The relationship between memory disruptive effects of REM sleep deprivation and neuropsychological dissociations of task requirements.

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THE RELATIONSHIP BETWEEN MEMORY DISRUPTIVE EFFECTS OF REM SLEEP DEPRIVATION AND NEUROPSYCHOLOGICAL DISSOCIATIONS OF TASK REQUIREMENTS

by

James Arthur Conway

B.Sc. Trent University, 1993

A Thesis
Submitted to the Faculty of Graduate Studies through the Department of Psychology in Partial Fulfillment of the Requirements for the Degree of Master of Arts at the University of Windsor Windsor, Ontario, Canada 1995
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ABSTRACT

The present study explores the relationship between human REM sleep and time-dependent memory consolidation processes. Specifically, it was hypothesized that differential effects on retention produced by post-learning REM sleep deprivation may be explained in terms of neuropsychological dissociations of task requirements. In order to test this possibility, a variety of memory tasks were assembled to be representative of subsets within both explicit/declarative and implicit/procedural domains. These include: Word Recognition, Word Fragment Completion, Tower of Hanoi, Corsi Block-Tapping Task, and the Rey-Osterrieth Complex Figure. Thirty-five undergraduate students from Trent University, Peterborough served as subjects. Subjects were presented with the stimulus materials in the evening, followed by random assignment to one of five sleep conditions: 1) Selective REM Sleep Deprivation (REMD; n=7), 2) Non-REM Sleep Deprivation (NREMD; n=7), 3) Total Sleep Deprivation (TSD; n=7), 4) Lab Recorded Controls (RECON; n=7), or 5) Normally Rested Controls (CON; n=7). Subjects were post-tested with the same materials after a 1-week retention interval. Results indicated that selective REM sleep deprivation following learning impaired retention of implicit priming and cognitive procedural learning while sparing explicit/declarative material. Results are discussed within a variety of theoretical frameworks, including distinct memory systems theories and accounts derived from the area of human information processing.
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CHAPTER 1
INTRODUCTION

Shortly after the discovery of rapid eye movement (REM) sleep by Aserinsky and Kleitman in 1953, it was proposed that this somewhat paradoxical state must serve some important function, one probably related to the processing of information by the brain. In light of this discovery, the line of investigation initiated by Jenkins and Dallenbach’s (1924) landmark demonstration of reduced forgetting during sleep seemed logically to point to a specific hypothesis concerning the function of REM sleep: that it is somehow necessary for, or conducive to, the process of memory consolidation (Dewan, 1969; Empson, 1971; Empson & Clarke, 1970; Feldman & Dement, 1968). Subsequent research concerning the sleep-learning hypothesis as it pertains to humans has yielded mixed results. Some laboratories have found evidence for REM involvement in consolidation (e.g., Allen, 1975; Empson & Clarke, 1970; Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994; Smith & Pirolli, 1989; Tilley & Empson, 1978), while others have failed to show a significant effect (e.g., Chernik, 1972; Ekstrand, Sullivan, Parker, & West, 1971; Feldman & Dement, 1968; Johnson, Naitoh, Moses, & Lubin, 1974; Muzio, Roffwarg, Anders, & Muzio, 1972). Furthermore, some results have been equivocal and
may even be interpreted as evidence for REM disruption of consolidatory processes (see

Previous research in this area was directed at answering the very broad question of
whether or not a REM sleep deprivation effect actually exists. Recent developments in
the independent fields of both sleep and human memory indicate that more specific
hypotheses are required. Such hypotheses would be directed towards determining the
specific conditions under which a REM sleep deprivation effect might reliably be
expected to occur. Current accounts of human memory phenomena (i.e., Moscovitch,
Weiskrantz, 1987) discredit the notion of memory as a single unitary construct, instead
proposing systemically and perhaps anatomically dissociable memory forms. Alternate
theoretical accounts (e.g., Blaxton, 1989; Jacoby, 1983; Jacoby & Kelley, 1987; Jacoby
attempt to explain these dissociations by positing different modes of processing, creating
a debate which is as yet unresolved.

Regardless of whether one endorses a systemic or an information processing
explanation, the data clearly show that research involving human memory requires
delimitative hypotheses and that differing experimental paradigms may be expected to
produce dissociated and even contradictory results. Given that an adequate
conceptualization of human memory is still (and slowly) emerging, it is not surprising
that research into sleep and memory consolidation processes has produced such mixed
results. This area, perhaps more than any other, has suffered from our limited knowledge of the constructs under investigation. "Learning", "memory" and "consolidation" are vague terms that represent broad hypothetical constructs; it is no small task for different investigators to systematically reduce them to operationally defined variables. The result has been the lack of a unified perspective on the types of questions being asked--a situation that reduces the validity of comparing results obtained by different laboratories and thus the quantity of analogous data from which to draw conclusions.

A few authors have considered the nature of the memory task as an important variable to be manipulated (e.g., Cartwright, Lloyd, Butters, Weiner, McCarthy, & Hancock, 1975; Greenberg & Pearlman, 1974; Greenberg, Pillard, & Pearlman, 1972), but in most cases no attempt has been made to reconcile these manipulations with any existing theoretical framework, whether cognitive or neuropsychological. The present study employed a neuropsychological framework, although alternate theories are not excluded from consideration in the attempt to interpret the results. It is hoped that the appeal to an existing conceptual framework for human memory phenomena will provide theoretical parameters leading to coherent and replicable results. We turn now to the historical origins of the research, followed by a description of the neurophysiology of sleep and human sleep patterns. A review of the experimental literature investigating the sleep-learning hypothesis will then be provided, followed by a discussion of the major theoretical accounts of human memory phenomena and the present experimental hypotheses.
Historical Origins of the Experimental Paradigm

The current line of research employs an experimental paradigm that was first conceived by Jenkins and Dallenbach (1924). These early investigators were not concerned with the role of sleep in memory consolidation processes, but rather with the utility of sleep as a condition in experiments testing alternate theories of forgetting. The first (and most simple) explanation of forgetting was that memories fade with the passage of time. Thorndike (1911) conceptualized learning as the formation of stimulus-response bonds through use, and his "law of disuse" stated that if a bond was not practiced it would decrease in strength until it was eventually lost. The attempt to specify those processes that operate over the course of time to produce forgetting gave rise to two opposing theories: decay theory and interference theory (Wingfield & Byrnes, 1981). Decay theory saw forgetting as a time-dependent process inherent to the nervous system in which unused representations in memory deteriorate over time independent of both the nature of the material and other learning experiences. Interference theory, on the other hand, proposed that forgetting results from the deleterious effect of other learning.

In order to address the problem of separating time-dependent effects from intervening learning effects in an experimental setting, Jenkins and Dallenbach (1924) posited that if subjects were presented with the learning material immediately prior to going to sleep, the potential for interfering experience would be minimized. Thus, sleep was seen as a convenient period during which the effects of the passage of time could be studied independently of interfering experience. The results of this landmark study
indicated that subjects did, in fact, experience less forgetting during a sleep-filled retention interval than during an equal period of wakefulness. This phenomenon has been replicated in many more recent studies (e.g., Barrett & Ekstrand, 1972; Benson & Feinberg, 1975, 1977; Dillon, 1970; Ekstrand, 1967; Idzikowski, 1984). This "sleep effect" on retention was originally interpreted as evidence supporting interference theory and damaging to decay theory, but another possibility remained: that sleep may actually facilitate memory consolidation (Tilley, Brown, Donald, Ferguson, Piccone, Plasto & Statham, 1992).

This possibility became even more intriguing with the discovery of rapid eye movement (REM) sleep by Aserinsky and Kleitman (1953). The existence of two qualitatively different kinds of sleep, REM and non-REM (NREM), led naturally to questions concerning their respective functions. By the late 1960s and early 1970s, a number of theories had emerged which proposed that REM sleep served to consolidate or otherwise reactivate, reiterate, or sift through recently acquired memories (Dewan, 1970; Empson & Clarke, 1970). These theories led to a number of experimental strategies, including the present approach, in which subjects are exposed to a unique learning situation followed by either normal sleep or selective (REM or non-REM) sleep deprivation. By including both normally-rested and non-REM sleep deprived controls, deficits in retention at post-testing in the REM deprived group can be interpreted as evidence for a REM sleep contribution to memory consolidation. A discussion of the neurophysiology of human sleep will facilitate a review of these experiments.
Human Sleep Patterns

Human sleep is not a homogenous state of unconsciousness. Rather, it is a set of complex and heterogeneous biological and psychological phenomena. Typically occurring in cycles, human and other mammalian sleep is composed of several stages that are remarkably consistent in terms of their order, timing, and electrophysiological characteristics. Moreover, sleep stages can be reliably and objectively measured using a polygraphic recording device which simultaneously monitors several electrophysiological parameters indicative of the level of CNS and muscle activity. For example, the electroencephalograph (EEG) measures electrical activity in the brain by detecting the summed activity of millions of cortical dendrites via electrodes attached to the scalp. This activity differs markedly depending on the stage of sleep that the organism is engaged in. Other physiological parameters that vary systematically with sleep stages include ocular movement (represented by an electro-oculogram, EOG) and muscle tension (electromyogram, EMG).

The patterning of human sleep stages is such that a person will usually begin by entering a relaxed state characterized by alpha brain waves of approximately 8-12 Hz frequency. Although not considered a form of sleep, this state marks the beginning of the cyclical progression through deeper stages of sleep collectively referred to as slow-wave, or non-REM sleep (Aserinsky & Kleitman, 1953; Kleitman, 1963). The first stage (stage I) of slow-wave sleep is normally entered soon after retiring, and is characterized by 7-9 Hz brain wave patterns. EEG frequency then drops to 5-8 Hz as the subject enters stage
II, 3-5 Hz in stage III, and 0.5-3 Hz frequency in stage IV. Stages III and IV are usually designated as deep slow-wave sleep, and these occur primarily within the first three hours of the sleep cycle. The second half of the night is mostly comprised of stage II and REM sleep, with REM sleep being most prominent in the early morning.

After passing through the four stages of non-REM sleep, individuals will typically return to a lighter stage of sleep before returning to deeper sleep again. This cyclical pattern occurs four or five times during the night at approximately 90 to 100 minute intervals (Aserinsky & Kleitman, 1953; Kleitman, 1963). The return to stage one from the deeper stages of sleep is referred to as "emergent" stage one, and it is during this stage that REMs and dreaming occur (Kleitman, 1963). Rapid eye movement (REM) or "paradoxical" (PS) sleep can be easily distinguished from slow-wave sleep based on the patterning of EEG, EOG, and EMG measures. During slow-wave sleep, subjects exhibit varying degrees of muscle tension, whole-body and limb movements, high-amplitude low-frequency EEG activity, and relatively little ocular movement. In contrast, REM sleep is characterized by prominent and rapid eye movements, low-amplitude high-frequency EEG activity, and increased respiration and pulse rates in the absence of any muscle tonus (Aserinsky & Kleitman, 1953). The inhibition of muscle tonus during REM sleep is sufficient to produce a temporary paralysis, and this is believed to serve the purpose of preventing injury or detection by predators that might result from motor responses elicited by intense dreaming. The term paradoxical sleep derives from the observation that although physiological parameters during this stage indicate high levels
of activity with a relatively lighter sleep, behavioural indices (subject self-reports and
difficulty arousing the subject) indicate a very deep sleep.

The first REM sleep period, which usually lasts less than 10 minutes, occurs
slightly more than one hour after sleep onset (Aserinsky & Kleitman, 1953; Kleitman,
1963). Following this, three to five more REM periods occur at approximately 90-min.
intervals, with a duration of 20 to 35 min. each. Therefore, a full night of sleep is required
to allow for only one or two hours of REM sleep (Kleitman, 1963). Most or all of the
bizarre and narrative “story” type of dreaming that we experience during the night occurs
during REM sleep. However, other dream-like phenomena such as night terrors, which
are vague affective states without a story line, are more likely to occur during non-REM
deep sleep (Kleitman, 1963).

Due to the physiological distinctiveness of REM sleep, as well as the paradoxical
nature of the high levels of cortical activity observed during this state, a number of
researchers and theorists have taken an interest in its potential functions, in an effort to
elucidate its biological and psychological significance. For example, Becker and Thomas
(1981) have related REM sleep to brain development in infants, and Greenberg, Pillard,
and Pearlman (1972) proposed a role for REM sleep and dreaming in adaptation to stress.
Vogel (1979) found a correlation between REM sleep and depression, and demonstrated
that selective REM sleep deprivation is capable of reducing endogenous depression. We
turn now to a review of the experimental literature investigating what has come to be
known as the sleep-learning hypothesis.
The Sleep-Learning Hypothesis: A Review Of The Literature

A considerable amount of research has been devoted to investigating the potential functions of REM sleep. Some investigators have been primarily concerned with the role of REM sleep in preparing the organism for subsequent learning (Chernik, 1972; Lewin & Glaubman, 1975), while others have addressed its role in consolidating previous learning (Ekstrand, 1972; Smith, 1991; Tilley & Empson, 1978). This review will revolve primarily around those studies that have employed a post-training REM deprivation (REMD) strategy to investigate deficits in the consolidation of previously learned material. Studies using other experimental paradigms (e.g., prior-REMD) have been largely inconclusive and have limited relevance to the present study. Animal studies of post-learning REMD have met with considerable success and will be reviewed briefly before the more ambiguous results of human experiments. For a detailed discussion of the animal literature, see Smith (1985) and McGrath and Cohen (1978).

