January 2015

What Happened Last Night? Sleep, Sex, and Recollection

Amanda Gale Renfro
Eastern Kentucky University

WHAT HAPPENED LAST NIGHT?
SLEEP, SEX, AND RECOLLECTION

By

Amanda G. Renfro

Thesis Approved:

Chair, Advisory Committee

Member, Advisory Committee

Member, Advisory Committee

Dean, Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at Eastern Kentucky University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made. Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in [his/her] absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature 

Date 6/20/2015

WHAT HAPPENED LAST NIGHT?

SLEEP, SEX, AND RECOLLECTION

By

Amanda G. Renfro

Bachelor of Science
Eastern Kentucky University
Richmond, Kentucky
2015

Submitted to the Faculty of the Graduate School of
Eastern Kentucky University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 2015

DEDICATION

This thesis is dedicated to my parents,
Duard and Helen Hamm,
for their unwavering love and support.

ACKNOWLEDGMENTS

I would like to thank my faculty mentor and professor, Dr. Adam L. Lawson, for all his understanding and guidance as I have continued my education and research in psychology. I would also like to thank Dr. Catherine Clement and Dr. Rosanne Lorden, who served as the other two members on my thesis committee, without whose patience and knowledge this thesis would not have been possible. I would also like to thank my wonderful friends, Jason Hays and Adam Kimbler, who encouraged and supported me through the endless evenings of data collection. Finally, I would like to express my appreciation for every member of the compassionate and knowledgeable faculty within the psychology department at EKU, who each contributed to my passion for research in his or her own unique way.

ABSTRACT

Previous research has repeatedly illustrated the beneficial influence of sleep on memory processes. Further, evidence has demonstrated the power of sexual valance to enhance memory for certain types of stimuli. The present study investigated the possible interaction effect between sleep and sexual valance on recollection memory in 44 undergraduate and graduate student participants at Eastern Kentucky University, based upon a method by Alger, Lau, & Fishbein (2012); however, in the current study, recollection memory items were words received audibly rather than visually. Behavioral data, electroencephalography (EEG), and skin conductance data was collected to assess memory performance, sleep progress, autonomic nervous system activity, and sleep-related behavior. Results indicated a significant interaction effect between condition (sleep/awake) and image type (sexual/nonsexual): words paired with sexual images were best recalled by sleep participants, while awake participants recalled nonsexual images better than sexual images.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

The human mind is a complex and perplexing puzzle: chief among its mysteries is the nature of memory. It is not uncommon to wonder why some memories become salient in our minds while others seemingly fade away. Why do we become so enamored with one specific book or movie, remembering details for years when we can scarcely recall what we had for lunch last Tuesday? For those outside of the field of cognitive neuroscience research, memory processes may seem arbitrary and fickle. In reality, there are many factors contributing to what we may or may not remember days, weeks, or even years into the future.

There are many complex physiological and social influences on human memory processes. Biological factors include such vacillating variables as hormones and neurotransmitters, as well as more predictable physiological influences, such as age and genetics (Sutton, 2011). Readily observable memory influences are related to an individual's immediate state: stress level (Wirkner, Weymar, Löw, & Hamm, 2013), physiological arousal (Cahill & McGaugh, 1998), alertness (Posner & Boies, 1971), affective state (Bisby & Burgess, 2014), sensation seeking (Renfro, Antoine, & Lawson, 2013) and sleep (Diekelmann & Born, 2010). Other important influences can be attributed to the characteristics of the stimulus itself, such as novelty (Petrides, 2011), and emotional valance (Gomes, Brainerd, & Stein, 2013). Despite the vast array of possible influences one could study regarding memory, two factors have been selected for exploration in the present study: sleep and sexual valance.

CHAPTER II

LITERATURE REVIEW

Memory

In everyday language, memory" is often used as a generic term for something an individual has encountered in the past and can later bring back to conscious awareness. In the field of cognitive psychological research, however, the term "memory" is often considered the outcome of two distinct processes: familiarity and recollection (Jacoby, 1991; Yonelinas, 2002). While many individuals may not consciously label the difference between these two concepts, they have undoubtedly experienced the distinction. *Familiarity* is a memory that results in a sense of gist-type "knowing". A person has the feeling that s/he knows or recognizes something, but is unable to identify the source (e.g. when, where, or how you learned the information) (Wagner, Gabrieli, & Verfaellie, 1997). Although familiarity memory requires a relatively low investment of cognitive effort and is relatively fast, it is more vulnerable to interference.

Recollection, on the other hand, is a type of memory that leads to context-based knowledge in which the individual recalls the information, as well as the context in which it was initially acquired (Wagner, Gabrieli, & Verfaellie, 1997). Context-based knowledge leads to a sense of "remembering". Recollection memory processes, while stable and less dependent on environmental cues, require a greater degree of cognitive processing. This dichotomy is often referred to as the *Dual Process Theory* of memory (Hasher & Zacks, 1979; Jacoby, 1991).

The unifying characteristic of all memory models is the notion that these processes operate, for the most part, independently of one another. Neuroanatomical models postulate that not only are these processes distinct, but are carried out via separate neurological pathways within the brain (Aggleton & Brown, 1999). Past studies have documented cases in which brain lesions have left patients with one memory process devastated, while the other remained completely intact (e.g., Aggleton & Brown, 1999;

Huppert & Piercy, 1978; Mayes, Meudell, Mann, & Pickering, 1988). Findings from such studies have generally lead researchers to associate familiarity with the parahippocampal gyrus and posterior sensory regions, and recollection with activation in the hippocampus and the left inferior prefrontal cortex.

According to anatomical models, the perirhinal cortex and lateral entorhinal area (two components of the parahippocampal region) create and preserve information regarding discriminative stimuli: this process represents the creation of what will likely become a familiarity memory (Aggleton & Brown, 1999; Eichenbaun, Yonelinas, & Ranganath, 2007; Yonelinas, 2002). In concert with this activity, the parahippocampal cortex and medial entorhinal area produce information regarding the context of the stimulus. Next, it is the job of the hippocampus itself to make the important connections between the "what" (product of the perirhinal cortex and lateral entorhinal area) and the "where" (contribution of the parahippocampal cortex and medial entorhinal area). The memory formation is complete when the learned stimulus information is encountered again, and the hippocampus reactivates the information created in the aforementioned process.

Much effort and research has gone into understanding the connections between the type of memory (familiarity and recollection) and the suspected structural brain areas implicated (parahippocampal and hippocampal). Memory researchers recognize, however, that these functions are not carried out in a modular fashion, but rather through the cooperation of multiple neurological areas distributed throughout the brain. Thus, while particular brain structures have been associated with familiarity and recollection retrieval processes, researchers have acknowledged that memory is not localized like some cognitive functions (e.g., language). While much debate continues concerning the exact dynamics between familiarity and recollection memories, there is little argument that they constitute very distinct methods of retrieval. Further, it is believed that these processes can be differentially influenced by certain conditions present at encoding, such as the previous night's sleep and/or emotional salience of the stimulus.

Sleep

Sleep is a part of life that most take for granted, serving merely as the period of unconsciousness that accentuates the transition between one day and the next. Most adults can remember the childhood admonishments from exhausted parents, advising them to get plenty of rest so they might better seize the benefits and opportunities of tomorrow. During the excitement of youth, few contemplate the complex mechanisms of sleep. Even fewer individuals consider how sleep influences personal experiences of the world beyond the notion of general fatigue. Despite the valuable advice of wise parents and general medical knowledge, it is commonplace for college students to sacrifice sleep for a variety of reasons, such as cramming for exams or socialization. Unfortunately, empirical research has shown not only does sleep deprivation negatively impact the body, but also compromises the brain's ability to consolidate both declarative and procedural memory (for review see Rauchs, Desgranges, Foret, & Eustache, 2005; Diekelmann & Born, 2010; Fishbein, 1971).

Sleep is not uniform across the night, but instead is composed of *five distinct stages* hat constitute the *sleep cycle* (Diekelmann & Born, 2010). Sleep stages are determined objectively through the observation of neural EEG oscillations, or *brain waves*. These brain waves are in turn categorized according to *Hertz* (the number of *cycles per second;* abbreviated as Hz) into five rhythms: (1) beta, (2) alpha, (3) theta, and (4) delta (Garrett, 2011). In addition to Hertz, amplitude of the oscillations also contributes to the classification of brain waves into one of the aforementioned rhythms, representing the synchronization of the neural firing. As the individual neurons begin to fire in concert with one another, amplitude of a brain wave increases, resulting in taller peaks and deeper troughs. Thus, in order to better understand sleep, one must first become familiar with this neural EEG language and how certain rhythms reflect cognition and consciousness.

Beta represents the bulk of alert consciousness (i.e., wakefulness), recognized by a frequency of 13 – 30 Hz and very low amplitude (Garrett, 2011). While beta is found throughout the brain, it is most evident in the frontal regions and tends to be symmetrical

in distribution across the hemispheres. Beta rhythm is believed to evidence focused attention and active, intentional cognitive processes. As expected, both gamma and beta activity have been shown to index recollection processes, although it must be noted that beta has also been implicated with familiarity (Foster & Harrison, 2004; Keizer, Verment, & Hommel, 2010). Also found in conscious individuals is *alpha* activity, which typically falls between 8 – 12 Hz, and possesses moderate level amplitude. Alpha activity is most commonly found in conscious subjects during periods of relaxation, meditation, or when sleep is imminent. Theta frequency is between 4 – 7 Hz, with amplitude greater than those of beta or alpha, representing a sort of "shallow" or "light sleep". Theta has also been shown to index general arousal when awake, and at least one study has connected familiarity memory with theta activity (Miyakoshi, Kanayama, Iidaka, & Ohira (2010).

