EXPLICIT AND IMPLICIT MEMORY FOR AUDITORY EVENTS OCCURRING IMMEDIATELY PRIOR TO SLEEP ONSET

by

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STATEMENT BY AUTHOR

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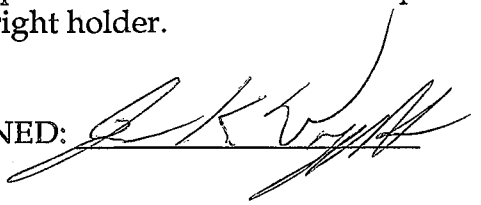
SIGNED: 

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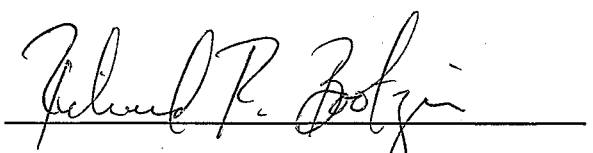

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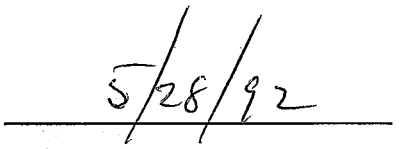

Date

DEDICATION

In the immediate sense, I would like to extend my heartfelt thanks to my colleagues in the Department of Psychology at the University of Arizona. My undergraduate research assistants, Jennifer Anthony and Sara Stevenson, deserve vigorous applause for their unpaid, often unstructured assistance and inspiration. As this was my first major project, I can only hope that they learned, along with me, the perils and pleasures of scientific research. Michael Perlis and Sean Drummond also deserve thanks for their assistance in the spectral analysis of the EEG data, which may ultimately help explain the phenomena we observed. Michael also gave valuable input about the proposal and manuscript draft.

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In particular, I thank Dick Bootzin for doing something that, unfortunately, far too few advisors may do -- he made himself available, in a calm and rational manner, for as long as it took whenever the progress was stopped by a question or unanticipated problem. I look forward to a long collaborative relationship as well as a strong friendship with him.

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As a final note, I must remove myself from the context of sleep research and step back to the larger field - Life. I thank my closest friends - for inspiring me, consoling me, and basically keeping me sane. You know who you are... Jose and Jon, Jimmy and Lauren, Deb and David, Mary, Mike (Uncle Mike), Heidi, Helene, Cynthia, Sharon (Miss Midnight), Mark (Brill), Konrad (K-rad/Konnie), and Melanie (Lily).

My best friend, and certainly my longest-running friend, is my father. Dad, you've always supported me in every way a father could - with finances, wisdom, and love. I can only hope I have and continue to return as much.

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ABSTRACT

The purpose of the present study was to examine explicit and implicit memory for auditory events presented immediately prior to sleep onset. The results of the present study suggest subjects allowed ten minutes of sleep demonstrate deficient explicit memory for auditory stimuli occurring immediately prior to sleep onset. Subjects showed free recall deficits for word pairs presented three minutes prior to sleep onset and recognition deficits for stimuli from the one minute prior to sleep onset. Implicit memory for word-pairs presented prior to sleep onset seemed intact, and no recency effect was observed. In contrast, subjects allowed 30 seconds of sleep demonstrate no equivalent memory deficits. The results are interpreted in terms of elaboration of stimulus encoding, interruption of consolidation, and retrograde vs. anterograde amnesia.

INTRODUCTION

Who has not been awakened from sleep for a brief telephone conversation, only to be amnesic for the content and perhaps even the occurrence of the call during the following day? Why is it that one can awaken during the night from a dream, briefly ponder its nature, and yet be able to retrieve virtually none of its rich content and affect upon awakening later that morning? What is the cause of this profound deficit? Indeed, there are many questions that can be asked concerning the interrelation between sleep and memory. As of now, however, there are few if any absolute answers.

Formal investigation of the effects of sleep on memory can be traced back at least to the research of Jenkins and Dallenbach (1924). These researchers had two subjects learn lists of nonsense syllables to a criterion of perfect immediate recall, and varied the post-learning delay to subsequent free recall testing. The delay intervals were one, two, four, or eight hours. Subjects learned the lists either during the hours of 11:30 p.m. to 1:00 a.m. or from 8:00 a.m. to 10:00 a.m. Thus, on some trials subjects learned the lists before going to sleep; on other trials, subjects learned the lists before beginning their regular daily activities.

Jenkins and Dallenbach found that in trials where the subjects had been allowed to sleep they had less forgetting (better retention) of the material than in the waking condition trials:

> These data show that there is a marked difference in the rate of forgetting during sleep and waking. On an average... more than twice as many syllables are reproduced by both Os (subjects) after

> intervals of sleep than after intervals of waking... This superiority becomes more and more pronounced as the length of the intervals increases (p. 609).

Jenkins and Dallenbach, along with others to follow, took these results to indicate that sleep had a facilitory effect on retention of information, perhaps through the prevention of subsequent interference from new information or stimuli. Interestingly, they found that the decay of memory seemed to decrease or even cease during sleep. The conclusion that sleep had a facilitory effect on memory has been supported, qualified, and challenged in countless studies during the intervening 68 years. Was the relatively superior performance in the trials when the subjects were allowed to sleep due to a direct memory-enhancing effect of sleep, or alternatively, did sleep prevent proactive interference from occurring? Proactive interference refers to the impaired recall of material due the presence of intervening stimuli between presentation of the target material and subsequent testing.

GOODENOUGH, PORTNOFF, & SHAPIRO, et. al.

In a series of studies investigating memory for events occurring during interruptions from sleep, a group of researchers re-examined the effect of sleep on memory. In one of their early studies (Portnoff, Baekeland, Goodenough, Karacan, & Shapiro, 1966), Portnoff and colleagues observed the effects of the length of wakefulness before return to sleep following learning of verbal material and later (post-sleep) long-term memory for the material. In the introduction to their report, they cited a finding in the Jenkins and Dallenbach study (1924) of direct relevance to their study:

> More was recalled following sleep than following wakefulness for all intervals of time, and forgetting appeared to stop entirely after 2 hr. of sleep. It was concluded the forgetting goes on at a slower rate during sleep than it does during wakefulness... An incidental finding of the same study, however, suggests that this may not apply to all situations. Retention tests given during the night, and followed by a continuation of sleep, were sometimes so completely forgotten by morning that Ss could not recall having taken them (p. 752).

In essence, Portnoff and colleagues were struck by the earlier work that, rather anecdotally, suggested that memory for events occurring during the sleep period were often not available for later recall.

To examine this phenomenon, the group awakened subjects sleeping in the laboratory, had them view a slide projector image of a word, had them repeat the word aloud, and then allowed them to fall asleep. On half of the subjects' trials, they were allowed to return to sleep without delay (no-delay condition). On the other half, the experimenters had the subjects engage in a five minute motor task before returning to sleep (delay condition). In the morning, subjects were tested for free recall and recognition memory for the material presented during the night.

The results indicated that trials of the delay condition were associated with significantly better recall and recognition in the morning testing than no-delay trials. Additionally, within the delay condition, sleep latency was significantly related to subsequent performance; words that were recalled were followed by longer periods of wakefulness. The authors also listed the median time to the appearance of the first spindle for each condition: 2.6 minutes in the no-delay condition and 18.2 minutes for the delay condition.