Animal Studies. Post-learning REM sleep deprivation experiments using animal subjects have been more successful than human studies at demonstrating deficits in the retention of previous learning. The basic experimental design is one in which naive experimental animals (usually rats or mice) are given training sessions in a traditional learning task such as bar pressing, radial arm maze learning, or shuttle avoidance. This is followed by selective deprivation of REM sleep. After a sufficient recovery period to control for the effects of sleep disruption per se, the animals are tested for retention of the previous learning. The usual procedure for selective REM sleep deprivation in rats has
been the "flowerpot" technique. This technique consists of placing the rat on an inverted flowerpot in a tank of water such that the rat must sit on the flowerpot in order to keep out of the water. The water level is kept just below the height of the inverted flowerpot, so that whenever the animal enters into REM sleep the lack of muscle tonus will result in the animal's face dipping into the water. Thus, the animal will be awakened whenever it enters into REM sleep. Rats quickly learn to sleep in an upright position, engaging in only slow-wave sleep. By placing rats on these flowerpots following some learning task, the effect of REMD on consolidation of learning can then be assessed by subsequent retest.

Approximately 65% of 45 published animal studies employing such a paradigm found positive evidence for REM involvement in the consolidation of memory (Smith, 1985). These detrimental effects of post-training REMD have now been demonstrated in a variety of tasks including two-way shuttle avoidance (Butler & Smith, 1981; Leconte, Hennevin, & Bloch, 1974; Pearlman & Greenberg, 1973; Smith & Butler, 1982; Smith & Young, 1980), appetitive bar press (Smith, Lowe, & Smith, 1977), and more recently the Morris water maze (Smith, Conway, & Rose, 1993a; 1993b).

Several theories have been proposed that may account for studies (e.g., Albert, Cicala, & Siegal, 1970, experiments 2 & 3) that failed to demonstrate a significant REMD effect. Dewan (1970) first proposed the programming (p) hypothesis of REM sleep, which states that REM sleep is a time for metaprogramming of information that prepares the organism for future learning and promotes the consolidation of previous
learning. Greenberg and Pearlman (1974) suggested that REM sleep is not required in
tasks for which the organism is biologically prepared. This theory may explain why
studies requiring an instinctually prepared response such as one-way avoidance (Albert,
Cicada, & Seigal, 1970) or passive avoidance (Fishbein, 1970) failed to show a significant
effect. It is also important to note that not all of these studies used reliable methods of
ensuring that REM deprivation occurred at the necessary times (Smith, 1985). In fact,
there is now substantial evidence to support the conclusion that the exact timing of REM
depression, relative to the experimental training session, is of paramount importance if
one is to demonstrate the REMD effect (Smith, 1991; Smith & Butler, 1982; Smith,
Conway, & Rose, 1993a, 1993b).

The importance of this variable is illustrated by the efficacy of combined
experimental strategies when investigating REM involvement in learning. An alternative
approach to the study of post-training REM sleep and memory has been to use EEG and
EMG monitoring following the learning task. The goal of this strategy is to show
increases in indices of REM sleep at the times believed to be involved in memory
consolidation. Twenty-six of 28 published studies employing this strategy have shown
increases in the number of REM periods and/or the size of the REM periods (Smith,
1985). For example, Smith, Lowe, and Smith (1977) observed increases in both REM
and slow-wave sleep during acquisition of an appetitive bar press task in rats. Employing
an aversive task, Smith and Lapp (1986) demonstrated increases in both amount of REM
sleep and number of REMs following acquisition of a shuttle avoidance task, also in the
rat. Smith and Butler (1982) found that these increases in REM sleep occurred only at specific times during a 24 hour period, and that the timing and duration of these periods depends on the type of task, amount of training, and strain of the animal (Smith, 1985).

Converging evidence from the sleep monitoring and sleep deprivation studies led to the proposal of critical periods for the completion of memory consolidation: these periods were termed "REM windows". Smith and Lapp (1986) provide an example of such convergent evidence. These investigators continuously monitored the sleep of rats undergoing two days of two-way shock avoidance training at 50 trials per day. The sleep records showed increases in REM sleep occurring 9-12 hours post-training. Furthermore, REMD applied at this time resulted in learning deficits. More recently, Smith, Conway, and Rose (1993a) found that REM deprivation resulted in deficits in acquisition of the Morris water maze by rats, and that the effect was confined to specific post-training periods that varied depending on the number of trials per training session. In a related study, Smith, Conway, and Rose (1993b) found that the disruptive effects on retention in rats, produced by post-learning injection of MK-801 (which blocks NMDA receptors), was also limited to specific post-training injection times. Since it has been demonstrated that REM windows may occur many hours after training (Smith, 1985; Smith & Lapp, 1986), this may account for the absence of REMD effects in studies that applied REMD only for relatively short periods of time immediately following training (Smith, 1985; Smith & Butler, 1982). Current animal studies are largely directed at determining the
types of learning tasks that are most sensitive to REM sleep deprivation, as well as the latency to onset of REM windows associated with each of these tasks.

Human Studies. The results of human studies of REM sleep and learning have been somewhat more ambiguous than the animal studies, with a lower percentage of positive findings. However, for reasons previously outlined, the quantity of analogous data from which to draw conclusions has been severely limited. Furthermore, recent studies employing more sophisticated operationalizations of learning (Smith, 1991; Smith & Pirolli, 1989) have produced more reliable, albeit conceptually ambiguous, results.

Human sleep has been monitored and recorded in experimental settings using EEG, EMG, and EOG measures. As with the animal studies, these measures have indicated post-learning increases over baseline in REM sleep. These appear to be associated with the nature and degree of learning that the individual has been involved in. For example, Glaubman, Orbach, Gross, Aviram, Frieder, Frieman, and Pelled (1979) found significant increases in REM time, but not NREM time, following exposure to a number of tasks demanding focussed attention (e.g., intelligence test items, logic deductions, dichotic listening tasks, and passages of prose). Smith and Lapp (1991) followed a group of university honours students and compared their sleep parameters with those of a control group no longer attending the university. The first sleep recording was made in August, before the beginning of the honours program; the second was made immediately after the completion of Christmas exams, and the third was made in the
following August after completion of the honours program. It was reasoned that the students would be undergoing an intense learning load, heightened at the time of Christmas exams, and that increases in REM sleep should occur as a result. Indeed, the results showed that the REM sleep of the students differed from that of controls. While control subjects showed no changes in REM sleep over baseline, the students demonstrated increases in number of rapid eye movements, or REM density.

Post-training sleep deprivation has also been used to investigate the relationship between sleep and learning in humans. Smith and Whittaker (1987) trained subjects in a difficult logic task known as the Wff'n'Proof, followed by deprivation of either the first four hours of sleep or the entire night, beginning at either 0, 24, 48, or 72 hours after initial learning. They found that subjects who were deprived of sleep on the same night as training, as well as those deprived of a night's sleep 48 hours later, performed significantly more poorly on the Wff'n'Proof post-test. It should be noted that this study did not selectively deprive subjects of REM sleep and therefore leaves open the question of REM involvement in consolidation processes. This problem was addressed by Tilley and Empson (1978) who compared the effects on story retention of selective REM sleep deprivation against a control group awakened an equal number of times during NREM (Stage 4) sleep. They found that recall accuracy following REMD was significantly poorer than that following S4 deprivation. This effect has also been demonstrated by Allen (1975) as well as Empson and Clarke (1970). More recently, Smith and Pirolli (1989) followed up on the work done by Smith and Whittaker (1987) and found that
Selective REM sleep deprivation was able to produce deficits in learning the Wff 'n' Proof logic task. At this point, it appears that REM sleep is the crucial element in these studies, although REM involvement seems to be limited to specific types of learning.

Two main differences between studies producing positive and negative results are: 1) the type of learning material, and 2) the amount of initial learning (Tilley et al., 1992). Studies producing positive results have tended to use semantically integrated prose or stories, whereas the negative studies used digits, paired associates, or nonsense syllables. It is interesting to note in this regard that the recent work of Smith and Whittaker (1987) and Smith and Pirolli (1991) employed both a complex logic task and a paired associate task. As expected, the paired associate tasks revealed no effect even within the same subjects who demonstrated a deficit in learning the logic task. Furthermore, the studies that yielded positive results usually presented the materials only once or twice whereas the negative studies usually required subjects to learn the lists to some criterion (Tilley et al., 1992). One exception to this is Allen (1975) who obtained positive results despite training to criterion. These findings seem to support theories proposing REM involvement only in meaningful or ecologically relevant material but not meaningless, rote learning (e.g., Fishbein & Gutwein, 1977; Lewin & Glaubman, 1975; McGrath & Cohen, 1978; Smith, 1991; Tilley et al., 1992).

Lewin and Glaubman (1975) proposed that REMD disrupts learning in tasks that require divergent, flexible thinking but not in tasks that require simple convergent thinking or rote memorization. They tested this possibility by having subjects learn one
of four tasks: 1) serial learning, 2) "clustering" memory, 3) word fluency, and 4) Guilford's Utility Test. Serial learning was considered to be a simple, convergent task. Guilford's Utility Test was considered to be a divergent task. Word fluency and clustering memory were deemed to be intermediate in this dichotomy. As predicted, Lewin and Glaubman (1975) found that REMD produced a deficit on post-test for Guilford's Utility Test, but not for the other tasks. In fact, REMD subjects actually showed an increment in performance for the convergent serial learning task.

The present paper is concerned with the hypothesis that differences between tasks that are disrupted by REMD and those that are not may involve a declarative vs. procedural dichotomy. This is the first attempt to reconcile the differential REMD findings with an established, working conceptualization of human memory. There exists a vast amount of neuropsychological, cognitive, and neurocognitive literature demonstrating these two dissociated forms of human memory. Whether these dissociations are systemic/anatomical in nature or processing based is still a lively debate, but not one that diminishes the utility of an appeal to these resources in attempting to determine the fundamental differences between tasks that could result in differential REMD effects. Positive results obtained in this context could be compared with the extant literature to provide a basis for coherent inferences and predictions capable of directing future research. A discussion of theoretical frameworks for human memory will facilitate the presentation of the experimental rationale and hypotheses.
Theoretical Frameworks for Human Memory

Research into human memory has a history spanning over one hundred years and has been characterized by a proliferation of tasks that have become standard paradigms throughout the field (Hintzman, 1990; Richardson-Klavehn & Bjork, 1988). However, recent developments have seen the emergence of a new category of tasks that has not only changed the way researchers assess memory, but also the ways in which the construct is conceptualized. In the areas of both neuropsychology and cognitive psychology, there has been a remarkable burgeoning of literature dealing with dissociations between traditional measures such as free recall, cued recall and recognition, and this new domain of tasks variably referred to as implicit, indirect, procedural, unconscious, or unaware.

Despite the plethora of terms that have been used in reference to these tasks, and the likelihood that they reflect more than a single process or construct, it is still possible to draw a basic distinction between these tasks and traditional measures of memory (Chiarello & Hoyer, 1988; Cohen & Squire, 1980; Richardson-Klavehn & Bjork, 1988; Schacter, 1987). This review will attempt to describe the basic nature of these tasks, as well as provide an acquaintance with the variety of theoretical frameworks that have been developed in an attempt to incorporate these tasks into a coherent account of human memory processes.

Generally speaking, in traditional tasks such as free recall or recognition the experimenter makes direct or explicit reference to a prior learning episode, while the
subject is required to use conscious recollection of that episode as a primary strategy to perform the task (Jacoby & Witherspoon, 1982; Schacter, 1987). In contrast, tasks commonly referred to as indirect, implicit, or procedural do not involve explicit reference to a prior episode and do not necessarily require the subject to engage in conscious recollection. In these tasks, retention is assessed by decreased response latencies or some other measure of task facilitation that can be attributed to previous experience (Schacter, 1987; Tulving & Schacter, 1990; Warrington & Weiskrantz, 1968).

Performance on these tasks reveals some interesting dissociations when compared to traditional measures such as free recall or recognition. For example, Tulving, Schacter, and Stark (1982) compared the performance of normal subjects on a word recognition task to performance on a task of word fragment completion. Subjects were shown a list of study words, and then asked either to identify previously studied words from a list that contained both studied and non-studied words, or to fill in word fragments (e.g., A_ A_ _IN for ASSASSIN) that were created from the same "target" and "lure" (old and new) words. Performance on both of these tasks was measured at retention intervals of one hour and one week. Results indicated that previous study facilitated performance on the fragment completion task (repetition priming effect), and that this priming was independent of recognition memory in two ways. First, the ability of subjects to correctly identify previously studied words (recognition memory) declined substantially over the 7-day retention interval, while the priming of word fragment completion remained essentially unchanged over this same time period. Second, subjects
demonstrated equivalent priming on all previously studied words, regardless of whether they could correctly identify them as "old" words during the recognition task. That is, the priming effect on fragment completion for any given word was not dependent on "conscious" recollection of having previously studied the word. Thus, performance on the two measures of retention was dissociated in terms of both rate of decline and cognitive requirements for successful completion.