Given the focus of this thesis on sleep, a brief summary of the EEG markers of sleep stages is warranted. The feeling of sleepiness constitutes Stage 1 of sleep, and is reflected by increases in alpha EEG waves (Garrett, 2011; Wagner & Born, 2008). Alpha amplitude is larger than beta waves, which predominate the EEG when a person is awake. This increase in alpha represents an increase of neural synchronization: as consciousness wanes, waves tend to fall in frequency, but increase in amplitude. *Theta* waves represent the transition of the brain into unconsciousness, as it is found in both Stage 1 and Stage 2 sleep. It is important to note that Stage 1 and Stage 2 sleep differ in that one loses the ability to willfully wake him/herself up in Stage 2. Another important difference as the sleep cycle progresses into Stage 2 is the appearance of *K-Complexes* and *sleep spindles*. Deep sleep is characterized by increases in *delta* wave activity, identifiable by its slow frequency of 1 – 3 Hz. Delta waves are very large amplitude, and this rhythm represents the greatest level of neural synchronization. Delta waves are used as a marker to determine the presence of slow wave sleep (SWS), but is also common in the neural activity of infants and children (Wagner & Born, 2008). Stages 1 through 4 represent *non-rapid eye movement* (REM) sleep, with Stages 3 and 4 further sub-divided into SWS (Garrett, 2011; Wagner & Born, 2008). During a typical night, the first half of sleep consists mainly of non-REM sleep, specifically SWS, while REM sleep is more prevalent

during the latter half. The natural progression of the sleep cycles is Stage 1 through Stage 4, which then reverses to proceed back from Stage 4 through Stage 1. Once the cycle has returned to the first stage, REM follows.

In the field of neuroscience, there is general agreement that a relationship exists between sleep and memory consolidation, though the exact function of sleep is often a bone of contention among researchers (Rauchs, et. al., 2005; Diekelmann & Born, 2010; Wagner & Born, 2008). One of the debated topics concerns the precise neurological processes that underlie the consolidation of memory during sleep. Of those researchers who dedicate themselves to the various psychological functions of sleep, most subscribe to one of the two predominant theories regarding the precise mechanisms of memory consolidation: (1) the synaptic homeostasis hypothesis, or (2) the active system consolidation hypothesis.

Researchers in support of the synaptic homeostasis hypothesis posit that the process of conscious learning leads to increased levels of overall synaptic strength, and that through sleep the brain is able to *downscale* to pre-learning levels (Diekelmann & Born, 2010). Thus, it would achieve synaptic homeostasis each night after novel learning experiences, permitting the individual to construct new neural connections the following day. In addition, the synaptic homeostasis hypothesis estimates that memory consisting of weak synaptic connections are terminated, leading to a more efficient overall network. Unfortunately, this hypothesis has some considerable problems, as it would suggest memories with weak retention would be discarded during sleep. Research, however, has shown this is simply not the case (Drosopoulos, Shultze, Fischer, & Born, 2007; Kuriyama, Stickgold, & Walker, 2004).

The second hypothesis, *active system consolidation,* purports that two copies of a potential memory are stored in the brain: one within the hippocampus and the other within the cortex most closely associated with the sensory modality that collected it (Diekelmann & Born, 2010; McClelland, McNaughton, & O'Reilly, 1995). During SWS sleep, the newly created neural pathways are repeatedly activated. After numerous reactivations over time, the information within the cortical location is consolidated and the hippocampal version can be terminated. In its purest form, the active system

consolidation theory does not credit REM sleep with any role in declarative memory consolidation, which is contrary to recent findings (Diekelmann & Born, 2010).

A predictable criticism of the active system consolidation is the inability to explain the impact of REM sleep on consolidation. In their study investigating the neurological impact of REM sleep deprivation on rats, Davis, Harding, and Wright (2003) discovered that long-term potentiation (LTP) in the CA1 region of the hippocampus was hindered by the deprivation of REM sleep, thus concluding that the REM sleep stage may offer a unique mechanism by which LTP occurs with greater potency. The authors randomly assigned rats to one of five groups: two served as controls, and the remaining three as levels of REM deprivation treatment by duration (24 hours, 48 hours, and 72 hours). After all rats had engaged in a learning task, one control group was returned to their cages, while the other was placed in the physical treatment condition without REM deprivation (hereafter REMD). This measure was to discern the potential effect of the treatment condition itself, apart from REMD. Rats assigned REMD treatment were placed upon an inverted pot surrounded by water that prevented the animal from entering REM sleep. The onset of REM triggered a loss of muscle contraction (atonia) that resulted in the animal falling into the water, and thus disrupted REM sleep. The control group that mimicked REMD was placed upon a larger pot to permit for the atonia of REM sleep without falling off into the water. Each rat was thereafter sacrificed and the CA1 location of the hippocampus isolated. Electrical stimulation was applied postmortem to determine LTP activity and maintenance between neurons. The results indicated that the greater the period of REM deprivation, the less robust the LTP found within the CA1 region of the hippocampus. Other researchers, however, pointed to the presence of physiological and psychological stress as likely confounds that might influence the performance of animals subjected to any REMD method. Although their findings had been published before Davis et al. (2003), Vertes and Eastman offer a cogent argument illustrating the multitude of unavoidable confounds regarding REMD, particularly that of physiological and psychological stress (2000).

More recent research suggests that declarative memory, also referred to as *hippocampus-dependent memory*, takes place to some extent, within both REM and non-

REM stages (Diekelmann & Born, 2010). The hippocampus-neocortical connection is dominant during slow brain wave oscillations of less than 1 Hertz, placing it into the realm of non-REM sleep (Marshall & Born, 2007). It is believed that during this low oscillation period, neurological pathways that were activated during a learning task or experience (referred to as encoding) are then reactivated and the information is eventually distributed to appropriate locations throughout the neocortex for long-term memory retention. While much of the debate regarding what occurs during which sleep stage appears quite dichotomous, recent findings suggest it is through the cooperation of both non-REM and REM brain wave patterns that all types of memory (declarative and procedural) are ultimately consolidated. It is theorized that the slower cyclical nature of SWS serves to repeatedly stimulate the same neural networks that were activated during the conscious learning experience (Ribeiro & Nicolelis, 2004). This is believed to strengthen hippocampal synaptic connections sufficiently before the lengthy process of distribution to a predestined location in the cortex during REM sleep, a process that is estimated to occur over an extended period of multiple sleep cycles.

While the aforementioned topics constitute two of the more popular dialogs regarding sleep and memory, they are by no means the limit. In 2008, German researchers Wagner and Born evidenced a relationship between the hypothalamo-pituitary-adrenocortical axis (HPAC) and declarative/emotional memory consolidation during sleep, illustrating the complexity of sleep's influence on memory. Declarative memories, particularly those charged with emotional salience, are reliant on the HPAC for proper consolidation during sleep. Thus, a casual glance of the literature portrays the relationship between sleep and memory as both labyrinthine and consociated: a collection of beautiful and complex puzzles whose implications touch every aspect of the human experience.

Naps

While the benefits of sleep on memory are often associated with a full night of sleep, positive effects for memory are not limited solely to a standard 8-hour night of

sleep. Previous research has demonstrated the performance-enhancing abilities of naps on both declarative memory (Schabus, Hodlmoser, Pecherstorfer, & Klosch, 2005; Schoen & Badia, 1984; Tucker et al., 2006) as well as procedural memory (Mednick, Nakayama, Cantero, Atienza, Levin, Pathak, & Stickgold, 2002; Milner, Fogel, & Cote, 2006; Robertson, Pascual, & Miall, 2004), with SWS and REM benefiting declarative and procedural memory, respectively (Diekelmann & Born, 2010). With regard to naps, however, there is some disagreement among the literature as to the duration necessary before sleep-related benefits emerge. Mednick et al. (2002) found that nap duration determined the performance of subjects on a procedural memory task: 30-minute naps prevented deterioration from pre-nap control levels, while a 60-minute nap lead to improvements in performance. In another study by Alger, Lau, and Fishbein (2012), the authors examined the influence of nap length on memory consolidation, comparing 10 minute, 60 minute, and non-nap conditions. While the 10-minute nap group outperformed the non-nap condition, these benefits were not retained when tested a week later. On the other hand, the 60-minute nap condition displayed the best performance of all three groups on both the initial test and the retention test one week later. The authors believed that while the 10-minute nap group did initially outperform the non-nap group, these benefits were temporary and not indicative of actual long-term memory consolidation processes.

Likewise, researchers Lahl, Wispel, Willigens, and Petrowsky (2008) reported that participants who took a 60-minute nap performed better on a word recall task compared to no-nap controls. Other studies, however, have linked benefits in memory to particular stages of sleep: Schabus et al. (2005) demonstrated improvements after naps containing SWS, specifically with high levels of theta activity occurring in and around the occipital cortices, while Muto, Arpaia, De Padova, Russo, and Ficca (2005) found benefits only after naps that contained REM sleep. The duration of naps most often used in memory research appears to be 60-90 minutes, as a nap of this length provides for SWS at 60-minutes, and REM at 90-minutes, with 90-minutes representing the length of the average adult sleep cycle (Diekelmann & Born, 2010).