The researchers stated that the relationship found within the delay condition suggested that a higher state of arousal during the interval between

stimulus presentation and sleep onset, and hence a longer sleep latency, led to better encoding of the stimulus information. Additionally, they thought that the differences between the delay and no-delay conditions suggested that NREM sleep interfered with the consolidation of information into long-term memory. In a follow-up study (Goodenough, Sapan, Cohen, Portnoff, & Shapiro, 1971), the group qualified their conclusions somewhat. They found differences between the delay and no-delay conditions, but with two important caveats. These differences were observed only when the instruction set for the delay task described the task as a test (as opposed to a game) and only if the subjects repeated the words aloud during their presentation.

The relationship between arousal level during learning and long-term memory performance has been given a lot of attention outside of the sleep laboratory. It has been reported that high, as compared to low, arousal during stimulus presentation is associated with poorer immediate recall of the material, but significantly better delayed recall (i.e.., Kleinsmith & Kaplan, 1963; Walker & Tarte; 1963). The authors of these studies have attributed the impaired immediate recall to the unavailability of the information, as it was tied up in the consolidation process at the time of the immediate testing. The delayed recall findings could be interpreted as evidence that high arousal during learning facilitates consolidation.

Findings from studies conducted during the late 1960s and early 1970s looking at memory associated with dream content bear on the study of memory for events occurring during interruptions of sleep. For example, it was found that experimentally controlled, "gradual" awakenings from REM sleep led to significantly fewer reports of dreamlike mental activity than similarly controlled,

abrupt awakenings (Shapiro, Goodenough, & Gryler, 1963). Subsequent studies led the authors to suggest that the gradual awakenings might have been long enough to allow for forgetting of REM mentation. In contrast, abrupt awakenings forced the subjects to focus on and report dream mentation before it could be lost to recall. They went on to suggest that the mental activity of the subjects who were gradually aroused might have been more thoughtlike, as opposed to dreamlike, as it could have actually been hypnopompic imagery that was recalled (Goodenough, Lewis, Shapiro, & Sleser, 1965; Shapiro, Goodenough, Lewis, & Sleser; 1965).

Another study from this time period (Baekeland & Lasky, 1969) found that subjects who were awakened from REM sleep and asked to give dream reports were often amnesic during the morning's recall for having given the reports earlier in the night. This finding could be thought of as quite similar to the failure to recall testing observed by Jenkins and Dallenbach (1924). Baekeland and Lasky reported that among the many variables associated with morning recall of prior REM reports was sleep latency after testing; shorter sleep latencies after dream reports were associated with poorer morning recall of those reports. In total, these studies all point to definite, though ambiguous, interaction between sleep and memory.

GUILLEMINAULT & DEMENT

In a specific attempt to investigate memory functioning in the minutes preceding sleep onset, Guilleminault and Dement (1977) sought to follow up on the suggestions from several researchers (Dement & Kleitman, 1957; Dement & Wolpert, 1958; Portnoff, Baekeland, Goodenough, Karacan, & Shapiro, 1966)

that, during sleep, encoding of new information into long-term memory may not be possible.

> One hypothesis is that dream experiences produce short-term memories, but then the subsequent formation of permanent or persistent engrams does not occur. For example, a dream experience may persist in short-term memory for perhaps 10 minutes before dying out. This could explain why an awakening after 10 minutes of REM sleep generally elicits the same amount of recall as an arousal after 20, 30 or even 60 minutes of REM sleep. It is as if the "gate" between short-term and long-term memory closes during sleep (Guilleminault & Dement, 1977, p. 440).

To test for the presence of such a "gate", Guilleminault and Dement presented single words to subjects, one word per minute, until sleep onset. As the investigators detected sleep onset, they shut off the audio system to the subject and allowed him/her to accumulate either 30 seconds or ten minutes of sleep. After the interval had passed, the experimenters awakened the subjects and tested them for recognition memory of the target items. The study sessions occurred during afternoon naps and each subject was tested four to six trials per session, on two separate occasions.

The results displayed a deficit of recognition memory for words presented in the window of time five minutes prior to sleep onset, though only in the condition where subjects were allowed ten minutes of sleep. Guilleminault and Dement did not observe a difference across treatment conditions for words presented from ten to six minutes prior to sleep onset. The authors concluded that they had observed the closing of the gate between short- and long-term memory, though they were uncertain as to the exact moment when the gate had closed. They proposed that a certain degree of sleepiness in

awake individuals might even be enough to shut off the consolidation process. Thus, in their view, the better memory performance in the 30 second sleep conditions, for words in the five minute window preceding sleep onset, was possible due to short-term memory traces of the material, as opposed to retrieval from long-term storage. It must be inferred from their data that after ten minutes of sleep, short-term memory for events occurring immediately prior to sleep onset was no longer available -- thus, the five minute window of retrograde amnesia.

There were, however, some methodological problems that limit the generalizability of these results to "normal" subjects. First, as in the Jenkins and Dallenbach (1924) study, only two subjects were tested. Also, the subjects were restricted to only two hours of sleep on the night prior to their laboratory testing, which may have greatly exaggerated or compounded the effects of sleep on memory performance. Additionally, and presumably due to the small sample size, no statistical analyses were presented in the report of the study. Thus, any conclusions must remain purely speculative. Furthermore, subjects were "asked not to guess" during the recognition testing, perhaps artificially biasing subjects to score below the level they might have, had guessing been allowed. Thus, words that were seemingly not in memory may actually just have not exceeded the subjects' decision thresholds. Finally, if in fact the event of sleep onset, or some subsequent duration or depth of sleep, closed the gate between short- and long-term memory, then one can say that there was a <u>retrograde</u> amnesia for the stimuli presented five minutes prior to sleep onset. However, if the decline in arousal preceding sleep onset was the causal factor behind the memory deficit, then one would conclude that there was an <u>anterograde</u> amnesia for the stimuli

presented five minutes prior to sleep onset. It may have been the case that subject performance in the 30 second sleep condition was not deficient, as in those trials short-term memory for the words was still available to the subjects. Regardless of these caveats, the study has been quite influential. The results are included in primary sleep reference books (e.g., Principles and Practice of Sleep Medicine, Kryger, Roth, & Dement, 1989).

ROTH, et. al.

In a study primarily aimed at examining the effects of various benzodiazepines on memory and sleep, some interesting observations were made that support the theory that consolidation is some how changed prior to, at the moment of, or slightly after the event of sleep onset. In this study (Roth, Hartse, Saab, Piccione, & Kramer, 1980), Roth and colleagues administered doses of flurazepam (Dalmane), lorazepam (Ativan), triazolam (Halcion) or placebo to subjects 30 minutes prior to lights out in the laboratory. Three hours after lights out, the experimenters awakened the subjects, entered the bedroom and gave them a series of active tasks. The tasks required the subjects to engage in various behaviors (taking pills of diverse appearances, putting on and taking off elements of clothing, and reading and setting a clock) and to produce different types of verbal information (producing a fictional story on a given topic, discussing made-up travel plans, and recalling a five digit number). Return to sleep was allowed 15 minutes after the initial awakening.