These types of dissociations have given rise to the aforementioned distinction between traditional explicit, or direct tasks, and implicit or indirect tasks. The dissociation of these two types of tasks, in terms of strength and duration of priming effects, has been replicated in a variety of contexts with both normal and amnesic subjects (Squire, Shimamura, & Graf, 1987), and patterns of performance on these types of measures have been double dissociated in patients suffering from Parkinsonism and Huntington's disease (Saint-Cyr, Taylor, & Lang, 1988). Chiarello and Hoyer (1988) obtained evidence that the normal aging process may differentially affect performance on implicit vs. explicit tasks. However, recent reviews of this topic indicate that current theories are unable to encompass all of the results (Meiran & Jelicic, 1995).

The fact that these two types of tasks produce very different pictures of how human memory is acquired, maintained, and even lost has suggested to some (e.g., Cohen & Squire, 1980; Squire, 1987; Tulving, 1985; Weiskrantz, 1987) that human memory is composed of distinct functional, and perhaps anatomical systems that are capable of operating independently, at least to the degree that would give rise to the aforementioned
dissociations. Other researchers (e.g., Blaxton, 1989; Roediger, 1984, 1990) dispute this interpretation, citing evidence that certain crucial variables related to perceptual conditions are capable of producing dissociations that cut across the basic implicit/explicit or procedural/declarative dichotomy. Still others are critical of rigid adherence to either interpretation (Hintzman, 1990).

It is also possible to classify theoretical approaches to memory dissociations according to an abstractionist vs. non-abstractionist distinction (Richardson-Klavehn & Bjork, 1988). Neuropsychological, multiple memory systems approaches are essentially abstractionist in nature, while information-processing theories are typically based on non-abstractionist positions. According to abstractionist positions, explicit/declarative or conscious memory depends on the formation and retrieval of specific representations of prior experiences, within a particular spatiotemporal context. Implicit/procedural memory, on the other hand, is assumed to reflect modifications of abstract knowledge structures for general lexical, semantic, or rule based experiences without encoding of specific information pertaining to spatiotemporal context (Richardson-Klavehn & Bjork, 1988). In contrast, non-abstractionist positions deny the necessity of making a distinction between memory traces for specific experiences and memory in the form context free abstract representations of knowledge. The adoption of either position creates both strengths and weaknesses for the theoretician, as will be illustrated in the following discussion of specific theoretical positions. It should be noted that in addition to the more prominent theoretical approaches mentioned above, some alternative interpretations have
been suggested, including the distinction between memory-as-object vs. memory-as-tool (Jacoby and Kelley, 1987, see below).

As a final note on terminology, the terms direct and indirect have been proposed to make relatively atheoretical reference to these two broad classes of memory tasks (Johnson & Hasher, 1987). As pointed out by Richardson-Klavehn and Bjork (1988), these terms facilitate discussion of memory dissociations by referring to characteristics of tasks with a minimum of “a priori assumptions concerning the mental states and processes involved in performing the tasks” (Richardson-Klavehn & Bjork, 1988, p.477). According to this nomenclature, direct tasks are defined as those in which the experimental instructions make reference to a specific spatiotemporal context in which the subject was personally present. Indirect tasks, on the other hand, are those in which the subject is required to perform some type of cognitive or motor activity without any reference on the part of the experimenter to prior events (Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988). Although distinctions can be drawn between the types of dependent measures employed for each of these tasks, the relevant dimension of this taxonomy is the emphasis on task instructions and requirements without reference to underlying psychological or anatomical structures or processes. The following review will employ the terms direct and indirect when attempting to integrate discussion across specific theoretical positions. Discussion within a particular framework will employ the terms most customary within the appurtenant literature.
Neuropsychology of Human Memory. The most commonly employed strategy when investigating the neuropsychology of human memory has been to study amnesia (Squire, 1982). The basic rationale of such studies has been that disorders of memory can provide insights into the structure, organization, and substrates of normal memory. This approach has been particularly successful because amnesia can occur as a specific deficit in the absence of other cognitive and intellectual impairments. Anterograde amnesia (inability to form new memories) is the type most relevant to the present study. Early studies of patients with anterograde amnesia (Baddeley & Warrington, 1970; Milner, Corkin, & Teuber, 1968; Scoville & Milner, 1957) were interpreted as evidence that the hippocampus and other related limbic structures were necessary for the transfer of information from short-term to long-term memory. However, subsequent studies of these patients (Cohen & Corkin, 1981; Cohen & Squire, 1980; Warrington & Weiskrantz, 1968, 1970) revealed that they were capable of forming certain types of long-term memories. The most thoroughly studied case is the famous patient H. M., who became profoundly amnesic following bilateral temporal lobectomy for the treatment of intractable epileptic seizures (Scoville & Milner, 1957). Milner (1965) succeeded in teaching H. M. a difficult perceptual-motor mirror-drawing task despite his inability to remember ever having seen the apparatus. Cohen and Corkin (1981) repeated this demonstration using the Tower of Hanoi, a complex cognitive puzzle. H. M. and other similar patients have also been shown to be capable of forming perceptual memories of pictures and words (Milner, 1970; Warrington & Weiskrantz, 1968,1970). These studies
used fragments of pictures or words that cannot be identified without first having seen their non-fragmented versions. Amnesics do not remember having seen the pictures or words previously, yet they can identify them from their fragments (Schacter & Graf, 1986). These observations clearly demonstrate that even patients suffering from severe anterograde amnesia are capable of retaining certain forms of learning (Graf, Squire, & Mandler, 1984).

In an attempt to explain why H. M. and other amnesics are able to learn tasks such as mirror drawing and the Tower of Hanoi, Squire (1982, 1987) proposed that a distinction can be drawn between information that is based on the acquisition of skills, rules, or procedures, and information that is based on specific items or data. According to Squire's taxonomy, the former is referred to as procedural memory, and is represented by tasks such as the Tower of Hanoi and mirror drawing, while the latter is termed declarative, and is represented by traditional memory tasks such as free recall and paired associates.

Researchers working from a neuropsychological perspective usually attribute these dissociated forms of memory to distinct memory systems. The declarative system (subserved by the hippocampus, amygdala and other limbic structures) is responsible for factual, verbalizable knowledge, while the procedural or "habit" system (subserved by the caudate nucleus and other neostriatal structures) is responsible for running off skilled behaviour without the need for conscious recollection (Saint-Cyr, Taylor, Trepanier, & Lang, 1992; Saint-Cyr, Taylor, & Lang, 1988; Saint-Cyr & Taylor, 1992; Squire, 1982).
Moscovitch (1992, 1995) recently presented a neuropsychological model of memory and consciousness based on Fodor’s (1983, 1985) distinction between modules and central systems (see also, Moscovitch & Nachson, 1995). This model can be described as cognitive-neuropsychological, and Moscovitch employs the terms implicit and explicit to refer to the two broad classes of memory tasks discussed above.

According to Moscovitch (1992), both implicit and explicit tests of memory can be further subdivided into two distinct subtypes. The first subtype of implicit test is termed procedural, and corresponds directly to Squire’s (1982, 1987) use of the term. The second subtype is referred to as “item specific”, and is concerned with the acquisition of particular types of information such as words, pictures or faces. Within this framework, the ability of amnesics to identify word and picture fragments is an example of preserved item-specific implicit memory. Explicit tests, within this framework, are subdivided into “associative/cue-dependent” tasks, and “strategic” tasks. In associative/cue-dependent tests a cue is sufficient to automatically elicit the memory. For example, when one responds “Ottawa” to the question “What is the capital of Canada?” In strategic tests, on the other hand, the cue does not automatically or associatively elicit a response, but rather initiates a systematic search for the required information. As Moscovitch (1992) points out, this type of process is often initiated by questions of a temporal nature, such as “What did you do three weekends ago?”

According to this model, cognitive and memory functions arise from the operations and interactions of both cortical modules and central systems. Modules are
information processing subsystems characterized by three features: domain specificity, informational encapsulation or cognitive impenetrability, and shallow output. Domain specificity refers to the processing of specific types of information by modules, as opposed to the integration of information carried out by central systems across domains. Informational encapsulation or cognitive impenetrability refers to the characteristic of modules whereby information is processed efficiently and automatically “without the distorting influence of expectancies and motivation” (Moscovitch, 1992, p.7). This gives rise to the third characteristic of modules, shallow output. It is only through the activity of central systems that modular output is interpreted and assigned meaning.

According to Moscovitch (1992), cortical input modules receive and process information at a perceptual, presemantic level and then deliver it to central systems for semantic integration. The activity of modules and central systems leaves perceptual and semantic records respectively. The perceptual records of cortical input modules are assumed to be responsible for repetition priming effects observed in tasks such as identification of picture and word fragments. The records of processing activity within the modules allow identical or similar information to be processed more efficiently when presented again, thus accounting for performance on item-specific tests of implicit memory (Moscovitch, 1992). Although the notion of modularity has been criticized and modified (e.g., Goldberg, 1995), this model remains one of the most comprehensive and empirically supported theoretical accounts of implicit vs. explicit memory. We turn now to positions derived from the area of human information processing.
Information-Processing Approach. Researchers working from an information-processing perspective generally prefer to use the terms implicit and explicit, rather than procedural and declarative. This reflects a general conceptual position in which the essential difference between these two types of tasks is the necessity of conscious awareness for successful performance. According to this view, explicit memory is assessed by any task that requires conscious recollection of the specific material being tested, and implicit memory is revealed when retention can be demonstrated in the absence of conscious awareness that learning has taken place (Blaxton, 1989; Duchek & Neely, 1989; Jacoby & Witherspoon, 1982; Parkin, Reid, & Russo, 1990; Roediger, 1984; Roediger, 1990; Schacter, 1987). However, some researchers working from an information-processing perspective have rejected this general position in favor of explanations based on distinctions between different modes of information processing that are differentially elicited by manipulating task instructions and requirements. In marked contrast to the proposition that implicit and explicit tasks tap different memory systems, these processing approaches assume that memory tests are composed of a number of component processes that can be classified into two or more distinct modes of processing. According to this view, the particular component processes involved, and the general mode of processing, differs greatly depending on the type of task and the instructions given by the examiner.

For example, Roediger and Blaxton (1987) and Jacoby (1983) have proposed a distinction between conceptually-driven (meaning) and data-driven (perceptual)
processes. It has been argued that previous research has consistently employed either conceptually-driven declarative tasks or data-driven procedural tasks, but never data-driven declarative or conceptually-driven procedural tasks. Blaxton (1989) attempted to address this issue by designing an experiment that used a graphemic cued-recall test that was considered to be a declarative task that was also data-driven, and a general knowledge priming task that was considered to be both "procedural" and conceptually-driven. For the graphemic cued-recall test, subjects studied a list of target words and then were given cue words chosen to look and sound like the target words, but that were not related to them in meaning (e.g., treasure as a cue for treason). The subjects’ task was to recall a word from the previously studied list that looked and sounded like the cue word. Blaxton (1989) argues that the visual and phonemic similarity discrimination requirements are perceptual, thus making this a data-driven task despite its verbal declarative elements. The conceptually-driven procedural requirement was ostensibly filled by a priming task employing general knowledge questions such as those found in the game Trivial Pursuit.

Although Blaxton’s (1989) results did show a dissociation between conceptually-driven and data-driven tasks, even within “declarative” and “procedural” domains, one would have to accept some rather bold assumptions regarding the fundamental nature of these tasks. The empirical basis for these assumptions is clearly lacking, and more recent analyses have concluded that the performance of amnesic patients is not adequately explained by the distinction between data-driven and conceptually-driven processes
Future research may provide the necessary support for information-processing theories, but at the present time it would seem most useful to adopt a systemic, neuropsychological framework for the study of REM sleep deprivation effects on retention.

**Alternative Approaches.** As previously mentioned, the theoretical positions most commonly encountered within the neuropsychological and information-processing literature do not exhaust the possibilities for how dissociations between direct and indirect tasks can be conceptualized. As Richardson-Klavehn and Bjork (1988) and Hintzman (1990) have pointed out, there is at present no entirely adequate account of the wide variety of observed memory phenomena, and future research would benefit from an integrative and more encompassing view to the available theoretical and empirical resources.

Jacoby and Kelley (1987) have interpreted the differences between direct and indirect tests of memory in terms of Polanyi’s (1958) distinction between memory as a tool and memory as an object. According to this interpretation, conscious recall occurs when a memory becomes the object of attention, as compared to the non-consciously influence of past experience when such experience is serving as a tool for the performance of a task. In traditional measures of memory, such as free recall or recognition, the subject’s focus of attention is on the past, so that memory for a prior episode can be treated as an object that “can be inspected and described to others” (Jacoby & Kelley, 1987, p.316). In contrast, when memory is used as a tool the
attentional focus is not on the past, but on the present, where prior experiences can influence perception, performance, and semantic interpretations, without the need for those prior experiences to enter the awareness of selective attention. When couched in philosophical terms, direct tasks involve entering into a subject-object relationship with one's own mental representations (i.e., a memory). In indirect tasks, on the other hand, these representations are never objectified, or distinguished from, the subject to which they belong.