Sexual Valance

Sexual valance of stimuli has also been demonstrated to positively influence memory processes, though such effects are far less researched than sleep (Bush & Geer, 2001; Parker & Furnham, 2007; Furnham & Mainaud, 2011). *Valance* of a stimulus is defined as the pleasant or unpleasant nature of a stimulus at the time of encoding (Oschner, 2000). In explicit memory tasks, sexually valanced stimuli (images, audio, story details) are better remembered than nonsexual stimuli. The beneficial influence of arousal salience on memory is found regardless of the individual's gender (Bush & Geer, 2001; Furnham & Mainmaud, 2011) or sexual orientation (Parker & Furnham, 2007; Wright & Adams, 1999). In regards to erotic versus romantic-based stories, males have displayed better memory for erotic-focused content, while females showed better memory of romantic-focused content. Interestingly, individuals with the most sexual experience demonstrated the most memory benefit for arousing stimuli (Lewis et al, 2007). Most research has found, however, that while sexually charged stimuli does elicit better recall than nonsexual stimuli, it has a negative influence on subsequent tasks that require extensive cognitive processing. In other words, sexual material tends to dominate competing thoughts.

Compared to the focus on the relationship between sleep and memory processes, research concerning the influence of sexual valance on memory is quite sparse. Fortunately, there is no such dearth of literature concerning the effect of emotional and physiological arousal on memory. This is particularly the case with emotions that activate the amygdala, which in turn activates the hippocampus and surrounding structures, leading to the formation of more enduring memories (Cahill & McGaugh, 1998). While this is traditionally believed to be the effect of predominantly negative events and stimuli, such is not always the case. Positive events can likewise stimulate the amygdala, harnessing the power of the amygdala-hippocampus connection to create more resilient memories. These influences can be found for both familiarity memories, as well as recollection processes (Gomes, Brainerd, & Stein, 2013).

Another oft-neglected component of the sleep-memory relationship is that of the endocrine system. Hormones play a crucial role in the consolidation of memories during sleep, particularly those of the hypothalamo-pituitary-adrenocortical axis (HPAC). The HPAC is comprised of three major players: the hypothalamus, the pituitary gland, and the adrenal glands (Lovallo & Thomas, 2000). Together these three areas regulate the secretion and regulation of stress hormones, specifically adrenocorticotropine (ACTH) and glucocorticoids. The influence of the HPAC reaches to the central nervous system (CNS) through the management of physiological processes, as well as the autonomic nervous system (ANS) through the activation of the fight or flight response. Of the various glucocorticoids, cortisol is perhaps one of the most important for the general preservation of life. It is produced within the adrenal cortex and helps to direct functions as basic as that of tissue regulation to those as complex as physiological and psychological arousal. Of particular interest here is the diurnal pattern of cortisol secretion that closely maps along the human sleeping and waking pattern. During the first half of a night's sleep when SWS predominates, activity within the HPA is minimized, resulting in lower concentrations of cortisol within the blood during non-REM sleep stages (Born & Fehm, 1998). Conversely, during the second half of the night while REM is dominant, the HPA becomes more active and releases higher levels of cortisol into the circulatory system (Wagner & Born, 2008). This increase in cortisol continues until morning, reaching its apex just before awakening.

The influence of cortisol is felt predominantly upon the hippocampus due to its wealth of mineralocorticoid (MR) and glucocorticoid (GR) receptors (Wagner & Born, 2008). It is through the concentrations of these corticoids that certain types of memory may be preferentially consolidated over others, depending upon whether the emotional salience necessitates amygdala-dependent memory processes. Further, it is suggested that cortisol activity in REM sleep may provide a dampening effect upon the dysfunctional over-consolidation of particularly emotional memories, such as those suffered by individuals with posttraumatic stress syndrome (PTSD). A second set of important players from the endocrine system is that of the sex hormones, particularly testosterone. In humans and other mammals, testosterone is the hormone believed to be most closely

associated with the male response, while both estrogen and testosterone are believed to influence the female response (Geer & Janssen, 2000). These two chemicals, important as they are to the reproductive response and success of our species, have been discovered to exert powerful influences over other important processes as well.

One of the more intriguing effects of sex hormones is the protective influence they seem to exert on memory processes for both men and women. In Ackermann, Spalek, Rasch, Gschwind, Coynel, Fastenrath, Papassotiropoulos, and de Quervain (2012), the authors demonstrated the beneficial effects of endogenous testosterone upon free recall in male participants. In their experiment, both male and female participants encoded 72 pictures from the International Affective Picture System (IAPS), as well as in-house picture sets. For each set of 72, three groupings of 24 represented emotionally positive, emotionally negative, and emotionally neutral stimuli. While participants were instructed to memorize the images, they were also assigned the task of ranking each image on a three-point Likert scale according to its perceived emotional valance: [1] Negative, [2] Neutral, and [3] Positive. This encoding portion lasted for approximately 22 minutes, with each image presented for 500 milliseconds. During the encoding task, participants were fitted with equipment for fMRI data collection. After each participant had completed the encoding phase, a sample of saliva was obtained to measure testosterone levels. Finally, the free recall task asked participants to recall as many images as possible with no time limit.

Results indicated a significant positive correlation between endogenous testosterone level and free recall of neutral valanced images in male, but not female, participants (Ackermann et al., 2012). Further, a second correlation was discovered between testosterone levels and activation of the amygdala during the encoding of neutral images for males only. The authors believed that these findings suggest a specialized function of testosterone in the memory processes of men: as the level of endogenous testosterone increases, males will perceive neutral stimuli as more arousing, leading to an increased activation of the amygdala. This in turn provides emotional salience during the encoding of the stimulus, leading to a more stable memory trace.

Estrogen, likewise, has been shown to provide neurological benefits leading to better memory. Numerous findings have demonstrated the modulating influence of estrogen on the neurogenesis and rate of cell death within the hippocampus of female laboratory animals (Galea, et al, 2008; Spencer, Waters, Romeo, Wood, Milner, & McEwan, 2009). In rats, estrogen achieves this influence through the increase of dendritic spine density and excitatory-type synaptic contacts in hippocampal CA1 pyramidal neurons, but this occurs only in female (but not male) animals (for review see Spencer, Waters, Romeo, Wood, Milner, & McEwan, 2009). Interestingly, these findings have been replicated in nonhuman primates, suggesting that the effect of estrogen may have a similar influence on human memory as well.

Through its hormonal influence, sexual behavior has been shown to affect sleep patterns in both human and other mammals (Andersen, Alvarenga, Mazaro-Costa, Hachul, & Tufik, 2011; Jiménez-Anguiano, Arteaga-Silva & Velázquez-Moctezuma, 2002). In their 2002 study, Jiménez-Anguiano, Arteaga-Silva and Velázquez-Moctezuma used golden hamsters to determine if significant changes in sleep patterns could be observed following sexual behavior. The researchers compared the EEG patterns of the subjects who were divided into three conditions: no sexual activity, 30 minutes of sexual activity, and 60 minutes of sexual activity. Results indicated that the two groups that engaged in copulation before sleep exhibited a significant increase of SWS, particularly SWS II (described as increases in Delta wave activity and decreases in muscle tone), compared to the non-copulatory control group. These findings were replicated in another study by the same authors the following year: the more time spent engaged in sexual activity, the longer the subjects spent in SWS II (Stage 4) during the subsequent sleep period (Jimenez-Anguiano, Arteaga-Silva, & Velazquez-Moctezuma, 2003). Conversely, short-term sleep deprivation has been observed to lead to measureable increases in sexual responsiveness in male rats. However, while there are more attempts at copulation, there is less success at completion (Zacone, De La Pena, & Dement, 1974).

Regarding females, the relationship between sex and sleep is a little more complicated. While testosterone is often believed to be the hormone predominately associated with sexual behavior and response, estrogen and progesterone are also

important (Andersen, Alvarenga, Mazaro-Costa, Hachul, & Tufik, 2011). Numerous studies have illustrated the negative impact of menopause on both sleep and the sexual functioning of women (Andersen, Alvarenga, Mazaro-Costa, Hachul, & Tufik, 2011; Dennerstein, Dudley, & Burger, 2001; Dennerstein, Randolph, Taffe, Dudley, & Burger, 2002; Dennerstein, Lehert, Burger, & Guthrie, 2007). Sexual dysfunction from falling estrogen and progesterone levels include decreases in sexual desire and receptivity. However, whether young or old, experiencing a dearth of endogenic testosterone spells problems for both sleep and sexual functioning. Women with abnormally low concentrations of testosterone experience decreased sexual interest and fantasy, as well as an inability to produce and maintain vaginal lubrication.

In both men and women with normal testosterone concentrations, research has found that sexual activity leads to increases in testosterone secretions found in saliva (Dabbs & Mohammed, 1992). The increases in testosterone secretion continued throughout the evening in which sexual activity was present, and decreased continuously on days in which participants did not engage in sexual activity. As with the previously mentioned studies involving golden hamsters and rats, human participants have provided evidence for a correlation between testosterone levels and length of certain sleep stages (Luboshitzky, Herer, Levin, Shen-Orr, & Lavie, 1999; Luboshitzky, Zabari, Shen-Orr, Herer, & Lavie, 2001). While not as robust a correlation is found with females, sleep-induced production of testosterone is often used as an indication of the emergence of the first REM sleep cycle in male participants. Like cortisol, testosterone exhibits a diurnal rise and fall that is moderated by sleep, particularly during SWS.