Recall for the details of the tasks was tested both immediately following task participation and upon awakening in the morning. Roth and colleagues found that subjects taking active drug pills prior to sleep onset had worse recall

performance vs. subjects taking placebo, both at post-task and morning testing. Specifically, they found recall poorer when the subjects fell back to sleep within 2.5 minutes or less after post-task testing, versus when the return-to-sleep-latency was five minutes or more. In light of these findings, the authors concluded the following:

> Our results support the memory consolidation hypothesis... These findings indicate that a critical period of wakefulness, 2-3 min in duration, is necessary before memories are consolidated. It also suggests that sleep per se may have amnesic properties (p. 236).

It was concluded that the deficits shown in the results supported a consolidation hypothesis of memory, versus a view that attributed the deficits to a problem with memory retrieval. In the former, the information is never (sufficiently) processed; in the latter, the stored information is very difficult to retrieve. The authors went on to suggest that further research studies should systematically vary the level of arousal and duration of wakefulness following nighttime stimuli presentations. Additionally, they recommended testing hypnotics other than the benzodiazepines, such as barbiturate hypnotics. In summary, the results of this study converged on the findings of Guilleminault and Dement, though it employed different stimuli and experimental conditions. However, the authors failed to differentiate the amnestic properties of benzodiazepines from the potential amnestic effects of sleep.

PRESENT STUDY

While the present study did not test the effects of hypnotics, it attempted to more precisely measure memory for events occurring immediately prior to

sleep onset. The experimental design was based on Guilleminault and Dement (1977), with modifications based on the current methodologies used in memory research. In keeping with their design, the present study employed an afternoon nap design, presented one stimulus per minute, had all subjects undergo both sleep conditions (30 seconds and ten minutes), and asked subjects to repeat the stimuli aloud after hearing them.

One of the limitations of the studies described above is that they utilized only tests of free recall or recognition memory. However, no tests of implicit memory were employed. By implicit memory, we mean the type of memory that Schacter (Schacter, 1987) described as being "encoded during a particular episode (and) is subsequently expressed without conscious or deliberate recollection" (p. 501). Schacter and others in memory research categorically distinguish implicit memory from explicit memory, that which relies on "conscious recollection of recently presented information, as expressed on traditional tests of free recall, cued recall, and recognition."

Memory researchers have shown that implicit and explicit memory may call upon different anatomical structures. Numerous studies (i.e.., Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984) have found that certain organic amnesic patients possess intact implicit memory, in the presence of radically impaired explicit memory. Therefore, this study also investigated whether or not a similar dissociation occurs in normal individuals at the transition from wake to sleep. To provide for comparability of data between the present and earlier studies, free recall and recognition tests were included as measures of explicit memory. Matched explicit and implicit versions of a paired-associate task were employed (see Appendix B for task instructions) so that explicit and

implicit memory could be compared directly. The selection of these tasks and selection of the stimulus material was modeled after those used in a study of memory during anesthesia (Kihlstrom, Schacter, Cork, Hurt, & Behr, 1990). In order to allow for paired-associate testing, word pairs were used as stimuli, as opposed to single words in the study of Guilleminault and Dement.

Spectral EEG data were collected from four scalp sites in order to allow for more specific quantification of the relationship between EEG and memory. Also, the subject size was increased over Guilleminault's & Dement's two to twenty. Efforts were made only to impose a minimal sleep restriction on the subjects' total sleep time the night before their laboratory testing, in order to minimize sleep deprivation effects on memory. Finally, subjects were encouraged to guess on the recognition task when unsure of a response.

HYPOTHESES

1. It is hypothesized that in memory testing subsequent to the 30 second sleep episodes, subjects will not display impaired free recall or recognition memory for the word pairs heard immediately prior to sleep onset. The presence of a "recency effect" should be evident in the free recall and recognition data.
2. It is hypothesized that in memory testing subsequent to the ten minute sleep episodes, subjects will display some degree of impairment of free recall and recognition memory for the word pairs heard immediately prior to sleep onset. Additionally, based on the sensitivity of the two tests as measures of waking memory performance, it is hypothesized that the

degree of impairment displayed on the free recall task will be greater than that in the recognition task.

3. It is hypothesized that the subjects' performance on the explicit paired-associate task will show a dissociation from that in the implicit paired-associate task. Additionally, it is hypothesized that the performance on the explicit paired-associate task will show a period of impaired performance shorter than that of the free recall task, but longer than that of the recognition task.

METHODS

SUBJECT SELECTION

Twenty subjects (ten female, ten male) were selected on the basis of their answers reported on a sleep habits questionnaire given to over 500 undergraduates from "Introductory Psychology" courses at the University of Arizona, in the Fall of 1991. A copy of this questionnaire is located in Appendix C.

Inclusionary criteria were as follows:

1. English as first or primary language
2. No complaint of major sleep pathology (i.e.., insomnia, sleep apnea, narcolepsy)
3. Average reported nocturnal sleep latency of 20 minutes or less
4. Average reported total sleep time of greater than five and less than nine hours
5. Interest in participating in a laboratory sleep experiment

Exclusionary criteria were as follows:

1. Current nicotine use of any amount (either through smoking or chewing)
2. Average reported weeknight bedtime before 9 p.m. or after 1 a.m.
3. Positive history of head injury or concussion
4. Positive history of hearing deficiency
5. Positive history of memory deficit
6. Current use of over-the-counter or prescription medication(s) possessing stimulant, depressant, or amnestic properties (i.e.., certain antidepressants, antihistamines, anxiolytics, and benzodiazepine hypnotics)

Respondents satisfying all criteria for the study (n = 70) were contacted by telephone. Research assistants gave the respondents a brief description of the study and, if they were interested in participating, scheduled them (as subjects) for an appointment in the sleep research laboratory (SRL). The assistants also informed subjects that they were to limit caffeine intake during the day of the study and the two preceding days to the equivalent of one cup of coffee (one cup of coffee, two cups of regular tea, or two caffeinated sodas), to refrain from alcohol or illicit drug use, to eliminate all naps, to keep a record of bedtimes and waketimes, and to regularize their bedtimes and waketimes. Bedtimes were fixed between the hours of 10:00 p.m. and 1 a.m.; waketimes were fixed between 6:00 a.m. and 9:00 a.m. In addition, subjects were asked to allow themselves no more than seven hours of sleep on the night prior to the study. All subjects verbally agreed to abide by these guidelines. To check compliance, subjects were asked to bring a diary of their bedtimes, waketimes, and estimated total sleep times for the three nights prior to the study with them to the laboratory. Out of the twenty subjects, only two or three reported minor violations of the requested bedtimes and/or waketimes.

APPARATUS

Stimulus Material and Audio Equipment

Ten lists, sixteen word pairs each, were culled from Palermo & Jenkins' (1964) book of normative data for word associations. Each list was composed of single words and their most-frequent associates, based on norms from 500 male and 500 female college students. Each list contained word pairs varying in associative strength from weak (near 0.1) to moderate (near 0.5). For example, a particular word pairing arrived at by 200 out of 1000 college students would have received a strength of 0.2. Lists were balanced so that average associative strengths ranged from 0.51 to 0.092. For each of the ten lists (Lists 1-10), four random orders were prepared (Orders A-D) (See Appendix D for lists and associative strengths of word pairs).