On the surface, it might seem that the memory-as-object vs. memory-as-tool distinction is simply another addition to the already long list of terms used to denote conscious vs. non-conscious expressions of prior experience. However, Jacoby and Kelley's (1987) interpretation does provide an interesting alternative for conceptualizing these phenomena. Furthermore, they address an important issue that has been problematic for many abstractionist theories. A number of studies have demonstrated that performance on indirect tasks is more sensitive to the match between pre- and post-test perceptual conditions (such as modality and surface features) than is performance on direct tasks (Roediger & Blaxton, 1987). This demonstration of context sensitivity is clearly problematic for strict abstractionist positions, since implicit/procedural memory is assumed to depend on the modification of abstract, context-free knowledge structures that contain no information about spatiotemporal context (Richardson-Klavehn & Björk, 1988; Roediger & Blaxton, 1987). However, Jacoby and Kelley's (1987) distinction between memory-as-tool vs. memory-as-object posits a fundamental similarity between
both manifestations memory. These theorists draw their distinction between how memories are used rather than how they are represented. According to this interpretation, both uses of memory rely on traces from specific prior experiences, thus overcoming the constraints of abstractionist theories. Moscovitch’s (1992) model of memory and consciousness, although derived from systemic, abstractionist positions, also overcomes this difficulty by proposing both procedural and item-specific implicit memory.

Experimental Rationale and Hypotheses

It would seem likely that previously demonstrated differential effects of REM sleep deprivation on memory have resulted from some coherent dissociation of task requirements. As we have seen, studies of human memory are laden with such dissociations; their potential for contributing to the sleep-learning debate is clear. Furthermore, REM sleep deprivation may prove to be a useful independent variable contributing to the ongoing debate over human memory systems. As can be seen from the preceding discussion, there are a number of theoretical approaches that would serve to guide an investigation into REM sleep and memory consolidation processes. The present study employed a variety of tasks that could be described as explicit/declarative, implicit, and procedural. Although a multiple memory systems, neuropsychological perspective was utilized in the experimental design; an attempt was made to include a sampling of tasks that would allow for some discussion within more than one theoretical framework.

Due to the exploratory nature of the undertaking, the memory “battery” was
somewhat loosely formulated in order to accommodate a wide range of potential outcomes. That is, tasks were selected that differ on a number of possible dimensions (e.g., verbal vs. nonverbal or verbal vs. visual-spatial) while still representing subsets within Squire's (1982, 1987) declarative and procedural domains. The Tower of Hanoi was included to be representative of rule-based procedural skill learning amenable to discussion within Squire's taxonomy, and Word Fragment Completion was included to represent item-specific implicit priming (Moscovitch, 1992). The Corsi Block-Tapping task was adapted to provide a nonverbal, visuospatial measure of item-specific implicit priming. Verbal and visual declarative/explicit learning were assessed by word recognition and the Rey-Osterrieth Complex Figure, respectively (detailed descriptions of the individual tasks appear under materials in the Method section).

Thus, the present study was conducted to assess the effects of independent manipulation of post-learning REM and non-REM sleep deprivation by comparing retention between groups on a variety of implicit and explicit dependent measures. Subjects were tested for immediate recall on each of these measures to provide a baseline for comparison after a one week retention interval. Sleep deprivation occurred on the night immediately following presentation of the tasks. Experimental subjects underwent one night of either total sleep deprivation (TSD) or selective REM sleep deprivation (REMD). Control subjects were divided into three groups: normally rested at home (CON), undisturbed sleep under laboratory sleep recording conditions (RECON), and
“yoked” controls (NREMD) who were awakened during non-REM sleep at a frequency and duration comparable to the experimental REMD group.

It was hypothesized that REM sleep deprivation would result in retention deficits associated with procedural or implicit task requirements and not with declarative or explicit requirements. For those tasks in which subjects are able to use conscious recollection of previously presented data as a primary strategy for performance, retention was expected to remain relatively intact as compared to those tasks that are mediated primarily by learning that is not directly accessible to consciousness. More specifically, it was predicted that all experimental and control subjects would demonstrate an equal level of retention, at both pre- and post-test, on explicit/declarative tasks (i.e., word recognition and recall of the Rey-Osterrieth Complex Figure). It was also predicted that retention would decline from pre- to post-test on these tasks.

Based on studies that have demonstrated a dissociation between implicit and explicit memory in terms of strength and duration of priming effects (e.g., Squire, Shimamura, & Graf, 1987; Tulving, Schacter, & Stark, 1982) it was predicted that control subjects would demonstrate a stable level of priming (little or no decline in retention), from pre- to post-test, on implicit/procedural tasks (i.e., Tower of Hanoi, Corsi Block-Tapping, and Word Fragment Completion). In contrast, it was predicted that the performance of experimental subjects (REMD and TSD) would decline over the one week retention interval on these same tasks.
The specific manifestation of these effects was expected to differ for procedural skill learning vs. item-specific implicit priming. Procedural learning was expected to be manifested as a general facilitation of later performance, such that control subjects would actually be able to solve the Tower of Hanoi more quickly and efficiently at post-test as compared to pre-test. Thus, it was predicted that control subjects would use significantly fewer moves to complete the puzzle at post-test, while experimental subjects would demonstrate little or no improvement over their initial performance. Item-specific implicit priming, on the other hand, was expected to remain stable across the one week retention interval for control subjects, while simultaneously declining in the experimental subjects. Thus, it was predicted that the Word Fragment Completion and Corsi Block-Tapping performance of control subjects would remain essentially unchanged across the one week retention interval, whereas experimental subjects were expected to demonstrate little or no residual priming on these tasks.
CHAPTER 2

METHOD

Subjects.

The subjects consisted of 35 first-year psychology students from Trent University, Peterborough. All subjects were between the ages of 18-24. Participation was on a volunteer basis, although academic credit was given for research participation. Potential subjects were screened and selected on the basis of their responses to a self-report sleep patterns questionnaire (see Appendix “A”). This questionnaire is concerned with sleep habits, quality and duration of sleep, caffeine/alcohol consumption, use of medications, and other related concerns. Students with odd sleep habits or who use drugs or alcohol were excluded from the study.

Materials.

Sleep stage monitoring and recording (Polysonomography) were performed using an 18 channel Nihon Kohden Neuroscan polygraph. An eight channel montage of surface electrodes was used, with two channels of EEG (recorded at C3 and C4), two channels of EOG (recorded from the lateral palpebral commissures), and two channels of EMG (recorded from anterior neck sites overlying the digastric and mylohyoid muscles). All active electrodes were referenced to the contralateral mastoid process.
The stimulus materials were a series of neuropsychological memory tests derived from relevant research studies investigating dissociations in human memory. Specifically, the dependent measures include: The Tower of Hanoi (a cognitive-procedural problem-solving task), Corsi Block Tapping Task (a test of visual-spatial memory adapted to reveal implicit priming), Rey-Osterrieth Complex Figure (a clinical and research measure of explicit visual memory), and Word Fragment Completion (word priming task of item-specific implicit memory). Word Fragment Completion was compared to standard recognition memory for the same word population. A detailed description and rationale for each task follows.

The Tower of Hanoi: The Tower of Hanoi is a complex cognitive-procedural task that consists of three wooden dowels vertically mounted in a linear fashion. The left dowel contains three to five (depending on desired level of difficulty) rings of different colours that are arranged according to size, with the smallest on top (see Appendix "B"). The subjects' task is to move the rings from the dowel on the far left side to the dowel on the far right side, such that they retain their original largest to smallest arrangement. The only rules are that the rings must be moved one at a time and a larger ring may not be placed on top of a smaller one.

There was no limit on the number of moves allowed, but correct solution requires a particular patterning of moves that can only be learned through trial and error. Deviation from this pattern extends number of moves required beyond optimal solution. Thus, the dependent measure for this task is the number of moves required to complete
the puzzle. Inclusion of this task was based on experimental studies of amnesics (Cohen & Corkin, 1981) showing it to be a spared function, later designated by Squire (1982) as cognitive procedural learning.

**Corsi Block-Tapping Task:** Corsi (1972) developed this block tapping task as a spatial analogue to Hebb's (1961) recurring digits task. The test materials consist of nine wooden blocks (approx. 1-1/4") randomly arranged on a board. The blocks are numbered on the examiner's side for ease of administration, but from the subject's position the blocks contain no distinguishing features (see Appendix "C"). The examiner taps out sequences of blocks with a pencil or wooden stick and the subject must immediately reproduce the sequence by tapping the blocks in the same fashion. The individual subject's immediate spatial span (maximum number of blocks reliably tapped in correct order) is first determined. Then a series of 23 block sequences is presented in which each sequence is one block longer than the individual subject's immediate spatial span. By presenting sequences that are one block longer than the measured span, a success rate of approximately 25% is obtained. Unknown to the subject, the 4th, 8th, 13th, 18th, and 23rd sequences within this series were actually repetitions of the initial sequence. All intervening sequences were unique. Over a number of trials, normal subjects gradually begin to demonstrate a higher probability of success on the repeating block sequence, while performance remains stable on the novel sequences. This increment in performance on the repeating sequence begins to occur before the subject is able to recognize the sequence as having been presented before. Thus, the dependent measure
for this task is the proportion of repeating sequences correctly reproduced by the subject. This task was included as a measure of nonverbal item-specific implicit priming (incidental learning of the repeating sequence). It is interesting to note that although this task can be used to demonstrate implicit priming, ongoing performance has been shown to be dependent on the integrity of the right hippocampal formation (Corsi, 1972; Milner, 1971), a region of the brain traditionally associated with explicit memory.

Rey-Osterrieth Complex Figure: The Rey-Osterrieth Complex Figure is a clinical and research measure of visual memory (see Appendix “D”). It has also been used as an index of visuospatial constructional ability (Spreen & Strauss, 1991), and qualitative aspects of performance on this task appear to reflect the relative integrity of right vs. left hemisphere systems (Binder, 1982). The figure is presented to each subject for four minutes during which time he/she is instructed to copy the figure as accurately as possible. Then the figure is removed from sight and the subject must reproduce it from memory. At post-test, subjects are again asked to reproduce the figure from memory, and retention is assessed by comparing this post-test reproduction to that obtained at pre-test. Subjects’ reproductions were scored by judging the presence or absence of 24 individual geometric elements in the subject’s reproduction (see Appendix “D”). Thus, the dependent measure for this task is the proportion of the total number of geometric elements that are present in the subject’s reproduction. This task has proven to be a very sensitive measure of nonverbal retention and has been included to assess the effect of REMD on a difficult, standardized, nonverbal/visual explicit task.
Recognition Memory vs. Word Fragment Completion: The word fragment completion vs. word recognition task was chosen as a comparison between item-specific implicit priming (Moscovitch, 1992) and explicit/declarative memory for the same word population. The words and fragments used in the present study were obtained from the appendix of Tulving, Schaeter, and Stark (1982), as were the general administration and testing procedures. The materials consisted of a pool of 192 words of seven or eight letters in length, with corresponding fragmented versions. They were relatively low frequency words, and the fragmented versions allowed for only one valid completion. Examples of the fragments used include A__A__IN for ASSASSIN, _E_D_L_M for PENDULUM, and _H_O_EM for THEOREM. Half of the words (96) were designated as “targets” and were presented to the subjects for study in booklet form (see Appendix “E”). The remaining 96 words served as “lures” to be randomly mixed with the targets on response sheets for both recognition and fragment completion. The response sheets contained equal numbers of targets and lures, with 24 of each appearing on each sheet. Thus, the total pool of 192 words was equally divided into four groups of 48 words, each of which served as a version of both the recognition and the word fragment completion response sheet. The word fragment completion response sheets corresponded directly to the word recognition response sheets (see Appendix “F”). The target words were presented to subjects one at a time for five seconds each. At post-test, subjects were given a response sheet for word fragment completion and were instructed to fill in the blanks with the first word that came to mind. Then they were given the recognition
response sheet, with instructions to circle all the words they could remember from the study list.

Procedure

Subjects arrived at the sleep laboratory between the hours of nine and ten o’clock, and were immediately presented with the word study list of targets for the recognition and word fragment completion tasks. Subjects were allowed to study each word for five seconds, and were given the following instructions: “You will be allowed five seconds to study each word, please attempt to learn each of the words as they appear”. They were not informed of the nature of the memory test prior to study. Following study of the word list, subjects were administered the Tower of Hanoi, Corsi Block Tapping Task, and Rey-Osterrieth Complex Figure, in a counterbalanced order. Subjects were required to perform five trials of the Tower of Hanoi and the experimenter recorded the number of moves to solution for each trial.

Following completion of these intervening tasks, each subject completed both a word recognition and word fragment response sheet consisting of both primed and unprimed words. Instructions for the recognition task were: “Please circle the words on this sheet that you recognize from the previous study list”. For the word fragment completion task, subjects were instructed to fill in the blanks with letters to form any real word. Subjects were told to use the first word that came to mind, and were allowed to complete the fragments in any order. The recognition task required only two or three minutes, while the fragment completion task was limited to twenty minutes.
Subjects were randomly assigned to one of five sleep conditions. Normally rested control subjects were asked to return home and go to bed for a normal night of sleep. Lab recorded controls spent two nights in the sleep lab, undisturbed, while standard polysomnographic measures were recorded. Subjects in the total sleep deprivation condition (TSD) were required to spend the night in a classroom where they were allowed to read, do homework, or watch movies. Totally sleep deprived subjects were continuously monitored to prevent napping, and were dismissed at 0700 hours, at which time they were allowed to return home. Subjects in the selective REM sleep deprivation condition (REMD) were required to spend two nights in the Trent University Sleep Lab. The first night was for acclimatization purposes, and although polygraphic sleep parameters were recorded, no deprivation procedures were involved. Immediately following completion of the experimental tasks on the second night, each REMD subject was fitted with electrodes for EEG, EOG, and EMG as is conventional for sleep recording. After the electrodes were secured and the polygraph operation checked, REMD subjects went to sleep and remained undisturbed for approximately three hours, or a maximum of approximately 30 minutes spent in REM sleep. During the second half of the night, when the majority of REM sleep occurs, each subject was awakened whenever the sleep record indicated that s/he was entering into REM. The procedure for REM awakenings involved knocking on the bedroom door, followed by turning on the lights. The experimenter then entered the room, confirmed that the subject was awake, and then asked the subject to spend five minutes doing simple addition to ensure complete
awakening. This procedure was repeated every time the subject entered into REM until 0700 hours when the subject was awakened for the last time and allowed to leave.