Electroencephalography (EEG)

EEG is the measurement of the brain's electrical activation between two or more electrodes placed on the scalp (Garrett, 2011). EEG is most commonly used to detect neural activity at certain locations on the scalp, providing detailed information concerning the speed of activation. The method, while not particularly adept at spatial resolution of the brain's activities, is perhaps one of the best at producing accurate

temporal information. EEG is capable of measuring changes in neural activity of approximately 1 millisecond and showing patterns of activation across the brain. It is these specific activation patterns, their frequencies and degree of synchronization, which comprise the brain rhythms described in this thesis (Garrett, 2011; Wagner & Born, 2008).

EEG continues to be used for the diagnosis of medical anomalies such as tumors of the brain and epilepsy; despite the fact more modern imaging techniques (MRI or CT) have become the standard (Borck, 2008; Garrett, 2011). EEG has been for decades, and continues to be, the primary technology for the diagnosis of epileptic seizures. One challenge with EEG is that any muscle movement that occurs near the scalp (e.g., blinking) interferes with the recording of brain waves. Thus EEG has a high potential for both biological and environmental interference (known as "artifacts"). Biological artifacts may include muscular movements or contractions in areas near the electrodes, such as those of the eyelid or retina. However, even if it were possible to ensure complete paralysis of subject muscle movement, there is still the chance of environmental factors influencing the readings, such as metal chairs, beds, desks, or even the electrical current in the walls. Due to this interference, substantial brain activation is lost, even with specialized computer programs employed to separate the true neural signals from artifact. Although these issues may make it less attractive to medical professionals, EEG is still the method of choice in sleep research because of the reliability to show the transition from light to deep sleep, as well as when a person is engaged in REM sleep.

Current Study Aims and Hypotheses

While not necessarily linear, prior evidence suggests a possible relationship between the three variables of interest in the present study: sleep, sex, and memory processes. Sleep has been clearly demonstrated to exert a powerful influence on memory processes, both declarative (Schabus et al., 2005; Schoen & Badia, 1984; Tucker et al., 2006) and procedural (Mednick et al., 2002; Milner et al., 2006; Robertson, Pascual, & Miall, 2004). Further, sleep has been shown to influence sexual behavior in male animal

studies, with deprivation leading to increased sexual responsiveness, but decreased copulation completion (Zacone, De La Pena, & Dement, 1974). Sexual behavior, in turn, has demonstrated its own hormonal influence over sleep: increases in SWS II (Stage 4 sleep) and delta activity were observed in subject post-copulation compared to non-sex controls (Andersen, Alvarenga, Mazaro-Costa, Hachul, & Tufik, 2011; Jiménez-Anguiano, Arteaga-Silva & Velázquez-Moctezuma, 2003; Jiménez-Anguiano, Arteaga-Silva & Velázquez-Moctezuma, 2003). Finally, sex and sexual valance has been shown to positively influence memory processes via the effects of both testosterone and estrogen upon the hippocampus (Galea, Uban, Epp, Brummelte, Barha, Wilson, Liebech, & Pawluski, 2008; Spencer, Waters, Romeo, Wood, Milner, & McEwan, 2008) and amygdala (Ackermann, et al., 2012).

The present study is intended to extend our scientific understanding of the possible relationships between sleep, sexual valance, and memory processes. As mentioned, previous research has evidenced a relationship between (1) sleep and memory, (2) sexual valance and memory, and (3) sex and sleep. Little research, however, exists examining the potential interconnections between these three areas within young, healthy, adult humans. In the present research, we seek to investigate the influences of these three variables both individually and jointly. The hypotheses of the present study are as follows:

Hypothesis 1

It is predicted that participants in the sleep condition will recall more words overall than participants assigned to the awake condition. This prediction is supported by the bulk of research on sleep's beneficial influence on memory processes (Mednick et al., 2002; Milner et al., 2006; Robertson, Pascual, & Miall, 2004; Schabus et al., 2005; Schoen & Badia, 1984; Tucker et al., 2006).

Hypothesis 2

All participants will recall more words associated with sexual valanced images than words associated with nonsexual valanced images. Previous research has illustrated that under some condition, sexual valance of stimuli leads to better encoding and retrieval processes (Ackermann, et al., 2012; Galea, Uban, Epp, Brummelte, Barha, Wilson, Liebech, & Pawluski, 2008; Spencer, Waters, Romeo, Wood, Milner, & McEwan, 2009). Therefore, we expect to see better recollection memory for words associated with sexual images compared to nonsexual images.

Hypothesis 3

An ordinal interaction effect will be found between condition (sleep/awake) and sexual valance of images, specifically, sexual images will be best recalled by participants in the sleep condition compared to participants in the awake condition. If the previous literature mentioned above for sleep and sexual valance individually benefiting memory processes holds, then we would expect to see the largest memory benefits for words associated with sexual images when participants sleep compared to when participants are awake.

CHAPTER III

METHOD

Participants

The present research collected data from 54 undergraduate students from Eastern Kentucky University. Due to failure to return a week later for the second experiment day, eight participants were excluded from the final data analysis, and an additional two participants were excluded for failure to reach criteria within five attempts, leaving a remaining subject pool of 44 (22 sleep, 22 awake). A required sample size of 44 (22 participants per group) was calculated based on a G*Power Analysis (Appendix G: Figure 2[1]). Inclusion criteria stated that participants must (a) be 18 years of age or older, (b) possess normal or corrected vision, (c) possess normal or corrected hearing, (d) be free of neurological, psychological, or sleep disorder, (e) possess no learning or reading disability, and (f) are not pregnant at the time of data collection.

The information regarding sleeping habits three days before the first experimental day were recorded in Sleep Journal 1 by participants, which was provided via email. Sleep Journal 2, in which the participants recorded their sleep routine for the following week, was given to them at the end of the first experimental day. During this time, participants were asked to refrain from any unnecessary substances that might influence the ability to maintain a normal and consistent pattern of sleep.

Materials

Biographical Questionnaire

The Biographical Questionnaire was an 11-item demographics form used to collect demographic information such as participant age, level of education, sex, gender

[1] All figures and tables are located within the appendix.

identity, sexual orientation, and frequency of sexual activity. The form also inquiries about participants' use and/or consumption of substances that may potentially influence sleep, ability to learn, memory processes, or arousability.

Stanford Sleepiness Scale (SSS)

The SSS is a one item, seven-point scale that measures the degree of sleepiness an individual reports at the moment of assessment. Participants rated how sleepy they felt on a Likert-type scale: [1] Feeling active, vital, alert, or wide awake, [2] Functioning at high levels, but not at peak; able to concentrate, [3] Awake, but relaxed; responsive but not fully alert, [4] Somewhat foggy, let down, [5] Foggy; losing interest in remaining awake; slowed down, [6] Sleepy, woozy, fighting sleep; prefer to lie down, [7] No longer fighting sleep, sleep onset soon; having dream-like thoughts, [X] Asleep.

Sleep Journals

Participants were be provided with two seven-page sleep journals to complete each night for three days before the initial date of the experiment, and for one week following, up until the day of the final testing day. In the journals, participants recorded the time of sleep onset each night, the time they woke up each morning, and if they suffered any sleep abnormalities.

Images

For the encoding and testing phases, a total of 36 images were selected from the *International Affective Pictures System* (IAPS): 18 of positive sexual valance, and 18 of positive nonsexual valance. In order for an image to be considered "sexually valanced", it contained provocative images of sexual behavior and/or nudity. Nonsexual images displayed positive, exciting events and scenery. All sexual images contained consensual, non-violent material.

Words

A total of 36 word pairs (72 words total) were selected for use from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982). The Toronto Word Pool consists of approximately 1,080 common words, each ranked on a Likert scale according to imagery and concreteness (1 = low imagery/concreteness, 5 = high imagery/concreteness). In this case, *imagery* refers to the ability of a word to elicit an immediate and distinct sensory experience in one's mind, while *concreteness* is defined as the degree to which the word describes a tangible, non-abstract item. For the purpose of this experiment, 140 highly ranked words (≥ 6 on both imagery and concreteness) were initially selected from the word list. From those initial 140 words, 68 words were discarded for the following reasons: descriptions of people or body parts, sexual connotations, violent/weapon imagery, and nouns describing animals/insects with the potential for creating negative affect. The 72 words that remained scored high in both imagery and concreteness, and were unlikely to create emotional/logical confounds during the memorization task.

Task

Bimodal Pair-Association Task

The bimodal pair-associates task used in the present study was modeled after that developed by Alger, Lau, & Fishbein (2012). In their study, the authors sought to determine if a nap containing SWS would allow for the protection and consolidation of declarative, recall memory. The researchers created the "bimodal pair-associations task" in which a participant was presented with both an auditory cue (easily distinguishable sound) and a visual presentation of a word pair. The participant were then instructed to memorize the word pair using whatever means they preferred until a success rate of approximately 75% is attained. They were then tested after either a 10-minute nap, 60-

minute nap, or passively watching a video. Participants were then tested again after one week.

Differences between the original model and the present method are as follows: the task consisted of 36 couplings of visual and auditory stimuli in which an image was presented to participants while they received two spoken words through a headset (one word followed by a second word). This departs from the original method in that the auditory words are the stimuli participants will be instructed to learn, where in the design created by Alger, Lau, & Fishbein (2012), the memory stimuli were words presented in a visual format. A change in the modality of the memory stimuli was necessary to prevent possible confounds from the simultaneous presentation of visual image as well as the words to be memorized.