The 160 word pairs were recorded into an Apple Macintosh SE/30 computer with Farallon's MacRecorder hardware and SoundEdit software. Each individual word, surrounded by a minimal amount of line interference, was parsed down to a one-second sample (plus or minus three one-hundredths of a second) and saved as a sound resource file. The experimenter then wrote a Macintosh HyperCard stack to control the presentation of the following: 1) the test words for volume calibration to the subjects; 2) the actual word lists, and; 3) the tone for awakening (a 1000 Hz pure tone, sine wave). During the actual presentations, the intra-pair word interval was one second (as measured from word 1 offset to word 2 onset) and the inter-pair interval was one minute (measured from the onset of word 1 of the first pair to the onset of word 1 of the next pair).

All auditory stimuli (test words, word pair lists, and awakening tone) were presented to the subjects from the Macintosh through two, small, bookshelf speakers (Radio Shack #40-2039B), amplified by a 20 watt p.a. system (Radio Shack # 32-2033A). The speakers were located at the headboard of the bed, on each side of the subject's head, at a distance of approximately two feet.

PROCEDURE

Initial Preparation

On the study day, the subject arrived at the SRL at 1:00 p.m., where he / she was met by the experimenter and given a brief tour of the laboratory (see Appendix E for the timeline of the laboratory procedures). After the tour, the experimenter described the study, outlined the consent form (see Appendix F), and answered any questions from the subject. After obtaining informed consent, the experimenter and a research assistant placed electrodes on the subject for polysomnographic (PSG) recording.

Scalp electroencephalogram (EEG) electrodes were placed according to the guidelines of the 10-20 System (Jasper, 1958). Gold cup electrodes were placed at sites FP1, C3, T3, and O1, affixed in place with collodion-soaked gauze patches. Silver-silver chloride disk-type electrodes for electro-oculogram (EOG) and electromyogram (EMG) recordings were affixed, held in place with double-sided adhesive collars and covered with Micropore surgical tape. EOG electrodes were placed at the left and right outer canthi, with the left electrode deviated down from the horizontal plane and the right electrode deviated up from the plane. Mentalis and submentalis EMG placements were used. EEG and EOG were recorded referentially, using contralateral mastoid placements of

silver-silver chloride, disk electrodes. EMG recordings were bipolar, between two of an available three EMG electrodes. (see Appendix G for PSG montage, filter settings, and amplifier sensitivity settings). All physiological data, a time signal, and an audio marker signal were collected on a Grass Instruments Model 8 EEG. Additionally, all EEG data and the time and audio signals were acquired in digital format to a Dell 310 computer. Analog signals were converted by a Data Translation DT-2801 A-D board and the digitization process was governed by Stellate System's Rhythm software (Version 7.0).

The electrode hookup was completed at approximately 2:00 p.m., at which time subjects were asked to use the SRL's bathroom, if necessary. The experimenter then aided the subject in getting into bed in the dimly-lit bedroom. Then, the experimenter entered the Control Room and began "subject calibrations" to ensure proper signal registration (see Appendix H for scripted instructions for subject calibrations). After calibrations, the experimenter played a series of test words over the audio system, asking the subject to respond with instructions to either raise, lower, or maintain the current volume. The subject was informed that the volume should be loud enough to allow for clear perception of the words, while being quiet enough to allow for sleep to occur.

Following volume adjustment, the experimenter re-entered the bedroom and gave the subject brief instructions for the first trial. The subject was told to listen for pairs of words, which would be played separated by intervals. The experimenter asked the subject to repeat each word pair aloud after hearing it, in order for him (experimenter) to know that he/she (subject) had heard the pair. Also, the subject was told to try to remain awake until five word pairs had been presented, at which time a brief, quiet tone would sound, reminding the subject

that it was okay to fall asleep at that point. However, the subject was asked to continue repeating any word pairs heard after the tone. Finally, the subject was told that he/she would be alerted later by an alarm-clock-like tone, asked to roll onto his/her back, and asked some questions about the word pairs presented during that trial. It was also stated that he/she may or may not have been asleep immediately prior to each arousal tone. If there were no questions, the experimenter asked the subject to get comfortable, turned off the lights, closed the door, and began the first trial. Word presentation commenced shortly (usually within 30 seconds) after the experimenter left the bedroom.

Stimulus Presentation and Subsequent Sleep

At lights out, the Macintosh HyperCard stack was activated and the audio presentation began, using the volume level calibrated just prior to the beginning of each trial. The experimenter and one of two research assistants monitored the polygraph for signs of the approach of sleep onset (slow eye movements and fragmentation of occipital alpha activity). After observing fifteen seconds of stage 1 NREM EEG activity in the C3 channel, the experimenter discontinued the audio presentation, except in instances when a word pair presentation was already in progress. In those instances, the experimenter waited for the next fifteen second period of stage 1 EEG before stopping the audio system.

Prior to the beginning of the first trial, the experimenter had determined the sleep condition for the first trial (by coin flip). Subjects were allowed to accumulate either 30 seconds or ten minutes of sleep. However, any trials in which the subject did not accumulate at least 20 seconds of sleep during the 30

second condition or 7.5 minutes of sleep in the ten minute condition were eliminated from the data set. After the required interval, the 1000 Hz tone was played over the audio system and the subject was asked to roll onto his/her back and open his/her eyes in preparation for the question session. For the second trial, the sleep condition was the opposite of the preceding trial. For example, if the first trial was a 30 second trial, then the next was to be a ten minute trial. If the subject did not fall asleep at all or did not sleep for the required interval of time, then the sleep condition for the second trial was the same as that sought after in the first trial. After one trial of each type was obtained, the order for the following trial was randomly selected. Testing was continued, in this fashion, for a maximum of five trials for any subject.

Memory Testing

After terminating the awakening tone, the experimenter activated a microcassette recorder, which provided a backup account of the subject's answers to the memory tasks. The experimenter then began by reading instructions (scripted statements located in Appendix B) for the first of the memory tasks, which were presented in the following order:

1. Free (unaided) recall
2. Either an explicit or implicit paired-associate task (randomly selected)
3. The other of the explicit or implicit task
4. Recognition ("yes/no" type)

All testing was conducted in the same sensory modality as the initial presentation (auditory), as per the recommendations of various memory researchers (e.g., Schacter, 1987, Kihlstrom, 1992). Testing was conducted via

intercommunication system, without the experimenter entering the bedroom or the bedroom lights being turned on. All subject responses were recorded on paper by a research assistant for later coding and entry into a computer.

The free recall task required the subject to recall any word pairs heard during that trial. The explicit paired-associate task involved playing the subject half (every other) of the first words of the trial's word pairs and asking him / her to say the words paired with them during the initial presentation. First words of target pairs were used along with first words of control pairs, matched with the target pairs for associative strength. Subjects were instructed not to guess in this task, to avoid contamination from implicit memory. The implicit task involved playing the other half of the first words of the trials' pairs, using targets and controls, and asking the subject to free associate by speaking the first word that came to mind. The recognition task consisted of the entire trials' word pairs, half from the target list and half from the control list. The subject was asked to judge whether or not the word pair was one of those presented in that trial. Guessing was encouraged in this task.