Non-REM sleep deprived subjects (NREMD) followed the same procedures as the REMD group, except that awakenings occurred during slow-wave sleep. These awakenings were matched to the REMD group in terms of duration and frequency. All subjects returned to the laboratory one week after initial testing at which time they were post-tested according to the same procedures used at pre-test. At this time subjects were also asked whether they had obtained any additional sleep after leaving the lab and whether they had rehearsed any of the tasks. The polysomnographic sleep record for each of the REMD, NREMD, and RECON subjects was interpreted and scored according to the standard criteria and methods provided by Rechtschaffen and Kales (1968).
CHAPTER 3

RESULTS

One way ANOVA’s were performed for each major electrophysiological and behavioral sleep parameter for the three polysomnograph recorded groups. The mean group values for each sleep parameter are presented in Table 1. ANOVA’s for measures of time in bed, latency to stage 1 onset, time in stage 2, and time in stages 3 & 4 indicated no differences on any of these sleep measures. A one way ANOVA for total sleep time indicated significant differences on this measure \[ F (2,18) = 8.62, p<.01 \]. Tukey-HSD post-hoc comparisons revealed that REMD subjects spent significantly less total time

Table 1.
Means and Standard Deviations of Sleep Parameters for each Sleep Condition

<table>
<thead>
<tr>
<th>Parameter (min)</th>
<th>REMD</th>
<th>NREMMD</th>
<th>RECON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in Bed</td>
<td>447.07</td>
<td>468.21</td>
<td>452.14</td>
</tr>
<tr>
<td></td>
<td>(33.33)</td>
<td>(15.71)</td>
<td>(12.98)</td>
</tr>
<tr>
<td>Total Sleep Time</td>
<td>374.79</td>
<td>428.71</td>
<td>433.07</td>
</tr>
<tr>
<td></td>
<td>(40.82)</td>
<td>(20.15)</td>
<td>(22.28)</td>
</tr>
<tr>
<td>Latency to Stage 1</td>
<td>13.14</td>
<td>9.21</td>
<td>7.79</td>
</tr>
<tr>
<td></td>
<td>(10.10)</td>
<td>(5.50)</td>
<td>(6.99)</td>
</tr>
<tr>
<td>Stage 1</td>
<td>37.36</td>
<td>19.00</td>
<td>10.43</td>
</tr>
<tr>
<td></td>
<td>(10.43)</td>
<td>(16.83)</td>
<td>(5.55)</td>
</tr>
<tr>
<td>Stage 2</td>
<td>204.43</td>
<td>200.71</td>
<td>191.79</td>
</tr>
<tr>
<td></td>
<td>(61.08)</td>
<td>(4.94)</td>
<td>(38.05)</td>
</tr>
<tr>
<td>Stage 3 + 4</td>
<td>107.79</td>
<td>110.29</td>
<td>138.86</td>
</tr>
<tr>
<td></td>
<td>(27.13)</td>
<td>(23.00)</td>
<td>(40.70)</td>
</tr>
<tr>
<td>REM Sleep</td>
<td>21.29</td>
<td>97.57</td>
<td>87.64</td>
</tr>
<tr>
<td></td>
<td>(13.96)</td>
<td>(15.42)</td>
<td>(28.00)</td>
</tr>
<tr>
<td>% REM Sleep</td>
<td>5.71</td>
<td>22.78</td>
<td>20.08</td>
</tr>
<tr>
<td></td>
<td>(3.71)</td>
<td>(3.74)</td>
<td>(5.87)</td>
</tr>
<tr>
<td># of REM Periods</td>
<td>6.57</td>
<td>4.43</td>
<td>3.71</td>
</tr>
<tr>
<td></td>
<td>(3.36)</td>
<td>(0.98)</td>
<td>(0.95)</td>
</tr>
<tr>
<td># of Awakenings</td>
<td>4.85</td>
<td>4.00</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(2.19)</td>
<td>(0.00)</td>
<td>(---)</td>
</tr>
<tr>
<td>Time Awake</td>
<td>67.36</td>
<td>39.50</td>
<td>19.07</td>
</tr>
<tr>
<td></td>
<td>(28.64)</td>
<td>(10.50)</td>
<td>(15.49)</td>
</tr>
</tbody>
</table>
in sleep than did NREMD or RECON subjects. Given that there were no group
differences in the amount of time spent in stages 2, 3, and 4, this difference in total sleep
time was attributable to the REM deprivation procedure. A one way ANOVA for time
spent in REM sleep indicated significant group differences $[F (2,18) = 29.69, p<.001]$, as
did the ANOVA for percentage of REM sleep within the total sleep architecture $[F (2,18)
= 28.41, p<.001]$. Tukey-HSD post-hoc comparisons confirmed that REMD subjects
engaged in significantly less REM sleep, with a significantly lower percentage of REM,
than did subjects in either the NREMD or RECON groups. The implications of a
reduction in total sleep time, resulting from the REM deprivation procedure, are
discussed in detail below. A one way ANOVA for number of REM periods entered (but
not successfully completed in the REMD group) indicated a main effect of group $[F
(2,18) = 3.53, p=.05]$. Tukey post-hoc comparisons revealed that REMD subjects entered
into REM sleep significantly more frequently than did RECON subjects, but not NREMD
subjects. Finally, independent t-test results indicated no significant difference in the
number of experimental awakenings for REMD and NREMD groups $[t (12) = 1.03,
p>.05]$.

**Dependent Measures of Implicit Memory**

Baseline scores on the Tower of Hanoi were obtained by computing the mean
number of moves to solution used by each subject on his/her last three (from a total of
five) trials on this task. The first two trials were considered to be practice trials reflecting
within session learning. Post-test scores were obtained by computing the mean number
of moves to solution used by each subject on his/her first three (of five) post-test attempts. Mean performance on the first three post-test trials was considered to be the most sensitive index of retention of previous learning. Baseline and post-test scores on the Corsi Block-Tapping task were expressed as the proportion of repeating sequences correctly reproduced by each subject at each testing session. Likewise, pre- and post-test scores for the Word Fragment Completion task were expressed as the proportion of target word fragments correctly filled in by each subject at each testing session.

Recall scores for each dependent measure of implicit memory were collapsed across groups and Pearson product-moment correlations were performed between each pair of tasks. Separate correlations were computed for pre- and post-test scores, and these are presented in Table 2. None of the implicit measures of memory was found to be significantly correlated.

Table 2.
Pearson Product-Moment Correlations Between Implicit Measures at Pre- and Post-test

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Pre-test (baseline)</th>
<th>Post-test (treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corsi</td>
<td>Hanoi</td>
</tr>
<tr>
<td>Corsi</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hanoi</td>
<td>.02</td>
<td>--</td>
</tr>
<tr>
<td>WFC</td>
<td>.06</td>
<td>.05</td>
</tr>
</tbody>
</table>
A multivariate analysis of covariance (MANCOVA) was performed on the three post-test dependent measures of implicit memory to determine if the groups differed in terms of their overall performance on implicit tasks. Baseline scores on these tasks were used as covariates in the analysis. The observed and adjusted group means for each task are presented in Table 3.

Table 3.
Observe and Adjusted Means of Post-test Scores for Five Sleep Conditions on Corsi Block-Tapping, Word Fragment Completion, and the Tower of Hanoi

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>REMD</td>
<td>23.81</td>
<td>25.67</td>
<td>29.17</td>
<td>27.21</td>
<td>30.38</td>
<td>31.30</td>
</tr>
<tr>
<td>NREMD</td>
<td>52.38</td>
<td>57.57</td>
<td>38.69</td>
<td>37.50</td>
<td>18.09</td>
<td>19.68</td>
</tr>
<tr>
<td>TSD</td>
<td>38.09</td>
<td>23.16</td>
<td>41.67</td>
<td>44.48</td>
<td>25.14</td>
<td>24.14</td>
</tr>
<tr>
<td>RECON</td>
<td>54.76</td>
<td>61.94</td>
<td>38.69</td>
<td>39.57</td>
<td>23.00</td>
<td>22.98</td>
</tr>
<tr>
<td>CON</td>
<td>58.09</td>
<td>58.80</td>
<td>45.83</td>
<td>45.29</td>
<td>27.91</td>
<td>26.43</td>
</tr>
</tbody>
</table>

Baseline performance on the Corsi Block-Tapping task was a significant covariate for post-test performance on both the Block-Tapping task (t=5.25, p<.001) and the Tower of Hanoi (t=2.45, p=.02), but not for Word Fragment Completion (t=1.94, p>.05).

Baseline Word Fragment Completion was a significant covariate for post-test measures of Word Fragment Completion (t=4.32, p<.001), and Corsi Block-Tapping (t=2.05, p=.05),
but not for the Tower of Hanoi \((t=.17, p<.05)\). Baseline performance on the Tower of Hanoi was not a significant covariate for any of the post-test measures.

With the use of Wilks’ criterion, the MANCOVA revealed a significant main effect of group for this combination of dependent variables \([F (12,66) = 5.20, p<.001]\). Univariate F-tests indicated that group differences were significant for Word Fragment Completion \([F (4,27) = 7.32, p<.001]\), the Tower of Hanoi \([F (4,27) = 3.68, p<.02]\), and Corsi Block-Tapping \([F (4,27) = 6.01, p=.001]\). Given the importance of demonstrating significant differences between selective REM sleep deprivation and non-REM sleep deprivation, planned orthogonal comparisons were performed between the REMD and NREMD groups for each of these three dependent measures. Significant differences were demonstrated, in the expected direction, for Corsi Block-Tapping \([F (1,27) = 10.99, p<.01]\), Word Fragment Completion \([F (1,27) = 8.19, p<.01]\), and the Tower of Hanoi \([F (1,27) = 13.75, p<.001]\). Thus, REMD subjects demonstrated significantly less retention on each of these tasks as compared to NREMD subjects.

Pairwise Tukey-HSD post-hoc comparisons performed on the adjusted group means for each of the implicit measures revealed no significant differences between any of the control groups (NREMD, RECON, and CON). Figures 1, 2, and 3 illustrate the mean pre- vs. post-test scores of the REMD group vs. the combined mean scores of all control groups on Word Fragment Completion, Corsi Block Tapping, and the Tower of Hanoi, respectively.
Figure 1. Mean word fragments completed by REMD vs. controls at pre- & post-test.
Figure 2. Mean repeating sequences correct by REMD vs. controls at pre- & post-test
Figure 3. Mean number of moves to solution by REMD vs. controls at pre- & post-test
Tukey comparisons also revealed significant differences, in the expected direction, between the REMD group and both the RECON and CON groups for Corsi Block-Tapping and Word Fragment Completion. Tukey comparisons performed between the REMD group and both the RECON and CON groups for the Tower of Hanoi approached significance in the expected direction. Although statistically more powerful orthogonal comparisons were not planned for the RECON and CON groups, it is interesting to note that such a comparison is capable of demonstrating a significant difference in Tower of Hanoi performance between the REMD and RECON groups \( F(1,27) = 7.05, p<.025 \).

Tukey post-hoc comparisons between TSD and REMD groups, as well as between TSD and all control groups, indicated that the performance of the TSD group was somewhat variable across the implicit memory measures. For the Corsi Block-Tapping task, these comparisons revealed significant differences, in the expected direction, between the TSD group and all control groups but not between the TSD and REMD groups. Thus, the block-tapping performance of TSD subjects was equivalent to that of REMD subjects, and both experimental groups demonstrated significantly less retention than any control group. However, Tukey comparisons also revealed that the TSD group did not differ significantly from any of the control groups on either Word Fragment Completion or the Tower of Hanoi. In fact, the TSD group was found to have significantly higher post-test scores than the REMD group on Word Fragment Completion. The implications of this finding are discussed below.
Dependent Measures of Explicit Memory

Baseline and post-test scores for the Rey-Osterrieth Complex Figure were expressed as a proportion of the total number of geometric elements contained in the stimulus figure that were present in each subject’s immediate and delayed reproductions. Baseline and post-test scores on the Word Recognition task were expressed as the proportion of target words correctly identified by each subject at each testing session. Pearson product-moment correlations were computed for Word Recognition and Rey Figure recall scores collapsed across groups at pre- and post-test. The correlation between these measures was not significant at baseline ($r = -.04$, $p = .82$) or at post-test ($r = -.23$, $p = .19$).

