 2F1C2A sequences than compared with the well-rested group (M=0.67, SD=0.17). However, only the intermediate group significantly varied by sequence, where they had a lower mean proportion correct for the 1F2C2A sequence than for the 2F1C2A sequence (p<0.001), and fewer correct for the 2F2C1A sequence than for the 2F1C2A sequence (p=0.003), as shown in Figure 2.

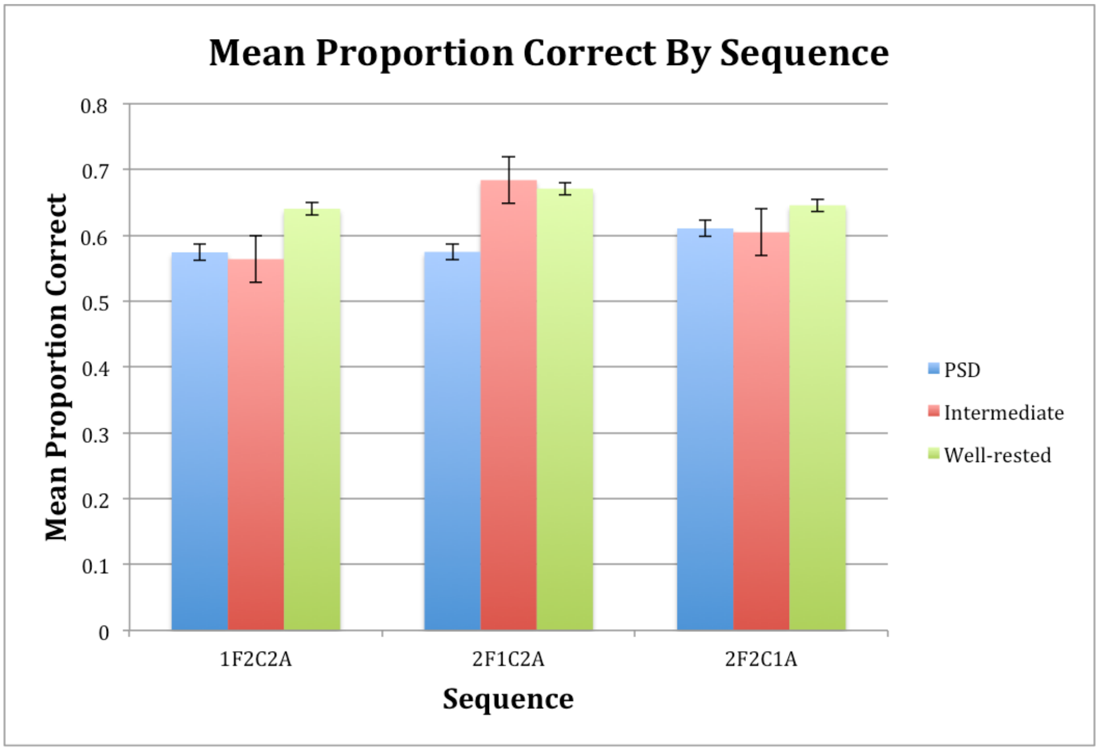

Figure 2. The effect of sequence type on proportion correct on ISR Task for each group.

Chapter 4

Discussion

The purpose of this study was to examine how partial sleep deprivation differentially affects semantic memory according to three word classes: function words, concrete content words, and abstract content words. These three word classes differ in their semantic representations, with concrete words having the richest semantic representations, function words having the least, and abstract words having more than function words, but less than concrete words.

Two of the hypotheses tested were that PSD individuals would 1) have lowest recall for all three word classes, with 2) the lowest recall for function words. That was because function words have the least semantic representations associated with them, and would be more difficult to recall, as compared to words with richer semantic content (i.e. content words).