Following memory testing, the volume was reset for the next trial. Then, the subject was asked to return to the desired sleeping position, close his/her eyes, and await the first word pair.

Debriefing

After the completion of the last trial, the subject was assisted out of bed and brought back into the SRL's hookup room. There, the research assistant removed the electrodes while the experimenter debriefed the subject and answered any questions. The subject was instructed to keep the details of the

experiment confidential until the completion of the entire experiment. The experimenter also invited the subject to return at a later date to receive feedback about his/her individual performance or that of the group as a whole. To date, none of the subjects have returned for feedback.

DATA SCORING AND ENTRY

As a conservative measure, when subjects were given more than one trial of a given sleep condition (i.e.., two 30 second trials), their performance was averaged across the trials at each minute prior to sleep onset.

For the free recall task, a given response received a score of "1" if it was in fact one of the word pairs presented. Full credit was given in instances when the subject generated an alternative form of one of the words in the pair, as in "chair...tables," instead of "chair...table." If the response included only one word from a presented pair, a score of "0.5" was given. A score of "0" was given when the subject failed to recall a given word pair.

For the explicit paired-associate tasks, it was necessary to adjust scores for the target word pairs by a guessing rate - the mean number of times subjects responded with the correct answer when presented with the first word of a control (unpresented) word pair, which was matched with the target word pair for associative strength. An adjusted or corrected score was calculated by subtracting subject's overall control scores from their target scores. In this task, a subject received a score of "1.0" for responding to the cue word from a target pair with the correct word or an alternate form of the correct word. Incorrect responses yielded a score of "0". Similarly for the implicit paired-associate task, when subjects responded with either the correct target, they received a score of

"1.0" for that word-minute. Incorrect responses received a score of "0.0". As above, an overall trial guessing rate was calculated for each subject/trial, by averaging the subject's scores for the control word pairs. Adjusted scores were calculated as above.

In the recognition task, subjects received a score of "1.0" for responding "yes" they had heard that particular word pair before, whether it was a target or a control word pair. "No" responses received scores of "0.0". The recognition adjusted scores reflect the target scores minus the control scores, as in the two previous tasks.

RESULTS

NUMBER OF WORDS PRESENTED

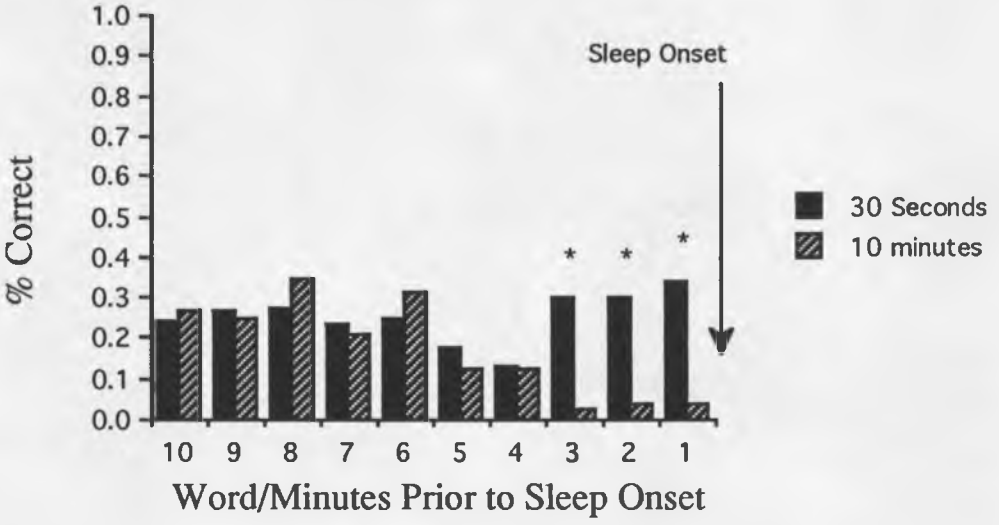
In the experiment, a total of 1184 word pairs were presented to the subjects. Subjects heard an average of 12.33 word pairs per trial (see Appendix I for detailed information). As subjects heard one word pair per minute, this figure (12.33) can serve as a rough approximation of the average sleep latency observed in the experiment.

FREE RECALL TASK

When comparing the results from the 30 second and ten minute sleep conditions at each of the ten minutes prior to sleep onset, the differences were only significant for word pairs presented three, two, and one minute prior to sleep onset (two-tail, paired t-test; p=.0033, p=.012, p=.0053). In other words, subjects recalled significantly more word pairs in the period from three minutes

to one minute prior to sleep onset when awakened from 30 seconds vs. ten minutes of sleep, as can be seen in Figure 1.

Figure 1. FREE RECALL: 30s vs 10m



Additionally, subjects recalled significantly more words in the 30 second trials than in the ten minute trials (mean x-y = 1.375, paired-t value = 2.817, p = .011).

EXPLICIT AND IMPLICIT PAIRED-ASSOCIATE TASKS

For the explicit paired-associate task, no differences were found in performance across the two sleep conditions at any of the eight word-minutes prior to sleep onset (two-tail, paired-t), for the data adjusted for the subjects' guessing rates (see Figure 2). However, due to the design of the experiment, with every other word being tested implicitly or explicitly, the "true" sample size for any given word-minute prior to sleep onset was much less than the original twenty subjects. As with the explicit form of this task, no differences were found

between the two sleep conditions for any of the eight word-minutes prior to sleep onset tested implicitly, recognizing the limited sample size for this analysis (see Figure 3).

Figure 2. EXPLICIT PAIRED-ASSOCIATE: 30s vs 10m (Adjusted)