Following the method of Alger et al. (2012), words selected consisted of two syllable nouns from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982) ranked high in both imagery and concreteness (mean score of 6.0 or greater). Participants were instructed to listen carefully to the spoken word pair while simultaneously associating the words with the presented image. They were told to memorize these audio/visual couplings through whatever means they deemed to be most effective.

For each trial, the image appeared first, followed by the audio word-pair. The image appeared on-screen for four seconds total (1 second before, 2 seconds during, and 1 second after audio), with a variable inter-trial interval (ITI) between trial presentations. The length of the ITI was dependent upon participant ANS arousal, and ended once s/he returns to pre-stimulus baseline. Sexual and nonsexual pairing were presented in random order. During the ITI, participants were instructed to fixate on the screen to maintain focus for the subsequent trial. Once the participant completed the 36 trials, s/he was tested to ensure encoding. To achieve confidence in encoding, a randomized cued recall task was utilized. Participants were presented with each image, as well as either the first or second word in the audio pair. The participant was then required to produce the correct corresponding word in the pair, with the goal of achieving a 75% criterion level for accuracy over the 36 trials. Participants were allowed to repeat the 36 couplings up to

five (5) times until the criterion was met. However, if they could not reach criterion after five attempts, they were dismissed from the study.

A similar session was then employed twice to test participant memory containing the previously learned 36 audio/visual couplings each. The first and last couplings for each participant were not present in their tests to eliminate primacy or recency effects.

Procedure

In order to collect data regarding the sleeping habits of each participant, an email was sent one week prior to the first experimental day. The email contained information regarding the requirements of participation (i.e. sleep times and awake times), the informed consent document, and a sleep log to record the three nights prior to participation. On the day of the experiment, approximately 15 minutes before scheduled participation time, participants completed the informed consent and provided the sleep journal. Afterward, participants were then introduced to the testing suite while the experimenter gave a brief explanation of the study, along with an opportunity for questions before the study began.

Participants were then equipped with two electrodes on two adjacent fingertips of the non-dominant hand in order to monitor ANS activation via galvanic skin response (GSR). When it comes to monitoring physiological arousal resulting from ANS activation, few indices are better suited than electrodermal activity (for review see Dawson, Schell & Filion, 2000). Electrodermal activity allows the researcher the ability to track miniscule and instantaneous fluctuations in the sweat secretions on the skin's surface which are influenced by the rise and fall of ANS reactivity. Typically in a research situation, two measurements are taken to gauge this activity: (1) the pre-stimulus, tonic skin conductance level (SCL), and (2) the post-stimulus, phasic skin conductance response (SCR). The SCL is subtracted from the SCR to determine the reactivity measurement, or the degree to which the individual orients toward or draws away from a target stimulus (Lagopoulos, Gordon, & Ward, 2006; Zuckerman, 1990).

The participant then reported the first of three SSS assessments to assess if any degree of excessive sleepiness was present (SSS Time 1). If the participant reported a rating of 3 or below (not sleep deprived), he or she was permitted to continue to the learning task. If the participant indicated a sleepiness score of 4 or above, they were given a 10-minute period of time to walk around in order to become more aware. In the learning task, the participant attended to the presentation of 36 audio/visual pairs (18 sexual valance images, 18 nonsexual valance images), and continued through the task until production success on the encoding test phase reached criterion (75% correct). After the learning task was complete, participants from each group were then randomly assigned to either the Sleep or Awake condition. Participants assigned to the Sleep condition were allowed a 90-minute sleep period in which they were placed on a twin-size inflatable mattress in a separate, darkened testing suite. Participants in the Awake condition were instructed to watch a non-arousing documentary for the 90-minute interval in the same testing darkened testing suite used for sleep participants.

Once the 90-minute Awake/Sleep condition was complete, the participants were brought back to the initial testing suite. After a 15-minute period was allowed for participants to become reoriented to their environments, they were asked to report the second indication of sleepiness via the SSS (SSS Time 2). If the participant reported a rating of 3 or below, they began the first testing phase. If the participant reported 4 or above, they were allowed additional time to awaken. In the first testing phase, participants engaged in cued-recall similar to that of the learning phase. Unlike training, however, they were only permitted one attempt to provide the correct responses. Participants were tested on the previously learned A/V pairings: the image and either the first or second of the corresponding audio words were presented, which then required the participant to provide the missing word. Sexual and nonsexual pairings were presented randomly. Once the participant finished the first test session, all physiological equipment was removed and the participant was provided with the Week 2 Sleep Journal to complete over the following week.

Exactly one week later, each participant returned to complete the follow-up testing session. After arrival, s/he provided Week 2 Sleep Journal and completed the final

of three Sleepiness Scale ratings (SSS Time 3). If the participant reported a rating of 3 or less, s/he was immediately tested on the A/V pairings in the same manner as the first testing session. Once the test was complete, participants were debriefed and permitted the opportunity to ask any questions.

Apparatus for Behavioral and Psychophysiological Data

The learning phase, testing phase, and recording of all behavioral data were completed and collected using Psychopy software. Electroencephalography (EEG) data were collected, recorded, digitized, and analyzed with Curry 7 Neuroimaging Suite (Compumedics Neuroscan) to ensure that each participant in the sleep condition achieved Stage 4 (SWS) sleep. Electrodermal activity (EDA) was recorded, digitized, and analyzed using Biopac software (Biopac Systems, Inc.). Skin conductance responses for each trial (i.e. presentation of each audio/visual pairings) were determined through the subtraction of the phasic EDA (maximum activation 0-4000 ms, post-stimulus) from the tonic EDA (-500 to 0 ms average, pre-stimulus onset).

CHAPTER IV

RESULTS

Sleep Journals (Week 1 and Week 2)

Participants were asked to provide sleep information for the three days preceding Day 1 (Sleep Journal 1), as well as the week between Day 1 and Day 2 (Sleep Journal 2). For participants assigned to the Awake group, the mean number of hours slept per night prior to Day 1 and Day 2 was 8.26 (*SD*=.94) and 8.18 (*SD*=1.16), respectively. For those in the Sleep condition, the mean number of hours slept per night prior to Day 1 and Day 2 was 8.12 (*SD*=1.40) and 8.06 (*SD*=1.13), respectively. An independent samples t-test revealed no significant differences between the two conditions regarding the amount of sleep recorded in either Sleep Journal 1 ($t(42)=.374$, $p=.710$) or Sleep Journal 2 ($t(42)=.348$, $p=.730$).

Stanford Sleepiness Scale (Time 1, Time 2, and Time 3)

A preliminary examination of sleepiness ratings via the Stanford Sleepiness Scale (SSS) was conducted. For the initial rating (sleepiness immediately prior to the encoding task), a significant effect of sleep/awake condition was discovered, $t(1,42) = -2.049$, $p = .047$. Sleep participants reported a higher mean sleepiness score of 2.41 (*SD*=.59) compared to their Awake counterparts who reported a mean of 2.09 (*SD*=.43). In essence, the participants randomly assigned to the Sleep condition reported themselves as being sleepier than did Awake participants immediately prior to the Memory Task (Appendix A: Table 1).

Bimodal Paired Associations Memory

Participant performance on the bimodal-paired association memory task was assessed at two points throughout the course of the experiment: after the 90-minute period of either the Sleep condition or the Awake condition (Test 1), and again exactly one week following the memory task (Test 2). The second task was included to determine the degree to which memory retention had taken place over a period of seven (7) days of regular sleep. After engaging in the memory task (achieving a 75% criterion), participants were then randomly assigned to either the Awake condition (n=22*,* 90 minute movie) or the Sleep condition (n=22, 90 minute nap). After the manipulation, participants completed Test 1 on the same day (Day 1). One week later, participants returned to complete Test 2 (Day 2). Memory accuracy was determined by comparing the number of correctly recalled words to the total number of words to be recalled, which produced a percentage correct for each participant Test 1 and Test 2. Participant responses that were discernably the intended word, although misspelled ("craddle" instead of "cradle"), were counted as correct responses for purposes of accuracy calculations.

Examination of Sleepiness as a Between Groups Condition

A mixed-design, repeated-measures analysis of variance (ANOVA) was conducted using condition (awake/sleep) and sleepiness scale score at Time 1 (with possible ratings of 1, 2, or 3) as between-subjects independent variables. Image type (sexual/nonsexual) and test time (Test 1/Test 2) served as within-groups independent variables, while memory accuracy was the dependent variable. SSS Rating at Time 1 was selected for use as a second between-subjects variable due to the significant difference between groups found in the independent-samples t-test explained above.

The results yielded a significant main effect for type of image, $F(1,38)=7.18$, $p<.05$, $\eta^{\neg}=.16$, with participants exhibiting better memory for words paired with nonsexual images (M=.825, SE=.031) compared to sexual images (M=.738, SE=.031). A significant main effect was also found for test time, $F(1,38)=17.69$, $p<.001$, $\eta^{\neg}=.32$, with

participants performing better at Test 1 (M=.858, *SE*=.023) than at Test 2 (M=.705, *SE*=.039) (Appendix B: Table 2).