A multivariate analysis of covariance (MANCOVA) was performed on the post-test Word Recognition and Rey Figure scores to determine if the groups differed in terms of their overall performance on explicit tasks. Baseline scores on these tasks were used as covariates in the analysis. The observed and adjusted group means for each task are presented in Table 4. Baseline performance on the Rey Figure was a significant covariate for post-test Rey Figure performance ($t = 4.81$, $p < .001$), but not for Word Recognition ($t = .99$, $p > .05$). Baseline performance on Word Recognition was not a significant covariate for either post-test measure. With the use of Wilks’ criterion, the MANCOVA indicated no significant main effect of group for this combination of dependent measures [$F (8,54) = .85$, $p = .57$]. Univariate F-tests confirmed that there were no significant group differences for Word Recognition [$F (4,28) = .35$, $p = .84$] or the Rey Figure [$F (4,28) = .
1.46, p=.24]. Thus, all experimental and control groups demonstrated equivalent levels of post-test retention on the explicit measures used in this study.

Table 4.
**Observed and Adjusted Means of Post-test Scores for Five Sleep Conditions on Word Recognition and the Rey-Osterrieth Complex Figure**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Dependent Memory Measure</th>
<th>Rey Figure</th>
<th>Word Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>REMD</td>
<td>45.83</td>
<td>54.50</td>
<td>47.62</td>
</tr>
<tr>
<td>NREMD</td>
<td>54.17</td>
<td>53.88</td>
<td>54.76</td>
</tr>
<tr>
<td>TSD</td>
<td>59.52</td>
<td>59.12</td>
<td>50.59</td>
</tr>
<tr>
<td>RECON</td>
<td>49.40</td>
<td>50.41</td>
<td>50.00</td>
</tr>
<tr>
<td>CON</td>
<td>76.78</td>
<td>67.80</td>
<td>46.43</td>
</tr>
</tbody>
</table>
CHAPTER 4
DISCUSSION

The results of the present study are consistent with the prediction that memory disruptive effects associated with REM sleep deprivation would be manifested in performance on tasks that are generally considered to be implicit or procedural in nature, while simultaneously being absent in the performance of explicit or declarative tasks. This supports the suggestion that previously observed differential effects of REM sleep deprivation on dissimilar tasks (Smith & Pirolli, 1989) can be attributed to a generally accepted implicit/explicit dissociation of task requirements. This finding should prove exciting to researchers interested in the relationship between REM sleep and human memory processes, as it may resolve a very long standing discrepancy in the interpretation of data obtained from different laboratories.

Furthermore, the results indicate that the involvement of REM sleep in memory consolidation processes can be considered another example of a factor that dissociates performance on implicit and explicit tasks. This has important implications for research and theory pertaining to human memory systems, because the identification of variables that are capable of predicting the presence or absence of a dissociation between performance on two different tasks has been the primary strategy for both the support
and disputation of existing theoretical frameworks. The involvement of REM sleep effects in this debate will undoubtedly shed additional light on the nature and significance of task dissociations. According to the present argument, the involvement of REM sleep in these phenomena provides strong support for a systemic, multiple memory systems approach, and seriously calls into question the viability of theories based purely on information processing.

The specific predictions of the present experiment were generated from an essentially neuropsychological perspective, positing distinct memory systems that can be described in terms of an implicit/explicit or procedural/declarative dichotomy. Within this discussion, the terms implicit and procedural are not used interchangeably; they refer to repetition-priming effects (as in word fragment completion) and rule-based skill learning (i.e., the Tower of Hanoi), respectively. Although a variety of theoretical frameworks are presented and discussed, the exploratory nature of this study precluded direct experimental testing of these positions. When interpreted and considered within differing conceptual frameworks, however, the results do provide some interesting suggestions for future research.

Some explanation concerning the differential performance of the two experimental sleep deprived groups is necessary. Both a selective REM sleep deprivation (REMD) and a total sleep deprivation (TSD) group were included in this study. It was predicted that both the REMD and TSD group would exhibit deficits in performance on the implicit and procedural measures. This prediction was based on the assumption that
total sleep deprivation would include REM sleep deprivation, as well as previous studies (Smith, 1991; Smith & Whittaker, 1987) that have demonstrated a memory disruptive effect of total sleep deprivation that was later isolated to REM sleep. The basic rationale was that if selective REM sleep deprivation resulted in deficits equivalent to those of total sleep deprivation, then it could reasonably be inferred that loss of REM sleep was the essential element in the TSD condition.

However, the TSD subjects in this experiment failed to demonstrate a consistent effect, and as a group they actually performed better than REMD subjects on Word Fragment Completion. The TSD group showed no decline in implicit priming of word fragments over the one-week retention interval, and their post-test performance on the Tower of Hanoi indicated that they had retained a significant degree of learning on this task. As previously mentioned, the prediction that TSD subjects would perform at least as poorly as REMD subjects was based on the assumption that total sleep deprivation would prevent post-learning REM sleep. However, follow-up interviews with TSD subjects indicated that these subjects actually engaged in substantial amounts of post-learning REM sleep. The TSD subjects performed the experimental tasks between 10 and 11 p.m. Since they were allowed to return home at 7 a.m., many of them went to sleep only eight to ten hours after learning the experimental tasks. Two of these subjects actually volunteered the information that they had gone to sleep immediately upon their arrival at home, at which time they reportedly dreamed extensively about the experience and the experimental tasks. Due to these obviously confounding circumstances, the
method of total sleep deprivation used in this study cannot be considered a valid one for studying the importance of post-learning REM sleep. Future research should employ a method whereby an entire night of sleep is lost with no opportunity to compensate for this during the day. Given this difficulty in interpreting the performance of TSD subjects, the present discussion will revolve around the performance of REMD subjects as compared to NREMD subjects and normally rested controls.

The second methodological issue that needs to be addressed concerns the small but statistically significant reduction in total sleep time that resulted from the REM deprivation procedure. One might argue that the performance of REMD subjects was adversely affected by a loss of sleep per se, rather than a specific loss of REM sleep. However, the REMD subjects spent an equivalent amount of time, as compared to NREMD and RECON groups, in all other stages of sleep. Other than the reduction in REM sleep time, there was no indication that this group experienced a significant disruption of overall sleep architecture. Previous research clearly shows that memory disruptive effects of sleep deprivation do not result from small, simple reductions in total sleep time, and the overall sleep architecture is a much more important consideration than is total sleep time (Smith, 1993).

A third, related issue concerns the number of experimental awakenings between the REMD and NREMD groups. Although there was no statistically significant difference in the number of awakenings between these groups, REMD subjects were nevertheless awakened with slightly greater frequency. Unfortunately, this situation
cannot be avoided. As a person becomes increasingly REM sleep deprived, there is a powerful tendency to enter into REM sleep. Thus, during the early morning hours of the sleep recording and deprivation procedures, REMD subjects will typically enter into REM sleep very frequently as compared to any form of control subjects. A true yoked control group is not possible for two reasons. First, NREMD subjects must be awakened during slow-wave sleep, and this does not occur as frequently as REM sleep, especially in the latter half of the night when the majority of REMD awakenings occur. In fact, many persons obtain no slow-wave sleep at all during the time when most REMD awakenings are taking place. Second, excessive NREMD awakenings will disrupt the overall sleep architecture, thus confounding the group. In brief, it is better to have a clearly defined control group that was awakened slightly less frequently, than to have a control group that did not complete a normally patterned cycle of sleep stages.

A multivariate analysis of covariance was used to determine the presence or absence of significant group differences in memory performance at post-test. This procedure was judged to be most appropriate because it enables the researcher to control for any potential group differences in initial level of performance when assessing the significance of post-test differences. This is an important consideration for the present experiment because the goal was to assess the impact of REM sleep deprivation on the consolidation of relatively fragile new learning. That is, there was a deliberate effort to avoid training subjects to a criterion, especially one that would render the consolidation effects of REM sleep unnecessary. It is likely that well-learned or over-learned material
will be adequately consolidated and recalled regardless of the quality of post-learning REM sleep. For this reason, the stimulus materials and procedures were required to be somewhat briefly and imperfectly learned, thus maximizing the need for post-learning consolidation. Therefore, it was judged that by covarying out the subjects’ initial level of performance, the most accurate assessment of group differences in consolidation would be obtained.

A somewhat unusual statistical finding emerged in that the various measures of implicit and explicit memory were not found to be correlated within these conceptual classifications. If the Tower of Hanoi, Corsi Block-Tapping, and Word Fragment Completion tasks are all measures of an underlying construct or latent variable (i.e., implicit/procedural memory), then one would expect them at least to be moderately correlated. The very low correlations among these measures appear to reflect relatively narrow distributions of scores. The performance of all subjects was very similar, and the scores on these tasks tended to fall within a relatively narrow range. It is well known that such a narrow range of scores will effectively undermine attempts to demonstrate a correlation between variables.

It should be noted that there are also conceptual reasons that may explain why these measures were not found to be correlated. Firstly, it appears likely that implicit memory is not a univocal phenomenon. Rather, “unconscious” expressions of retention can be divided into different types, such as item-specific implicit priming as seen in Word Fragment Completion and cognitive procedural learning (with an additional motor
component) as seen in the Tower of Hanoi. In addition, the measures were carefully chosen to be representative of different broad cognitive domains. For example, item-specific implicit priming was assessed using both a verbal task (Word Fragment Completion) and a nonverbal, spatial task (Corsi Block-Tapping). Likewise, explicit retention was assessed using a word recognition task and a visual memory task (Rey Figure). Moreover, the cognitive requirements and anatomical substrates of ongoing performances on these tasks may be quite distinct from the implicit memory traces they leave behind. For example, ongoing performance of the Corsi Block-Tapping task is known to be dependent on the integrity of the hippocampal formation, a generally accepted anatomical substrate for explicit memory. Nevertheless, performing this task can leave an implicit memory trace that appears to be a distinct issue from the nature of the task at the time that it is being performed. Although all of these tasks may leave some form of implicit memory trace, they may nevertheless be radically different in terms of what they are tapping at the time of performance, and this will be reflected in the scores obtained and the correlations between them.

In the present experiment, the selective disruption of implicit and procedural types of learning was demonstrated in two subtly distinct ways. First, REM sleep deprivation apparently altered the time course of implicit repetition-priming effects. Previous studies (e.g., Tulving et. al., 1982; Squire et. al., 1987) indicate that the duration of implicit priming effects is considerably longer than for explicit forms of retention such as free recall and recognition. As demonstrated by the recognition vs. fragment completion task,
REM sleep deprivation effectively eliminates this implicit/explicit time course
dissociation. REMD subjects failed to demonstrate any residual priming at post-test
Word Fragment Completion. This observation was also supported by the data from
block-tapping. Control subjects demonstrated evidence of priming on the repeated
sequence even after a one week retention interval, whereas sleep deprived subjects
performed no differently than at pre-test. Again, this suggests that the time course of
implicit priming effects is influenced by REM sleep.

Second, normally rested controls demonstrated a practice effect on the Tower of
Hanoi such that performance actually improved during the one week retention interval.
This effect was not demonstrated by the REMD subjects. This suggests that learning on
this task benefits from time spent away from the task (a finding that would be expected
from studies of distributed practice), and that REM sleep plays a role in this phenomenon.
According to the sleep-learning hypothesis, REM involvement would take the form of
increased processing and consolidation of the previous learning during REM sleep, which
would then facilitate later performance.

We turn now to a more detailed consideration of the pattern of results obtained
across measures, in an attempt to reconcile this pattern with one or more existing
theoretical frameworks. The main experimental hypothesis will be stated in the
terminology of each conceptual taxonomy, and the results obtained for each experimental
task will be compared to the outcome predicted by adopting each of these positions. It is
hoped that this approach will provide an adequate assessment of each theoretical
framework's potential for explaining the memory disruptive effects of REM sleep deprivation.

According to Squire's (1987) systemic model of memory, the tasks used in the present experiment would be considered representative of subsets within declarative and procedural domains. Within this framework, traditional measures of episodic and semantic memory are classified as declarative tasks, while rule-based skill learning and priming are subsumed under a procedural heading. According to this model, the word recognition and Rey Complex Figure drawing tasks used in the present study would be subserved by the declarative system, while performance on the Tower of Hanoi, Corsi Blocks, and Word fragment completion would be subserved by the procedural system. Thus, the main experimental hypothesis was that the memory disruptive effects of REM sleep deprivation would be manifested in performance on tasks of a procedural nature, but not on declarative type tasks.

The results of the present experiment can be adequately explained in these terms, since deficits in performance were in fact demonstrated on the Tower of Hanoi, Corsi Block-Tapping, and Word Fragment Completion tasks, while performance on the Rey Figure and word recognition tasks remained unaffected. However, these results can also be reconciled within alternate theories, and thus do not provide direct support for Squire's (1987) taxonomy. It should be noted that the present experiment was intended as a preliminary, exploratory endeavor, and made no predictions which could not be handled
on a very general level. Thus, Squire's (1987) procedural/declarative dichotomy seems an appropriate description of the results.