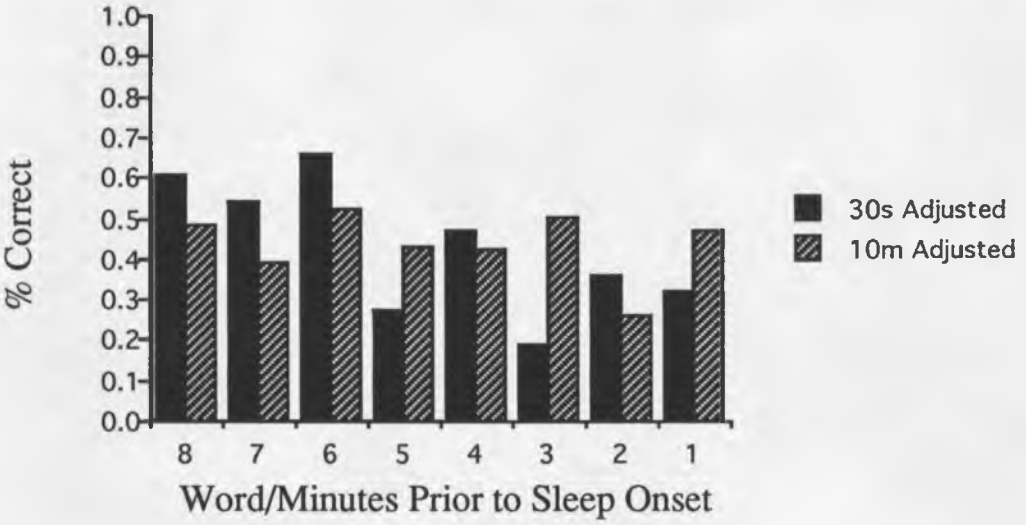
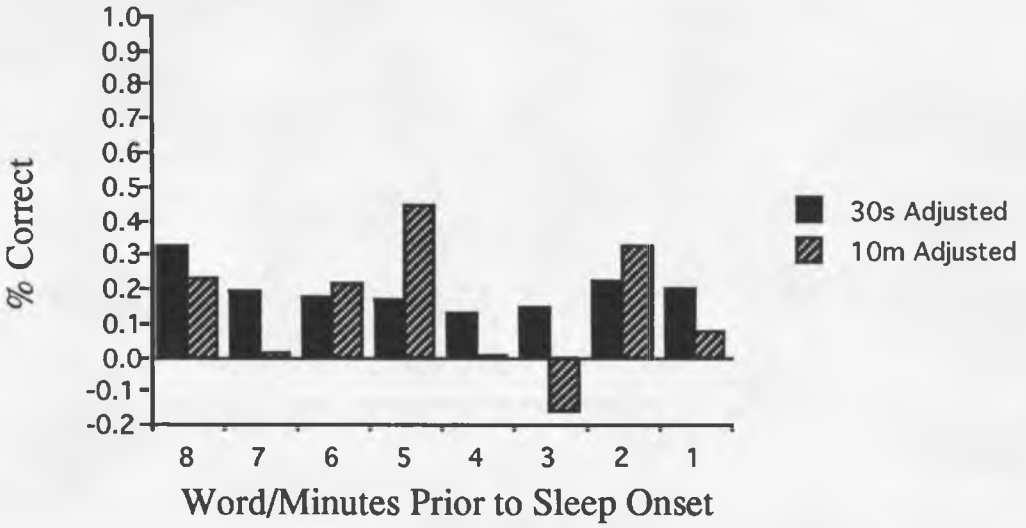


Figure 3. IMPLICIT PAIRED-ASSOCIATE: 30s vs 10m (Adjusted)



In preparation for analysis of variance, the subjects' performance in each of the eight minutes prior to sleep onset was averaged in two-minute groups,

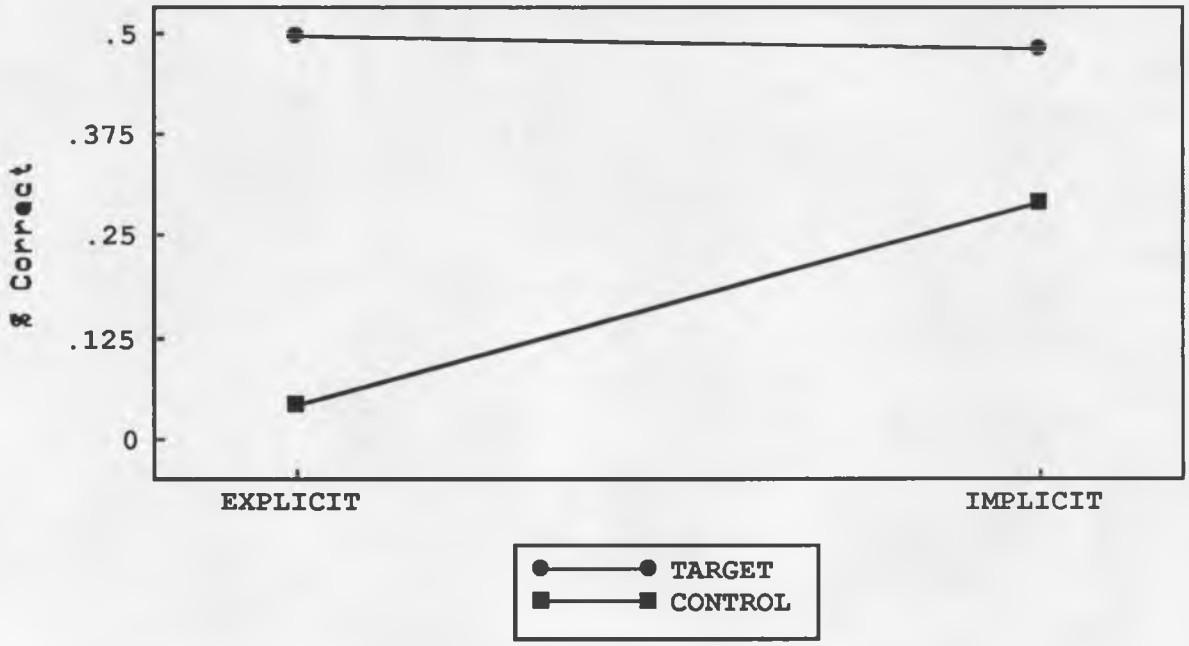
since every other presentation was tested either explicitly or implicitly. Thus, the values for the eight and seven minutes prior to sleep onset were averaged, as were the values for six and five minutes, four and three minutes, and two and one minute. Conservative procedures were then enacted to fill in any missing data cells, following suggestions published by Winer (1971). The procedure involved filling each missing cell with a value based on the equally-weighted averages of both that individual's performance in the rest of the trial and the overall performance of the other subjects for the word pairs in that particular minute prior to sleep onset. One degree of freedom was subtracted from the appropriate error terms for each cell filled (total of 12 missing cells filled).

A 2x2x2x4 ANOVA (explicit/implicit [task type] x target/control [word type] x 30 second/ten minute [sleep condition] x two-minute group position relative to sleep onset [time]) was run to compare the data from the explicit and implicit paired-associate tasks. There were highly significant values for main effects of word type and task type ($F = 98.679$, $p = .0000$; $F = 14.222$, $p = .0013$, respectively). As can be seen in Table 1, subjects were much more accurate on target than on control words. The main effect of task type needs to be interpreted within the context of the interaction of task type and word type, which was significant ($F = 20.490$, $p = .0002$). The interaction indicates that the subjects' performance for implicit targets was not much greater than for controls. Thus, surprisingly weak priming took place. In contrast, there was a dramatic difference between the explicit target and control means (see Figure 4).