A significant interaction effect was found between the awake/sleep condition and image type; $F(1,38) = 4.64$, $p<.05$, $\eta^{\neg}=.11$ (for means of sleepiness rating by condition see Appendix C: Table 3; for means of sleepiness rating by condition for Day 1 see Appendix D: Table 4; for means of sleepiness rating by condition for Day 2 see Appendix E: Table 5). Simple effect analyses revealed that participants in the awake condition exhibited a significant difference in accuracy scores between sexual and nonsexual images ($F=10.84$, $p<.01$, $\eta^{\neg}=.22$), recalling more words paired with nonsexual images ($M=.84$, $SE=.05$) than words paired sexual images ($M=.68$, $SE=.05$) (see Appendix F: Figure 1).

Also, a marginally significant effect between Awake and Sleep conditions was found for sexual images; $F=3.23$, $p=.08$, $\eta^{\neg}=.08$, wherein sexual images lead to better recall of memorized words in subjects assigned to the Sleep condition ($M=.79$, $SD=.043$) than those assigned to the Awake condition ($M=.68$, $SD=.046$). These results suggest that when recall for words paired with sexual images is considered, Sleep participants marginally outperformed Awake participants.

CHAPTER V

DISCUSSION

The story of sleep, sex, and memory that unfolded throughout this experiment is fascinating, though a bit contrary to some of the previous literature. Three interesting relationships were discovered between sleep and sexual valance with regard to recollection memory processes: (1) Words paired with nonsexual images were better recalled than those with sexual across both conditions, (2) Awake participants performed better at recalling words associated with nonsexual images compared to those with sexual images, and (3) sexual images were better recalled by individuals in the Sleep condition compared to those in the awake condition.

The primary objective of the present study was to investigate the possible influences of sleep and sexual valance on memory processes, particularly that of recollection memory. It would not be an exaggeration to state that nearly all research on sleep and memory processes have established a link between the two, illustrating the importance of sleep to the consolidation of memory process, whether declarative (Schabus et al., 2005; Schoen & Badia, 1984; Tucker et al., 2006) and procedural (Mednick et al., 2002; Milner et al., 2006; Robertson, Pascual, & Miall, 2004).

Concerning the first hypothesis, it was predicted that participants in the sleep condition would generally outperform their awake counterparts on tests of recollection memory regardless of the type of image. This was not found to be the case, as there was no statistically significant difference between the two groups for memory accuracy overall. However, a significant interaction was discovered between awake/sleep condition and sleepiness SSS scale ratings immediately before the encoding task (Time 1). Participants in the sleep condition who ranked themselves as very alert (SSS rating of 1) performed significantly better than individuals in the awake condition. It is important to note, however, because sleepiness rating was a subject variable, rather than an experimentally manipulated variable, these results should be interpreted with caution. Among those remaining participants who were drowsier at Time 1, the direction reversed

and awake participants appeared to perform better, although not to a statistically significant extent. These findings are partially consistent with the bulk of previous literature that demonstrates the beneficial influence of sleep on memory processes (Diekelmann & Born, 2010). However, the accuracy difference between the awake and sleep condition was not as robust as would have been expected considering the aforementioned findings in previous studies. This may likely be due to the small sample size in this study as compared to others in the area, thus future research should seek to increase the overall sample size.

In our second hypothesis, it was predicted that words associated with sexual valanced images would be better recalled than words associated with nonsexual valanced images. Results did not support our prediction, quite the opposite: participants better recalled words paired with nonsexual images compared to those with sexual images. While this finding runs contrary to expectations, it is consistent with some previous research. While some previous literature demonstrates the influences of sexual images on memory (Ackermann, et al., 2012; Galea, Uban, Epp, Brummelte, Barha, Wilson, Liebech, & Pawluski, 2008; Spencer, Waters, Romeo, Wood, Milner, & McEwan, 2009), there are occasions noted when sexual imagery is detrimental. In a study by Wright and Adams (1999) the sexual valance of stimuli served as a double-edged sword. While the sexual nature of a stimulus might lead to better memory for the item itself, it also interfered with complex cognitive tasks.

Similar to the findings of Wright and Adams (1999), Bushman (2007) discovered that violent and sexual advertisements were least remembered when contained within a violent or highly sexual program. The author explained these results as demonstrating the "expensive" nature of sexual imagery in regard to working memory processes. Sexual valance demands more attention from the individual, which then leaves little remaining working memory available to perform the cognitive task. In the case of the present study, such an explanation is certainly plausible. Participants were instructed to memorize a significant amount of information via two sensory modalities, which would then be recalled during the testing phase. Satisfactory performance on recollection memory tasks demands a degree of effortful encoding (Wagner, Gabrieli, & Verfaellie, 1997).

Therefore, if the sexual nature of the images were compromising available working memory as was seen with Wright and Adams (1999) and Bushman (2007), it stands to reason that similar results would be found here. It would be interesting to see if this potential interference would still be present if the process under investigation were recognition memory, a process believed to be more automatic and less taxing on working memory (Wagner, Gabrieli, & Verfaellie, 1997). This phenomenon likely explains the additional finding concerning awake participants, in which words paired with nonsexual images were better recalled than those with sexual images.

The final hypothesis for the present study predicted sleep participants would better recall words associated with sexual imagery than those in the awake condition. Although the effect was marginal, the results supported the hypothesis: when looking at sexual images only, individuals in the sleep condition recalled more words than those in the awake condition. Why might sleep participants better recall words associated with sexual stimuli compared to awake participants? The answer may in the intersection between the differences in SSS Time 1 ratings and the results concerning our unsupported second hypothesis. Based on the findings of previously cited literature, it is tenable that separate sets of circumstances are converging on the two conditions. It is possible that participants in the awake condition, who reported being more alert at SSS Time 1, are suffering from attentional/working memory overload when presented with sexual content, thereby leaving less resources available to encode words associated with valanced images. Participants who were assigned to the sleep condition, conversely, did not seem to suffer the same detriment. One possible interpretation of this finding is that sleep served to mitigate the negative influence of sexual valance on recollection memory in the present task for those assigned to the that condition.

The current study is valuable because it illustrated an important connection between three separately investigated relationships: (1) sleep and memory, (2) sex and memory, and (3) sex and sleep. The findings demonstrate an interesting interaction between sleep and sexual valance on recollection memory processes. Like all previously conducted research, however, this study has significant limitations. An important limitation in this study has been time: while the sleep subjects were given 90 minutes to

reach Stage 4 (SWS) sleep, most were not able to achieve REM during that time. This was likely due to the artificial nature of the lab, as well as time lost while attempting to adjust to the initial discomfort of the EEG cap against the pillow. The most recent literature on sleep and memory has suggested that both SWS and REM sleep are necessary for effective memory consolidation to occur (Diekelmann & Born, 2010), and unfortunately, many participants were unable to attain both of these important components during the 90-minute sleep period. Unfortunately, it was not possible to allot for a longer period of sleep, as the research system in place could not allow for a total per-participant experimental time longer than 3 hours.

Another potential limitation is the video selected for the awake participants: while the video (Samsara) was selected for its seemingly non-stimulating nature, it nevertheless elicited mixed reactions from the participants. The same movie was shown to all awake participants in an attempt to prevent confounds, but in doing so, not all participants found it similarly non-arousing. In the future, perhaps it would be best to let the participant select a video s/he considers to be non-stimulating, or to present other simple stimuli like music or an audio book.

While there are limitless possibilities for future directions in this research, one interesting area would be potential sex differences in the influences of sleep and sex on recollection memory. Unfortunately, the present study did not have a representative sample of male participants and thus did not permit for investigating such differences. Further, it would be fascinating to look at different types of valance, specifically positive versus negative images. Finally, if conducted in an environment with ample resources, it would be most enlightening to look at the influence of sleep as a full night's sleep instead of a 90-minute nap. This would permit multiple SWS-REM cycles to occur immediately after the encoding task, and according to the abovementioned findings, this would increase the likelihood of demonstrating positive memory effects for sleep. Another interesting area for future research might be to investigate these variables with both high and low level of sexual arousal.

The results of this study suggest a possible interaction between the memory benefits of sleep and the autonomic impact of sexual valance, though the details of this

relationship are not entirely clear. Future research and replication with more experimental time and resources will be necessary to pin down the precise mechanisms driving the interaction between sleep and sex on recollection memory processes.

REFERENCES

Ackermann, S., Spalek, K., Rasch, B., Gschwind, L., Coynel, D., Fastenrath, M., Papassotiropoulos, A., & de Quervain, A. (2012). Testosterone levels in healthy men are related to amygdala reactivity and memory performance. *Psychoneuroendocrinology, 37*, 1417-1424.

Aggleton, J. P. & Brown, M. W. (1999). Episodic memory, amnesia, and the hippocampal-anterior thalamic axis. *Behavioral and Brain Sciences, 22,* 425-489.

Alger, S. E., Lau, H., & Fishbein, W. (2012). Slow wave sleep during a daytime nap is necessary for protection from subsequent interference and long-term retention. *Neurobiology of Learning and Memory, 98,* 188-196.

Andersen, M. L., Alvarenga, T. F., Mazaro-Costa, R., Hachul, H. C., & Tufik, S. (2011). The association of testosterone, sleep, and sexual function in men and women. *Brain Research, 1416,* 80-104.

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature*, *411*, 305-309.

Berkowitz, L. (1984). Some effects of thoughts on anti-social and prosocial influences of media effects: A cognitive neoassociation analysis. *Psychological Bulletin, 95,* 410-427.