The neuropsychological model of memory and consciousness proposed by Moscovitch (1992) divides memory tests into implicit and explicit domains, each of which is further subdivided into two distinct types of tasks. As previously outlined, explicit tasks may be either associative/cue-dependent or strategic, and implicit tasks can be either procedural or item-specific. The word recognition task used in the present experiment would represent an associative/cue-dependent explicit test, while performance on the Rey Figure might be considered more "strategic". The Tower of Hanoi, as with Squire's model, represents cognitive procedural learning, while the Corsi Blocks and Word Fragment Completion are examples of item-specific, repetition-priming in the implicit domain. Again, the obtained pattern of results is consistent with this classification of tasks. However, the theoretical framework presented by Moscovitch is more detailed, and thus may prove more useful in guiding future research.

As previously outlined, researchers working from an information processing perspective espouse non-abstractionist theories, and do not propose multiple memory systems to account for the relevant human memory phenomena. The distinction between data-driven (perceptual) and conceptually-driven (meaning) processes, proposed by Jacoby (1983) and Blaxton (1989), serves as an excellent example of this approach (Roediger, 1990), and will be taken as illustrative in the present analysis.
According to Blaxton (1989), typical procedural or priming tasks are mediated primarily by perceptual operations, and can thus be classified as data-driven. Traditional explicit/declarative tasks, on the other hand, tend to be meaning-based and rely heavily on conceptual elaboration. These tests are therefore referred to as conceptually-driven. This theory holds that dissociations can be expected to occur between data- vs. conceptually-driven processing, and that previously observed dissociations between procedural and declarative domains are an artifact of the tendency for declarative tests to be conceptually-driven, and procedural tests to be data-driven (Richardson-Klavehn & Bjork, 1988). Thus, data-driven tasks should produce dissociations when compared to conceptually-driven tasks even within explicit/declarative and implicit/procedural domains.

Based on this approach, the word recognition task used in the present study would be considered a typical example of a conceptually-driven task which could also be described as explicit or declarative. Likewise, the Tower of Hanoi, Corsi Blocks, and word fragment completion tasks would coincide with both a data-driven and implicit/procedural classification. Therefore, these tasks cannot directly test the proposition that dissociations should occur between perceptual an meaning-based processing demands even within declarative and procedural domains. However, it could be argued that, while still representing an explicit/declarative task, performance on the Rey-Osterrieth Complex Figure is mediated by visual data-driven processes, not conceptually (meaning) driven processes. Thus, it could be predicted that results
obtained on this measure should be aligned with those of other data-driven tasks, and not with other conceptually-driven tasks. The results of the present study indicate that performance on the Rey Figure was not impaired by REM sleep deprivation, a finding that is not consistent with a conceptually-driven vs. data-driven framework. However, the actual cognitive processes involved in performance on this task remain a matter of speculation, and the potential for verbal mediation leaves open the possibility of performance based on conceptual meaning. By the same token, the data-driven vs. conceptually-driven distinction lacks empirical support for the assumed cognitive processes involved in the performance of various tasks.

As a further argument against the processing approach, it should be noted that REM sleep is a basic and even primitive biological phenomenon, present in many lower organisms. It seems unlikely that the functional utility of this phenomenon would respect boundaries based on human cognitive processes such as conceptual elaboration. This argument alone could easily be countered by proposing that data-driven processes are common to both man and animals, and that REM sleep serves to consolidate these types of functions regardless of whether or not conceptually-driven processes are present in any particular organism. However, the failure of REM sleep deprivation to produce deficits in retention of the Rey-Osterrieth Complex Figure raises some doubt as to the utility of “conceptually-driven” as the most accurate description of memory functions spared by REM sleep deprivation. If the dissociations demonstrated between REM deprived and control subjects can be assumed to reflect the same underlying processes that have
produced previously observed dissociations, then a systemic or neuropsychological explanation seems more consistent with the involvement of REM sleep in these processes. Nevertheless, it must be acknowledged that drawing a sharp distinction between systemic and processing frameworks is tenuous. As noted by Roediger (1990), the attempt to define what constitutes a memory system, and to differentiate it from a mode of processing, is an extremely difficult theoretical undertaking. This is not a debate that can be resolved in the present paper.

Jacoby and Kelley (1987) have interpreted dissociations of performance on different memory tasks in terms of Polanyi’s (1958) distinction between tool and object. This approach has distinct advantages over other more mainstream approaches, and in general provides a workable framework for the results of the present study. According to this approach, explicit or declarative memory functions arise when “memory is treated as an object that can be inspected and described to others.” (Jacoby & Kelley, 1987, p.316). To use terms more customary to the philosophical tradition from which this framework arose, it is posited that the human subject enters into a subject-object relation with one (or more) of its own subjective representations or constructs. Implicit or procedural manifestations of memory, on the other hand, result when previous experience functions as a tool in the perception and interpretation of subsequent events, as well as in the ongoing performance of tasks in which the attentional focus is on the present, rather than the past. Implicit learning is seen as a modification of the subject that will potentially influence later subject-object interactions without ever becoming “objectified” in its own
right. This concept also has its origins in philosophical accounts from the perspective of existential phenomenology, as in the writings of Maurice Merleau-Ponty (1948), which express notions of a “pre-cognitive” influence on human experience.

Within this framework, the distinction is made between two different ways in which otherwise similar memory is used in present cognition and/or overt behaviour. Thus, predictions are based on the ways in which different tasks are likely to engage one or the other mode of memory use, primarily through a differential attentional focus on the past or present. The word recognition and Rey Figure tasks used in the present study tend to focus the subject’s attention on a previous episode, thus promoting the use of memory-as-object. In contrast, the Word Fragment Completion, Tower of Hanoi, and Corsi Block-Tapping tasks would demand that the focus of attention be placed on the present task requirements, thus allowing the use of memory-as-tool. Stated in the terminology of this conceptual framework, the present hypothesis was that REM sleep deprivation would selectively impair the functioning of memory-as-tool while sparing memory as object. Thus, the tool vs. object distinction would predict that deficits in task performance should be associated with conditions where the subject’s focus of attention is on present task demands, and facilitation of performance is necessarily mediated primarily by memory-as-tool. The results of this experiment are consistent with such an interpretation, since the observed effects were limited those tasks that would tend to maintain attention on the present task demands, while being absent on tasks that specifically call attention to a previous learning episode. As previously stated, the distinction between tool and object
avoids difficulties encountered by strict abstractionist positions, and yet is still capable of providing an adequate general account of the effects observed in the present study.

It could be suggested, based on the results of the present study, that the use of memory-as-tool is facilitated by processes occurring during REM sleep. Since even simple animals are assumed to use memory as a tool, the adaptive significance of REM sleep would be equally applicable to both man and animals. The ability to render memory as object, and employ it in this fashion, would seem a unique capacity of man, thus limiting the relevant dissociation phenomena to human memory systems while retaining a role for REM sleep in the functioning of lower organisms.

Conclusions

Overall, the results of the present study support the hypothesis that previously observed differential effects of REM sleep deprivation are attributable to neuropsychological dissociations of task requirements. Previous studies (Smith & Whittaker, 1987; Smith & Pirolli, 1989) have demonstrated an effect of REM sleep deprivation on a complex logic task but not a traditional paired associate task. The present study indicates that this differential effect of REMD on dissimilar tasks can be generalized to well known tests of implicit/procedural vs. explicit/declarative learning. Thus, it would seem likely that previously unsuccessful attempts to demonstrate a REMD effect (Chernik, 1972; Ekstrand, Sullivan, Parker, & West, 1971; Feldman & Dement, 1968) have resulted from a tendency to assess these effects using simple, traditional, explicit tests of memory.
In reference to the debate over differing theoretical frameworks for human memory phenomena, the present study provides only general implications which cannot address this debate in a conclusive manner. Although the results of this experiment seem to be more consistent with the systemic than with the information processing approach, more specific hypotheses based on a wider variety of tasks would have to be developed and adequately tested before the effects of REM sleep deprivation can contribute significantly to this debate. However, the present author would suggest that the involvement of REM sleep in implicit and procedural but not explicit/declarative tasks strongly suggests that a fundamental distinction exists between them, and that this distinction arises from some adaptive biological property of the organism.

For example, selective attention serves an adaptive function in that only limited amounts of information can be effectively dealt with at one time. However, it would not be adaptive for the organism to simply discard all the sensory input which exceeds this capacity. One could speculate that evolutionary forces have selected for the ability or tendency to attend to certain types of sensory input while other types are handled at a pro-cognitive level. The high levels of brain activity during REM sleep may reflect processing of information which would otherwise be neglected in comparison to the elaborative processing that occurs through conscious cognition.

As for future research, REM sleep deprivation may prove to be an extremely valuable independent variable in the ongoing debate over human memory systems, and addressing the conceptually-driven vs. data-driven distinction is clearly the next step in
this line of research. Just as strength and duration of priming effects, as well as surface features and other perceptual characteristics of stimuli, have been used to demonstrate dissociations between measures and contribute to conceptual model building, so may REM sleep deprivation be used for these purposes. The present study addressed only the most basic issue of whether or not REM sleep is differentially involved in explicit and implicit task requirements. The possibilities for more refined future research testing specific hypotheses are virtually endless.

For example, the previously outlined distinction between data-driven and conceptually-driven processes could be tested by applying REM sleep deprivation subsequent to exposure to a variety of tasks that more directly address this dichotomy. However, as previously mentioned, the development of such tasks would require an empirical basis that is lacking. Perhaps the most prudent course of action at this time would be to begin a series of replications of previous dissociation studies, incorporating REM sleep deprivation as an additional factor. Experiments of this nature could document more precisely the effect of REM sleep deprivation on various conceptions of human memory, as well as further explicate REM deprivation effects on the time course of implicit priming. It would be especially interesting to see how the effects of REM deprivation relate to the performance of amnesic subjects. If REM sleep is involved in the consolidation of implicit and procedural learning, then it could be hypothesized that amnesic subjects should be especially sensitive to the memory disruptive effects of REM
sleep deprivation. In the absence of any potentially mitigating influences of explicit retention, deficits in implicit retention might be profound.

Finally, research is needed to address the developmental dimensions of these phenomena. It is well known that REM sleep follows a predictable developmental course. Infants engage in substantially more REM sleep than do older children, and the percentage of REM sleep within the overall sleep architecture continues to decline with each developmental phase (i.e., adolescence, adulthood, old age). Future research should address the question of whether or not implicit and procedural memory also follow a developmental course that can be differentiated from that of explicit memory abilities, as well as the degree to which such a developmental course is related to developmental changes in REM sleep. Within this context, notions of crystallized vs. fluid abilities may have some explanatory value. The question of what constitutes new learning that may (or may not) require further consolidation during REM sleep would seem to depend on the individual's pre-existing structure of abilities, and this appears to vary systematically across different age groups.
REFERENCES


Smith, C. T., & Lapp, L. (1986). Prolonged increases in both PS and number of REMs following a shuttle avoidance task. *Physiology and Behavior, 36*, 1053-1057.


APPENDIX "A"

SLEEP PATTERN QUESTIONNAIRE

PERSONAL DATA

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<td>OCCUPATION</td>
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PLEASE RESPOND BY CIRCLING THE NUMBER IN EACH QUESTION WHICH DESCRIBES YOU BEST:

1. Do you usually have a good night of sleep?
   1. Yes
   2. Yes, except for about one night per week
   3. My sleep is less than sound 2-3 nights per week
   4. My sleep is less than sound 4-5 nights per week
   5. I hardly ever get a good night of sleep

2. How long would you estimate that it takes for you to fall asleep after "lights out"?
   1. Within 15 minutes
   2. Between 15-30 minutes
   3. Between 30-50 minutes
   4. Between 1-2 hours
   5. Longer than 2 hours

3. Do you ever awaken without cause in the night?
   1. Never or seldom
   2. About once per night
   3. 2-3 times per night
   4. 4-5 times per night
   5. More than 5 times per night

4. Do you ever awaken earlier than you want to in the morning and find that you are unable to get back to sleep?
   1. Never or seldom
   2. 1-2 times per month
   3. 1-2 times per week
   4. 3-4 times per week
   5. Almost all of the time
5. About how many hours of sleep do you get per night?
   1. More than 10 hours
   2. Between 8-10 hours
   3. Between 7-8 hours
   4. Between 6-7 hours
   5. Between 5-6 hours
   6. Between 4-5 hours
   7. Between 3-4 hours
   8. Between 2-3 hours
   9. Less than 2 hours

6. Have you felt that you have been sleeping poorly?
   1. No
   2. Recently—the last month
   3. In the last 6 months
   4. In the last year
   5. In the last 1-3 years
   6. In the last 4-6 years
   7. Longer than 6 years

7. What is your usual bedtime?
   1. Before 10:00 p.m.
   2. Between 10:00 and 12:00 midnight
   3. Between 12:00 midnight and 2:00 a.m.
   4. After 2:00 a.m.
   5. Other ... Please specify: _______________________

8. Are you usually tired at bedtime?
   1. Almost always
   2. Only sometimes
   3. No, usually not

9. How long does it take you to respond to your sleepy feeling by going to bed?
   1. About 15-20 minutes
   2. About 20-30 minutes
   3. About 30-40 minutes
   4. About 40-60 minutes
   5. Longer than 1 hour

10. What time do you usually get up in the morning? (Within an hour)
    1. Before 6:00 a.m.
    2. Between 6:00 and 8:00 a.m.
    3. Between 8:00 and 10:00 a.m.
    4. After 10:00 a.m.
    5. Other ... Please specify: _______________________

11. Do you usually go to bed at the same time each night?
    1. Almost always
    2. Yes, except 1-2 times per week
    3. Yes, except 3-4 times per week
    4. My bedtime varies more often than 4 times per week
APPENDIX "A"