The PSD group the lowest recall for all three word classes as compared with the well-rest group. Moreover, the PSD group had the lowest recall for both function and abstract words, though slightly better recall for concrete words, as compared with the intermediate group. However, since it has been recommended that 9 hours of daily sleep is more appropriate for college students, the intermediate group from this sample can be considered PSD as well (American Academy of Sleep Medicine, 2015). With this standard, the PSD individuals (i.e. less than 8 hours of sleep) did have the lowest recall for all three word classes as compared with the well-rested individuals, thus supporting the first hypothesis. This shows that PSD overall does affect semantic memory.

However, the only significant decrease in recall was shown with abstract words, so the second hypothesis was not supported. The PSD group recalled fewer abstract words as compared with the other two sleep groups; the difference for abstract word recall between the PSD group and the intermediate group was not significant. Again, this could be due to the fact that, for this sample, both those groups are considered PSD. Nonetheless, this still does support a negative role for PSD in semantic memory impairment for abstract words. Because of their lack of direct sensory referents, the meanings of abstract words are less imaginable and have weaker semantic representation than concrete words, and the lower recall for abstract words confirmed this semantic effect (Jefferies et al., 2009).

We also hypothesized that the PSD group, as compared with other sleep groups, would have the lowest recall for 2F1C2A sequence because it contains the least amount of concrete words. Consequently, it decreases the associated semantic representations for this sequence to less than that of the other sequences (i.e. 2F2C1A and 1F2C2A). This effect was apparent in the PSD group, as it had a lower recall for this type of sequence as compared with the other two sleep groups. Thus, the third hypothesis was supported by these results. Accordingly, the decreased recall of this sequence in PSD appears to indicate the impact of PSD in semantic memory impairment for words with weaker semantic representations.

It should also be noted that, as was used in the Derise (2015) study, we considered using chronic partial sleep loss as a measure in designating the sleep groups. That is determined by estimates given of each participant's weekly average length of daily sleeping. However, this measure did not differentiate the participants as well as the sleep duration each person claimed that they had just the night before their testing. Though chronic partial sleep loss may have affected the results, it is difficult to assess and thus was not considered in this study, in preference to an assessment of their prior night's sleep. Tables comparing the demographics of chronic partial sleep loss and sleep loss the night before the study can be found in the Appendix (Table 3 and Table 4).

In conclusion, with an improved design over the prior study by controlling more factors, PSD appeared to impair semantic memory, and supported the general results of the Derise study. Specifically, the results indicated that the abstract word class, with its less semantic representations, is more susceptible to semantic impairment from PSD. Furthermore, the lower recall of sequences that contained more words of weaker semantic representations indicate that these types of words are indeed vulnerable to PSD. Application of these findings may be useful in developing screening tests of PSD with word class effect to prevent the many possible human-related errors that arise due to PSD. This can be especially helpful in professions where PSD effects on performance can be fatal (e.g. health care, military, long-distance truck, train, bus, and airplane transportation).

Limitations

This study had several limitations to it. First, even though our sample size was substantial, it was not entirely representative of the general population. Participants were all in the strict age range of 18-23 and had very similar education level. In addition, the gender distribution was skewed, with 81% of participants being females. This may have affected the results because studies have shown that females tend to outperform males in verbal memory tasks (Li, 2014). Moreover, the categorization of participants as PSD, intermediate, and well rested depended upon a subjective self-report questionnaire, which only assessed their prior night’s sleep duration. Furthermore, even though the serial position effect for word classes was considered for the first and last word positions, the effect of word class in the middle three positions was not. In order to examine its possible effect, 90 trials would be required to balance for all possible combinations of word classes, which was not possible given the time restraint of each session in the current study. Lastly, studies have established the effect of caffeine on wakefulness (Lim & Dinges, 2008). Although participants were instructed to refrain from consuming caffeine prior to testing, nevertheless, some participants did report consuming caffeine.

Suggestions for Further Research

In order to achieve more accurate results and strengthen the findings, a more representative sample must be used by including a wider demographic of participants. Moreover, participants’ sleep should be monitored to ensure that reported sleep duration is accurate and reliable, and also to control any confounding effects of varying sleep quality. This could be done by using a sleep actigraph. Future studies should also have a method for controlling caffeine consumption by participants prior to testing, or exclude data of those that consumed caffeine. The inclusion of all 90 possible word-sequence combinations mentioned above can provide insight into a possible effect of word class for the middle three positions.