Bisby, J. A., & Burgess, N. (2014). Negative affect impairs associative memory but not item memory. *Learning & Memory, 21*(1), 21-27.

Borck, C. (2008). Recording the brain at work: The visible, the readable, and the invisible in electroencephalography. *Journal of the History of Neurosciences, 17,* 367-379.

Born, J., Fehm, H. L. (1998). Hypothalamus–pituitary–adrenal activity during human sleep: A coordinating role for the limbic hippocampal system. *Exp Clin Endocrinol Diabetes , 106*, 153–163.

Bush, S., & Geer, J. H. (2001). Implicit and explicit memory of neutral, negative emotional, and sexual information. *Archives of Sexual Behavior*, *30,* 615–631.

Bushman, B. J. (2007). That was a great commercial, but what were they selling? Effects of violence and sex on memory for products in television commercials. *Journal of*

Applied Social Psychology, 37(8), 1784-1796.

Cahill, L. & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *TINS, 21*(7), 294-299.

Cohen, J. (1988). *Statistical power analysis the behavioral sciences.* (2nd Ed.). Hillsdale, N. J.: Erlbaum.

Dabbs, J. M., & Mohammed, S. (1992). Male and female salivary testosterone concentrations before and after sexual activity. Physiology & Behavior, 52(1), 195-197. doi:10.1016/0031-9384(92)90453-9

Datta, S. (2000). Avoidance task training potentiates phasic pontine-wave density in the rat: A mechanism for sleep-dependent plasticity. *The Journal of Neuroscience, 20*(22), 8607-8613.

Davis, C. J., Harding, J. W., & Wright, J. W. (2003). REM sleep deprivation-induced deficits in the latent-to-peak induction and maintenance of long-term potentiation within the CA1 region of the hippocampus. *Brain Research, 973*, 293-297.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (2nd Ed.), *Handbook of Psychophysiology* (pp. 200-223). United Kingdom: Cambridge University Press.

Dennerstein, L., Dudley, E., Burger, H. (2001). Are changes in sexual functioning during midlife due to aging or menopause? *Fertility and Sterility, 76*(3), 456-460.

Dennerstein, L., Randolph, J., Taffe, J., Dudley, E., Burger, H. (2002). Hormones, mood, sexuality, and the menopausal transition. *Fertility and Sterility*, *77*(4), 542–548.

Dennerstein, L., Lehert, P., Burger, H. G., Guthrie, J. R. (2007). New findings from non-linear longitudinal modeling of menopausal hormone changes. *Human Reproduction Update, 13*(6), 551–557

Diekelmann, S. & Born, J. (2010). The memory function of sleep. *Sleep, 11,* 114-126.

Drosopoulos, S., Shultze, C., Fischer, S., & Born, J. (2007). Sleep's function in the spontaneous recovery and consolidation of memories. *Journal of Experimental Psychology: General, 136*(2), 169-183.

Eichenbaun, H., Yonelinas, A. R., & Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annu Rev Neurosci, 30,* 123-152.

Fishbein, W. (1971). Disruptive effects of rapid eye movement sleep deprivation on long-term memory. *Physiology & Behavior, 6,* 279-282.

Foster, P. S., & Harrison, D. W. (2004). Cerebral Correlates of Varying Ages of Emotional Memories. Cognitive And Behavioral Neurology, 17(2), 85-92. doi:10.1097/01.wnn.0000124917.16017.23

Friedman, D. & Johnson, R. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Technique, 51*, 6-28.

Friendly, M., Franklin, P. E., Hoffman, D., Rubin, D. C. (1982). The Toronto word pool: Norms for imagery, concreteness, orthographic variables, and grammatical usage for 1,080 words. *Behavior Research Methods & Instrumentation, 14*(4), 375-399.

Furnham, A., & Mainaud, L. (2011). The effect of French television sexual program content on the recall of sexual and nonsexual advertisements. *Journal of Sex Research*, *48*, 590–598.

Galea, L.A., Uban, K. A., Epp, J. R., Brummelte, S., Barha, C. K., Wilson, W. L., Liebech, S. E., & Pawluski, J. L. (2008). Endocrine regulation of cognition and neuroplasticity: Our pursuit to unveil the complex interaction between hormones, the brain, and behaviour. *Canadian Journal of Experimental Psychology, 62*(4), 247-260.

Garrett, B. (2011). *Brain and Behavior.* Sage Publications, Inc. Los Angeles, CA.

Geer, J. H. & Janssen, E. (2000). The sexual response system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (2nd Ed.), *Handbook of Psychophysiology* (pp. 200-223). United Kingdom: Cambridge University Press.

Gomes, C. F., Brainerd, C. J., & Stein, L. M. (2013). Effects of emotional valance and arousal on recollective and nonrecollective recall. *Journal of Experimental Psychology, 39*(3), 663-677.

Hasher, L. & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*(3), 356-388.

Huppert, M. S. & Piercy, M. (1978). The role of trace strength in recency and frequency judgments by amnesic and control subjects. *Quarterly Journal of Experimental Psychology, 30,* 346-354.

Jacoby, L. L. (1991), A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30,* 513-541.

Jimenez-Anguiano, A., Arteaga-Silva, M., & Velazquez-Moctezuma, J. (2003). Masculine sexual activity affects slow wave sleep in golden hamsters. *Brain Research Bulletin, 59*(6), 429-432.

Johnson, R., Kreiter, K., Zhu, J., & Russo, B. (1998). A spatio-temporal comparison of semantic and episodic cued recall and recognition using event-related brain potentials. *Cognitive Brain Research, 7,* 119-136.

Keizer, A. W., Verment, R. S., & Hommel, B. (2010). Enhancing cognitive control through neurofeedback: A role of gamma-band activity in managing episodic retrieval. Neuroimage, 49(4), 3404-3413. doi:10.1016/j.neuroimage.2009.11.023

Kuriyama, K., Stickgold, R., & Walker, M. (2004). Sleep-dependent learning and motor-skill complexity. *Sleep & Memory Research, 11*, 705-713.

Lagopoulos, J., Gordon, E., & Ward, P. B. (2006). Differential BOLD responses to auditory target stimuli associated with a skin conductance response. *Acta Neuropsychiatrica, 18,* 105-114.

Lahl, O., Wispel, C., Willigens, & B., Petrowsky, R. (2008). An ultra short episode of sleep is sufficient to promote declarative memory performance. *Journal of Sleep Research, 17,* 3-10.

Lawson, A. L., Liu, X., Joseph, J., Vagnini, V. L., Kelly, T. H., & Jiang, Y. (2012). Sensation seeking predicts brain responses in the old-new task: Converging multimodal neuroimaging evidence. *International Journal of Psychophysiology, 84,* 260-269.

Lewis, R. J., Gibbons, F. X., & Gerrard, M. (1986). Sexual experience and recall of sexual vs. nonsexual information. *Journal of Personality, 54*(4), 676-693.

Lovallo, W. R. & Thomas, T. L. (2000). Stress hormones in psychophysiological research. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (2nd Ed.),

Handbook of Psychophysiology (pp. 200-223). United Kingdom: Cambridge University Press.

Luboshitzky, R., Herer, P., Levin, M., Shen-Orr, Z., & Lavie, P. (1999). Relationship between rapid eye movement sleep and testosterone secretion in normal men. *Journal of Andrology, 20*(6), 731-737.

Luboshitzky, R., Zabari, Z., Shen-Orr, Z., Herer, P., & Lavie, P. (2001). Disruption of the nocturnal testosterone rhythm by sleep fragmentation in normal men. *J. Clin. Endocrinol. Metab. 86* (3), 1134–1139.

Marshall, L. & Born, J. (2007). The contribution of sleep to hippocampus-dependent memory consolidation. *TRENDS in Cognitive Sciences, 11*(10), 442-450.

Mayes, A. R. Meudell, P. R., Mann, D. & Pickering, A. (1988). Location of lesions in Korsakoff's syndrome: Neuropsychological and neuropathological data on two patients. *Cortex, 24,* 367-388.

McCall, K. M., Rellini, A. H., Seal, B. N., & Meston, C. M. (2007). Sex differences in memory for sexually-relevant information. *Archives of Sexual Behavior, 36*(4), 508-517.

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why are there complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychology Review, 102*(3), 419-457.

Mednick, S. C., Nakayama, K., Cantero, J. L., Atienza, M., Levin, A. A., Pathak, N., & Stickgold, R. (2002). The restorative effect of naps on perceptual deterioration. *Nature Neuroscience, 5*(7), 677-681.

Miller, E. K. & Desimone, R. (1993). Parallel neuronal mechanisms for short-term memory. *Science, 263,* 520-522.

Milner, C. E., Fogel, S. M., & Cote, K. A. (2006). Habitual napping moderates motor performance improvements following a short daytime nap. *Biological Psychology, 73*, 141–146.

Miner, A. (1993). Individual differences and memory: Need for cognition interacts with encoding and retrieval manipulations. *Dissertation Abstracts International*, *54*,

529-662.

Miyakoshi, M., Kanayama, N., Iidaka, T., & Ohira, H. (2010). EEG evidence of face-specific visual self-representation. Neuroimage, 50(4), 1666-1675. doi:10.1016/j.neuroimage.2010.01.030

Muto, V., Arpaia, I., De Padova, V., Russo, E., & Ficca, G. The effect of daytime naps on the recall of verbal material. In: Proceedings of the 1st Congress of the World Association of Sleep Medicine, Medimond: Bologna; 2005: p. 29-34.