12. Do you usually get up at the same time each morning? (Within an hour)
   1. Almost always
   2. Yes, except 1-2 times per week
   3. Yes, except 3-4 times per week
   4. The time that I get up varies more often than 4 times per week

13. Has your bedtime changed?
   1. No
   2. Recently--the last month
   3. In the last 6 months
   4. In the last year
   5. In the last 1-3 years
   6. More than 3 years ago

14. Has your time to get up changed?
   1. No
   2. Recently--the last month
   3. In the last 6 months
   4. In the last year
   5. In the last 1-3 years
   6. More than 3 years ago

15. Do you feel that you get enough sleep?
   1. Yes
   2. Not quite enough
   3. Feel short of sleep, but can still function
   4. Feel short of sleep and feel that it interferes with my day
      a great deal

16. Are you currently taking drugs to improve your sleep?
   1. Yes
   2. No

17. Is/Are the drug(s):
   1. Not applicable
   2. Over the counter
   3. Prescription
   4. Both

18. How often do you take the drug(s)?
   1. Not applicable
   2. Not more than once a week
   3. About 1-2 times per week
   4. About 3-5 times per week
   5. Every night

19. Do you feel that the drug(s) improve your sleep?
   1. Yes, without question
   2. Seemed to at first, but now doesn't seem so effective
   3. Seemed to at first, but now I have to take more the drug to
      get the same effect
   4. No, does nothing to improve my sleep
   5. Not applicable
APPENDIX "A"

-4-

20. Does your drug produce any feeling of daytime grogginess or sluggishness?
   1. Not applicable
   2. No, not at all
   3. Yes, but not very much and I can function quite well
   4. Yes, to a certain extent and it interferes with my day
   5. Yes, to a great extent and it interferes with my day a great deal

21. Do you take sedative or anti-anxiety drugs during the day? If so, how long have you been taking them?
   1. Do not take them
   2. Less than 2 weeks
   3. Between 2 weeks and 2 months
   4. Between 2 months and 6 months
   5. Between 6 months and 1 year
   6. More than 1 year

22. Do you take stimulant medication during the day? If so, how long have you been taking it?
   1. Do not take it
   2. Less than 2 weeks
   3. Between 2 weeks and 2 months
   4. Between 2 months and 6 months
   5. Between 6 months and 1 year
   6. More than 1 year

23. Do you smoke or take nicotine in any form?
   1. Yes
   2. No

24. Which of the following do you smoke?
   1. None
   2. Cigarettes
   3. Cigars
   4. Other (i.e., snuff)

25. How many cigarettes do you smoke per day?
   1. None
   2. Less than 10
   3. Between 10 and 20
   4. Between 20 and 30
   5. Between 30 and 40
   6. Between 40 and 50
   7. More than 50

26. How many cigars do you smoke per day?
   1. None
   2. Less than 2
   3. Between 2 and 4
   4. Between 4 and 6
   5. Between 6 and 8
   6. More than 8
APPENDIX "A"

27. Approximately how many cups of tea and/or coffee do you drink during the day?
   1. None
   2. Less than 2
   3. Between 2 and 4
   4. Between 4 and 8
   5. Between 8 and 12
   6. Between 12 and 18
   7. More than 18

28. Approximately how long does it take you to get out of bed and feel fully awake in the morning?
   1. Less than 5 minutes
   2. Between 5 and 15 minutes
   3. Between 15 and 30 minutes
   4. Between 30 minutes and 2 hours
   5. Between 2 and 3 hours
   6. Longer than 3 hours

BELOW IS THE STANFORD SLEEPINESS SCALE (SSS). PLEASE READ THE 7 LISTED LEVELS OF AROUSAL AND USE THE LEVELS TO ANSWER QUESTIONS 29-31:

LEVEL 1--Wide awake; fully alert; functioning at a high level; head clear
LEVEL 2--Functioning at a high level, but not at peak; able to concentrate
LEVEL 3--Relaxed; awake, not at full alertness; responsive
LEVEL 4--A little foggy; not at peak; let down
LEVEL 5--Fogginess, beginning to lose interest in remaining awake; slowed down
LEVEL 6--Sleepiness; prefer to be lying down; fighting sleep; woozy
LEVEL 7--Almost in reverie; sleep onset soon; loosing struggle to remain awake

29. How do you feel your usual SSS level is when you feel most alert?
   1. LEVEL 1
   2. LEVEL 2
   3. LEVEL 3
   4. LEVEL 4
   5. LEVEL 5
   6. LEVEL 6
   7. LEVEL 7

30. What do you feel your SSS level is when you feel least alert?
   1. LEVEL 1
   2. LEVEL 2
   3. LEVEL 3
   4. LEVEL 4
   5. LEVEL 5
   6. LEVEL 6
   7. LEVEL 7
APPENDIX "A"

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31. What do you feel your average daily SSS is?
   1. LEVEL 1
   2. LEVEL 2
   3. LEVEL 3
   4. LEVEL 4
   5. LEVEL 5
   6. LEVEL 6
   7. LEVEL 7

32. At what time of day do you usually feel most alert?
   1. Shortly after you awaken
   2. Several hours after you awaken
   3. 5-6 hours after you awaken
   4. More than 6 hours after you awaken

33. Do you take naps during the day?
   1. Yes, regularly
   2. Yes, 2-3 times per week
   3. Yes, once per week or less
   4. No, hardly ever

34. If you do take naps, how long, on average, would they last?
   1. 10 minutes or less
   2. 20 minutes or less
   3. 30 minutes or less
   4. 34 minutes of less
   5. 1 hour or less
   6. 1 hour or more
   7. 2 hours or more
   8. None of the above

35. Do you ever feel like napping but do not have the opportunity?
   1. No
   2. Occasionally
   3. Fairly often
   4. Yes, often

36. Do you snore?
   1. Yes, regularly
   2. Sometimes
   3. Only once in a while
   4. Never
   5. Other ... Please specify: ________________________________

37. Does your bed partner ever complain of being kicked?
   1. Yes
   2. No
   3. Not applicable
APPENDIX "A"

38. Do you have trouble breathing during your sleep?
   1. Yes
   2. Sometimes
   3. No

39. Do you ever get restless, writhing leg movements before and/or during sleep?
   1. Yes
   2. Sometimes
   3. No

40. Do you ever have back pain?
   1. Yes
   2. Sometimes
   3. No

41. Are you being treated for a physical ailment?
   1. Yes, now
   2. Within the last month, but not currently
   3. Within the last year
   4. No

42. Are you taking medication for the problem?
   1. Yes
   2. Within the last few weeks, but not now
   3. Within the last year
   4. No

43. Have you been treated for any psychological problem recently?
   1. Never
   2. Yes, in the last few weeks
   3. Within the last 6 months
   4. Within the last 2 years
   5. Within the last 10 years

44. Have you ever suffered from extreme confusion upon awakening?
   1. Yes
   2. Occasionally
   3. No

45. Have you ever experienced daytime episodes of complex behaviour (such as getting on a bus, carrying on a conversation, etc.) at the end of which you have no memory?
   1. Yes
   2. No

46. Have you ever done shift work which lasted at least a month?
   1. Yes
   2. No
   3. I am currently doing shift work
APPENDIX "A"

47. Is your bedroom noisy?
   1. No, very quiet
   2. Moderately noisy
   3. Yes, noisier than I would like

48. Do you work or read before going to bed?
   1. Yes
   2. Sometimes
   3. No

49. Do you work or read in your bedroom before going to sleep?
   1. Yes
   2. Sometimes
   3. No

50. Do you consider your bedroom or bed to be uncomfortable or insufficient in any way? (i.e., too cold, mattress too hard, covers too heavy, etc.)
   1. Yes
   2. No

51. Which of the following most closely fits your sleep posture?
   1. Spend most of the night on my side or stomach
   2. Spend a lot of the night on my side or stomach, but some on my back
   3. Spend a lot of the night on my back

52. Which of the following is most typical of what you do in the hour before going to bed?
   1. Some kind of active physical activity
   2. Some kind of mental work
   3. Reading
   4. Watching television
   5. Some kind of competitive game such as cards
   6. Other ... Please specify: __________________________

53. Do you usually have something to drink before bed?
   1. No
   2. Yes, a cold or room temperature beverage
   3. Yes, a hot beverage
   4. Other ... Please specify: __________________________

54. Do you usually have something to eat before bed?
   1. No
   2. Yes, a small snack
   3. Yes, a large snack
   4. Other ... Please specify: __________________________
APPENDIX "A"

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55. Do you do anything to help you fall asleep?
   1. No
   2. Yes, a bath or shower
   3. Relaxation technique or meditation technique
   4. Special exercises
   5. Food or drinks
   6. Listen to music or watch television, read, etc.

56. If the answer to any of the above techniques is YES, how regular are you in doing the activity?
   1. Only once a week at most
   2. 2-3 times per week
   3. 4-5 times per week
   4. Almost every night
   5. Not applicable

57. How often do you drink alcoholic beverages?
   1. Never
   2. Very occasionally
   3. Once per week
   4. 2-3 times per week
   5. 3-4 times per week
   6. Almost every day

58. When you drink, how much would you likely consume at one time? (A drink is 1 beer, 1 glass of wine, 1.5 oz. of hard liquor, etc.)
   1. Not applicable
   2. 1 drink
   3. 2-3 drinks
   4. 4-5 drinks
   5. 6-7 drinks
   6. 8-9 drinks
   7. 10 or more drinks

59. How often do you take mind-altering drugs of any kind?
   1. Never
   2. Very occasionally
   3. Once per week
   4. 2-3 times per week
   5. 3-4 times per week
   6. Almost every day
### APPENDIX "C"

| 3-6-1-7 | 8-7-5-2-4-3 | 2-1-3 | 7-8-4-9-6 |
| 3-2-5-4 | 6-1-8-4-9-2 | 5-9-7 | 3-6-4-2-8 |
| 5-9-1-6-8 | 3-5-9 | 4-7-6-8 |
| 7-4-2-1-9 | 4-2-7 | 3-9-1-5 |

#### PRIMING SEQUENCES

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[ Examiner's view ]
APPENDIX "D"
APPENDIX "E"

AARDVARK

BLARNEY

CROQUET

HYDRANT

MENTHOL

SANSKRIT

ADENOID

BOROUGH
APPENDIX "E"

CUPCAKE

IMBIBER

MONOGRAM

SCIMITAR

AGNOSTIC

BOURBON

CUTLERY

INERTIA
APPENDIX "E"

NEONATE

SEXTANT

ALLEGORY

BRAHMIN

DELIRIUM

INKWELL

NOCTURNE

SILICON
APPENDIX “E”

ANALOGUE

BRAZIER

DINOSAUR

ISTHMUS

OCTOPUS

SPATULA

ANTENNA

BULLOCK
APPENDIX "E"

ELECTRON

KATYDID

oration

SPROCKET

ANTIQUE

CABARET

EMISSION

KNAPSACK
APPENDIX "E"

PARAFFIN

SWAHILI

APLOMB

CAVALRY

ESPRESSO

LACROSSE

PENDULUM

TEQUILA
APPENDIX "E"

APRICOT

CHICORY

EXPOSERENT

LAGGARD

PETUNIA

THYROID

ASBESTOS

CHIPMUNK
APPENDIX "E"

FILTRATE

LECTERN

PHOENIX

TRICYCLE

ATROCITY

CHUTNEY

FLANNEL

LETTUCE
APPENDIX "E"

PIMENTO

UNIVERSE

BACHELOR

CLARINET

GAZELLE

LEXICON

POLLIWOG

VENDETTA
APPENDIX "E"

BASILICA

COBBLER

GI ZZARD

LITHIUM

RAINBOW

VERMOUTH

BAYONET

COCONUT
APPENDIX “E”

GRANARY

MADEIRA

RHETORIC

VICEROY

BEESWAX

COPYCAT

HEXAGON

MARTINI
APPENDIX "E"

RHUBARB

WAVELET

BEHAVIOR

COSSACK

HORIZON

MAZURKA

RUFFIAN

YOGHURT
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APPENDIX "F"

CAVALRY
LECTERN
PHARAOH
BEGONIA
PENDULUM
YEOMANRY
LINEAGE
MASCARA
ISTHMUS
ASBESTOS
DEMOCRAT
SPATULA
GIZZARD
BOROUGH
PARANOIA
ROTUNDA

BOGEYMAN
COSSACK
SCIMITAR
CHIMNEY
IMBIBER
MIGRAINE
CUPCAKE
TRICYCLE
ANYBODY
TAFFETA
BACHELOR
DINOSAUR
SORGHUM
CASHMERE
CHIPMUNK
FILTRATE

KUMQUAT
EPITAPH
RUFIAN
ADENOID
ANALOGUE
HIBISCUS
LEXICON
ALMANAC
BANDANNA
INSOMNIA
VENDETTA
GAZZETTE
VERANDAH
MONOGRAM
CORVETTE
PHOENIX
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VITA AUCTORIS

James Conway was born to Michael and Barbara Conway on June 1st, 1965, in Oshawa Ontario. He graduated from Trent University in 1993 with an Honours Bachelor of Science. Since 1993, he has been a graduate student in the Clinical Neuropsychology programme at the University of Windsor.