Appendix

Tables

Table 1. General Demographics and Characteristics of Participants

<table>
<tr><th colspan="6">Sleep Duration*</th></tr>
<tr><th>Group</th><th>Size</th><th>Mean (Hours)</th><th>SD</th><th>Range</th><th>SE</th></tr>
<tr><td>PSD</td><td>28</td><td>5.20</td><td>1.16</td><td>3.0-6.5</td><td>0.22</td></tr>
<tr><td>Intermediate</td><td>25</td><td>7.21</td><td>0.37</td><td>6.6-7.8</td><td>0.07</td></tr>
<tr><td>Well-rested</td><td>38</td><td>8.53</td><td>0.70</td><td>8.0-11.0</td><td>0.11</td></tr>
<tr><th colspan="6">Age</th></tr>
<tr><th>Size</th><th>Mean (Years)</th><th>SD</th><th>Range</th><th colspan="2">SE</th></tr>
<tr><td>91</td><td>19.89</td><td>1.18</td><td>18-23</td><td colspan="2">0.12</td></tr>
<tr><th colspan="6">Gender</th></tr>
<tr><th colspan="2"></th><th colspan="2">Size</th><th colspan="2">Proportion</th></tr>
<tr><td colspan="2">Female</td><td colspan="2">74</td><td colspan="2">0.813</td></tr>
<tr><td colspan="2">Male</td><td colspan="2">17</td><td colspan="2">0.187</td></tr>
</table>

*Note: Sleep duration calculations were based on hours of sleep of the night before study participation.

Table 2. Proportion Correct on ISR Task of Word Class in Last Position of Sequence by Sleep Group.

Group	Size	Concrete words		Function words	
		Mean	SD	Mean	SD
PSD	28	0.64	0.13	0.55	0.16
Intermediate	25	0.63	0.15	0.60	0.15
Well-rested	38	0.66	0.16	0.64	0.18

Table 3. ANOVA of Proportion Correct on ISR Task according to Word Class.

Effect	Num DF	Den DF	F-value	Pr>F
Group	2	88	1.65	0.198
Word Class	2	176	9.66	0.000
Group * Word Class	4	176	3.67	0.007

Table 4. ANOVA of Proportion Correct on ISR Task according to Sequence.

Effect	Num DF	Den DF	F-value	Pr>F
Group	2	88	1.78	0.175
Sequence	2	176	6.85	0.001
Group * Sequence	4	176	4.10	0.003

Table 5. ANOVA of Proportion Correct on ISR Task according to Word Class in the First Position.

Effect	**Num DF**	**Den DF**	**F-value**	**Pr>F**
Group	2	88	1.78	0.175
Position (First)	2	176	2.00	0.138
Group * Position (First)	4	176	1.03	0.394

Table 6. ANOVA of Proportion Correct on ISR Task according to Word Class in the Last Position.

Effect	**Num DF**	**Den DF**	**F-value**	**Pr>F**
Group	2	88	1.78	0.175
Position (Last)	2	176	4.45	0.013
Group * Position (Last)	4	176	1.60	0.177

Table 7. Hours of Sleep the Night Before Testing for Each Sleep Group.

Group	Size	Mean (Hours)	Range	SD	SE
PSD	28	5.20	3.0-6.5	1.16	0.22
Intermediate	25	7.21	6.6-7.8	0.37	0.07
Well-rested	38	8.54	8.0-11.0	0.70	0.11

Table 8. Average Amount of Sleep during the Week for Each Sleep Group.

Group	Size	Mean (Hours)	Range	SD	SE
PSD	28	6.83	4.5-8.75	1.03	0.20
Intermediate	25	7.14	4.5-9.5	1.10	0.22
Well-rested	38	87.63	6.0-9.5	0.82	0.13

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