Noh, E., Herzmann, G., Curran, T., & de Sa, V. R. (2014). Using single-trial EEG to predict and analyze subsequent memory. Neuroimage, 84712-723. doi:10.1016/j.neuroimage.2013.09.028

Oschner, K. N. (2000). Are affective events richly recollected or simply familiar? The evidence and process of recognizing feelings past. *Journal of Experimental Psychology, 129*(2), 242-261.

Parker, E., & Furnham, A. (2007). Does sex sell? The effect of sexual programme content on the recall of sexual and nonsexual advertisements. *Applied Cognitive Psychology, 21*, 1217–1228.

Posner, M. I., & Boies, S. J. (1971). Components of attention. Psychological Review, 78(5), 391-408. doi:10.1037/h0031333

Rauchs, G., Desgranges, B., Foret, J., & Eustache, F. (2005). The relationship between memory systems and sleep stages. *J. Sleep Res. 14*, 123-140.

Renfro, A. G., Antoine, K., & Lawson, A. L. (2013). Sensation seeking influence on memory for positive events. *North American Journal of Psychology, 15*(3), 609-622.

Ribeiro, S. & Nicolelis, M. A. (2004). Reverberation, storage, and postsynaptic propagation of memories during sleep. *Memory & Sleep Review, 11*, 686-696.

Robertson, E. M., Pascual, A., & Miall, R. C. (2004). Current concepts in procedural consolidation. *Nature Reviews: Neuroscience, 5*, 1-7.

Schabus, M., Hodlmoser, K., Pecherstorfer, T., & Klosch, G. (2005). Influence of midday naps on declarative memory performance and motivation. *Somnologie, 9*(3), 148-153.

Schoen, L. S. & Badia, P. (1984). Facilitated recall following REM and NREM naps. *Psychophysiology, 21*, 299–306.

Spencer, J. L., Waters, E. M., Romeo, R. D., Wood, G. E., Milner, T. A., & McEwen, B. S. (2009). Uncovering the mechanism of estrogen effects on hippocampal function. *Front Neuroendocrinol., 29*(2), 219–237.

Sutton, J. (2011). Influences on memory. *Memory Studies, 4*(4), 355-359.

Tucker, M. A., Hirota, Y., Wamsley, E. J., Lau, H., Chaklader, A., & Fishbein, W. (2006). A daytime nap containing solely non-REM sleep enhances declarative but not procedural memory. *Neurobiology of Learning and Memory, 86*(2), 241-247.

Vertes, R. P. & Eastman, K. E. (2000). The case against memory consolidation in REM sleep. *Behavioral and Brain Sciences, 23*, 793-1121.

Wagner, U. & Born, J. (2008). Memory consolidation during sleep: Interactive effects of sleep stages and HPA regulation. *Stress, 11*(1), 28-41.

Wagner, A. D., Gabrieli, J. D., & Verfaellie, M. (1997). Dissociations between familiarity processes in explicit recognition and implicit perceptual memory. *Journal of Empirical Psychology, 23*(2), 305-323.

Wirkner, J., Weymar, M., Löw, A., & Hamm, A. O. (2013). Effects of pre-encoding stress on brain correlates associated with the long-term memory for emotional scenes. Plos ONE, 8(9), doi:10.1371/journal.pone.0068212

Wright, L. W. & Adams, H. E. (1999). The effects of stimuli that vary in erotic content on cognitive processes. *The Journal of Sex Research, 36*(2), 145-151,

Yamamoto, J., Suh, J., Takeuchi, D., & Tonegawa, S. (2014). Successful Execution of Working Memory Linked to Synchronized High-Frequency Gamma Oscillations. Cell, 157(4), 845-857.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Memory and Language, 46,* 441-517.

Zacone, V., Pena D. L., & Dement, W. C. (1974). Heightened sexual interest and sleep disturbance. *Perceptual and Motor Skills, 39,* 1135-1141.

Zuckerman, M. (1990). The psychophysiology of sensation seeking. *Journal of Personality, 58*(1), 313-345.

APPENDICES

APPENDIX A:

Table 1

Table 1.
Group Differences for Sleep Journals and Sleepiness Scale Rating

	df	t	*p*
Week 1 Sleep Journal	(1,42)	.37	.71
Week 2 Sleep Journal	(1,42)	.35	.73
SSS Time 1 Rating	(1,42)	-2.05*	.05*
SSS Time 2 Rating	(1,42)	.91	.37
SSS Time 3 Rating	(1,42)	.20	.84

*Difference is significant at the .05 level or below.

APPENDIX B:

Table 2

Table *2*.
Repeated-Measures, Mixed-Design ANOVA.

	df	*F*	*p*	η¬
Awake/Sleep Condition (*between*)	(1,38)	.644	.43	.02
SSS Time 1 (*between*)	(1,38)	.48	.62	.03
Condition * SS Time 1 (*between*)	(2,38)	2.94*	.07*	.13*
Image Type	(1,38)	7.18**	.01**	.16**
Image Type * Condition	(1,38)	4.64**	.04**	.11**
Image Type * Test Time	(1,38)	.70	.41	.02
Image Type * SS Time 1	(2,38)	1.03	.37	.05
Image Type * Condition * SS Time 1	(2,38)	2.04	.14	.10
Image Type * Test Time * Condition	(2,38)	1.57	.22	.04
Test Time	(1,38)	17.69**	.00**	.32**
Test Time * Condition	(1,38)	.00	.99	.00
Test Time * SS Time 1	(2,38)	.44	.65	.02
Test Time * Condition * SS Time 1	(2,38)	1.37	.27	.07

* Effect is marginally significant at the .07 level or below.

** Effect is significant at the .05 level or below.

APPENDIX C:

Table 3

Table 3.
Total Mean Accuracy by Condition and Sleepiness Scale Time 1 Rating

Condition	Sleepiness Rating	Mean	*Std. Err.*
Awake			
	1	.667	.099
	2	.785	.023
	3	.829	.057
Sleep			
	1	.944	.099
	2	.725	.725
	3	.739	.739

APPENDIX D:

Table 4

Table 4.
Mean Accuracy (Day 1) by Condition and Sleepiness Scale Time 1 Rating

Condition	Sleepiness Rating	Mean	*Std. Err.*
Awake			
	1	.778	.087
	2	.872	.021
	3	.861	.050
Sleep			
	1	.972	.087
	2	.821	.026
	3	.844	.028

APPENDIX E:

Table 5

Table 5.
Mean Accuracy (Day 2) by Condition and Sleepiness Scale Time 1 Rating

Condition	Sleepiness Rating	Mean	*Std. Err.*
Awake			
	1	.556	.146
	2	.698	.034
	3	.796	.084
Sleep			
	1	.917	.146
	2	.629	.044
	3	.633	.046

APPENDIX F:

Figure 1

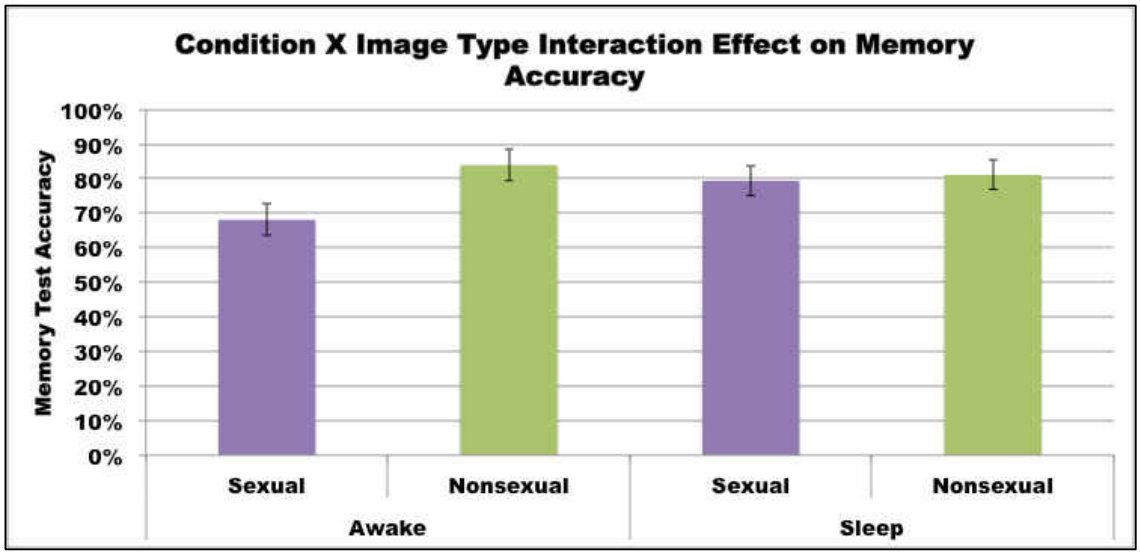

Figure 1. Condition and Image Type Interaction Effect on Memory Accuracy.

APPENDIX G:

Figure 2

Effect Size	0.40
α err prob	0.05
Power (1-β err prob)	0.95
Number of Groups	2
Number of Measurements	36
Total Sample Size	**44**

Figure 2. Power Analysis. A power analysis was performed based on information from Cohen (1988). To achieve the required large effect size for F tests for ANOVAs (repeated measures, between factors), it would be necessary to collect data from 44 participants.