Table 1. Means for Explicit / Implicit Paired-Associate ANOVA

Main: task type		**Main: word type**	
EXPLICIT	.2653	TARGET	.4834
IMPLICIT	.3806	CONTROL	.1625
Main: time			
8-7 mins	.3417	4-3 mins	.2797
6-5 mins	.3555	2-1 mins	.3148

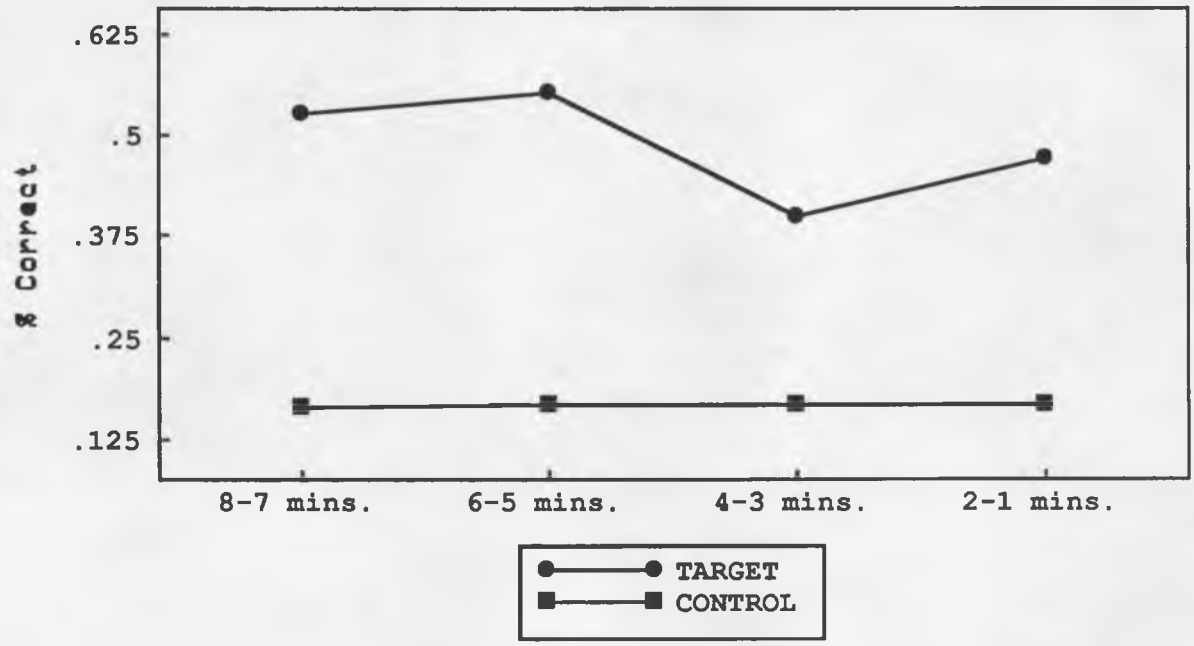
FIGURE 4. MEANS FOR TASK TYPE x WORD TYPE INTERACTION



There were also nonsignificant trends for the main effect of time ($F = 2.465$, $p = .0715$), the interaction of word type and time ($F = 2.497$, $p = .0688$), the three-way interaction of task type with sleep condition with time ($F = 2.303$, $p = .0867$), and the four-way interaction between each of the four main effects ($F = 2.300$, $p = .0870$). Data for the four-way interaction are not presented, as the interaction was not interpreted. As can be seen in Table 1, the means for main effect of time decreased approaching sleep onset. As can be seen in Figure 5,

The means from the interaction between the main effects of word type and time indicate that for the targets, performance got worse as sleep onset approached, with a recovery in the two-minute period immediately prior to sleep onset. This suggests the presence of a recency effect.

FIGURE 5. MEANS FOR WORD TYPE x TIME INTERACTION



For the three-way interaction, in the explicit task, subject performance in the 30 second sleep trials was better than performance in the ten minute for words presented earlier before sleep onset (see Figure 6). In contrast, for the implicit task, there was no relative advantage of the 30 second condition over the ten minute condition (see Figure 7).

FIGURE 6. MEANS FOR 3-WAY INTERACTION (EXPLICIT)

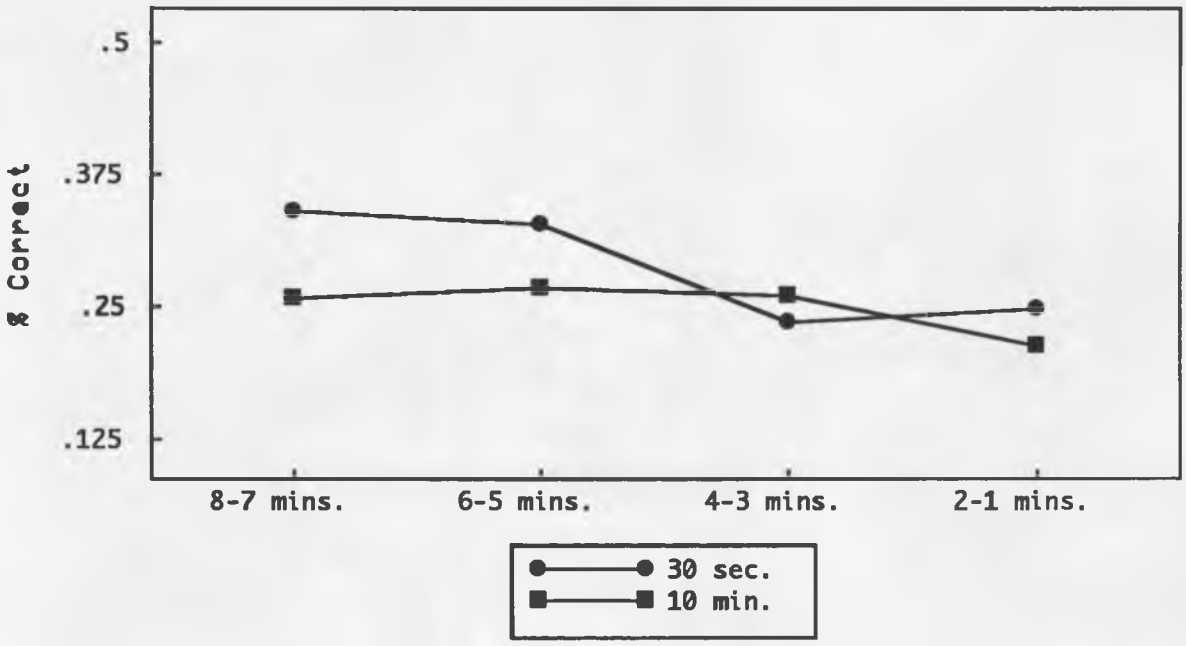
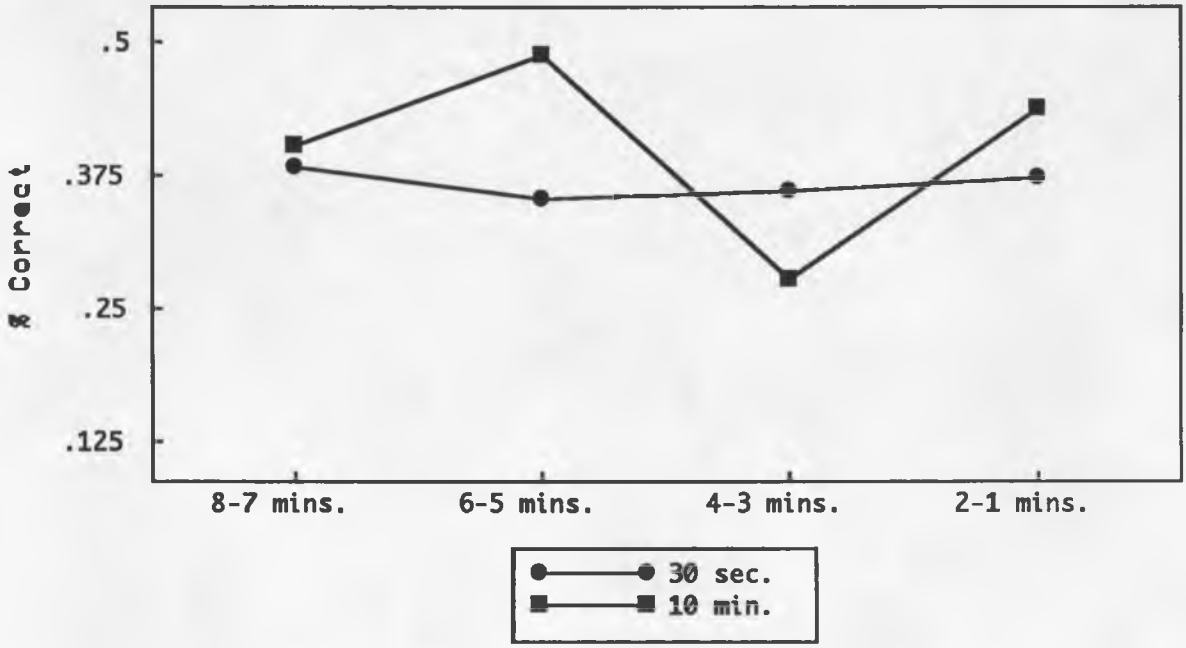


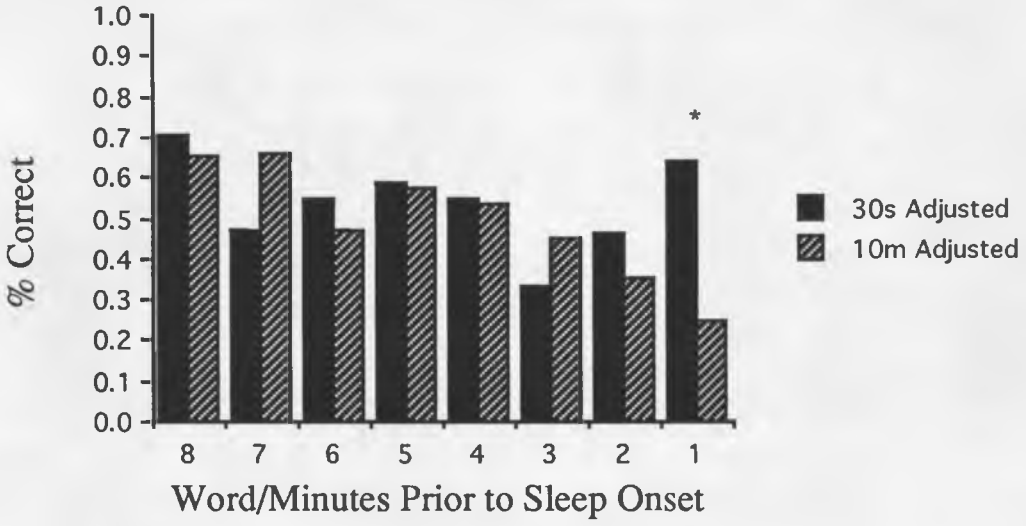
FIGURE 7. MEANS FOR 3-WAY INTERACTION (IMPLICIT)



RECOGNITION TASK

A comparison of the differences between subject's adjusted scores (targets-controls) on recognition testing for the eight word-minutes prior to sleep onset revealed significantly poorer performance during the ten minute sleep condition for only the single word pair immediately preceding sleep onset (64% vs. 25%, two-tail, paired t-test; p=.0013; see Figure 8).

Figure 8. RECOGNITION: 30s vs 10m (Adjusted)



For the purposes of analysis of variance, the data set was narrowed to the eight word-minutes prior to sleep onset. In a 2x2x8 ANOVA (target/control [word type] x 30 second/ten minute trial [sleep condition] x word-minute prior to sleep onset [time]), there were three significant effects. The main effects of word type and sleep condition were significant ($F = 92.688$, $p = .0000$; $F = 5.691$, $p = .0276$; respectively). The means for the main effect of word type indicate that subjects performed significantly better on targets than controls, as would be expected in a recognition task (see Table 2). The means for the main effect of

sleep condition indicated that, overall, subjects performed better on the 30 second than the 10 minute trials (see Table 2).

Table 2. Means for Recognition ANOVA

Main: word type		Main: sleep condition	
TARGET	.7818	30 sec.	.5522
CONTROL	.2837	10 min.	.5133

The three-way interaction of word type x sleep condition x time was significant ($F = 2.207$, $p = .0375$). A graph of the means for the effects in the three-way interaction indicate the presence of a recency effect within the target data for the 30 second trails, for the final two word-pairs prior to sleep onset. Concurrently, there is continuation of the ongoing decline in performance in the ten minute trials (see Figure 9 and Figure 10).

FIGURE 9. MEANS FOR 3-WAY INTERACTION (TARGET)

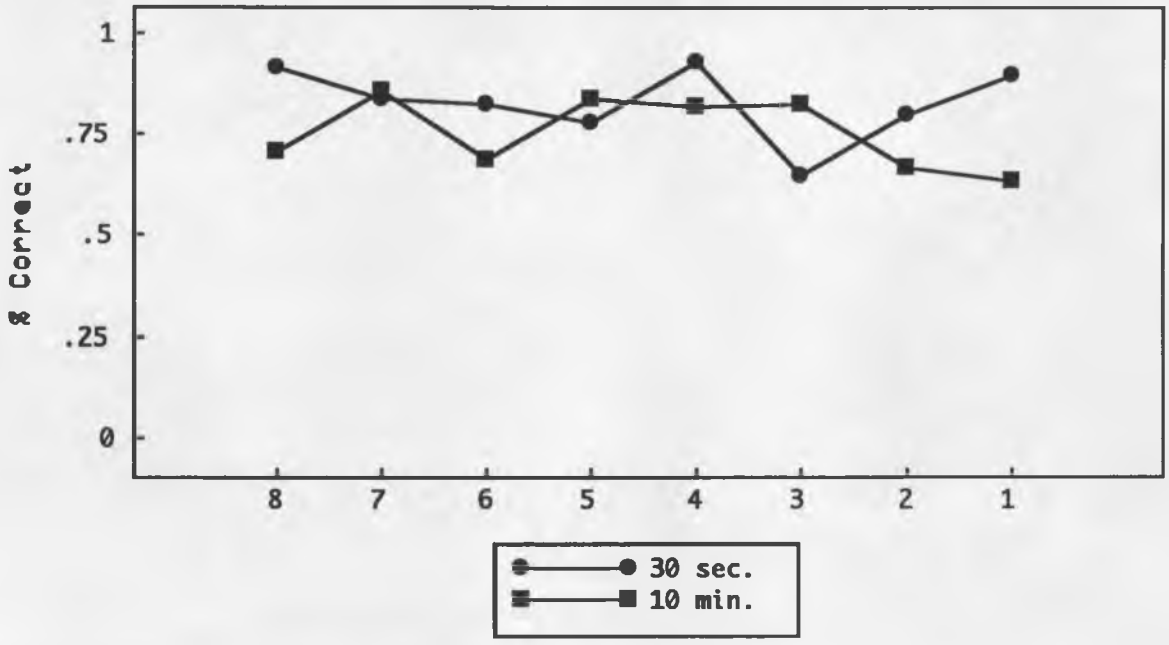
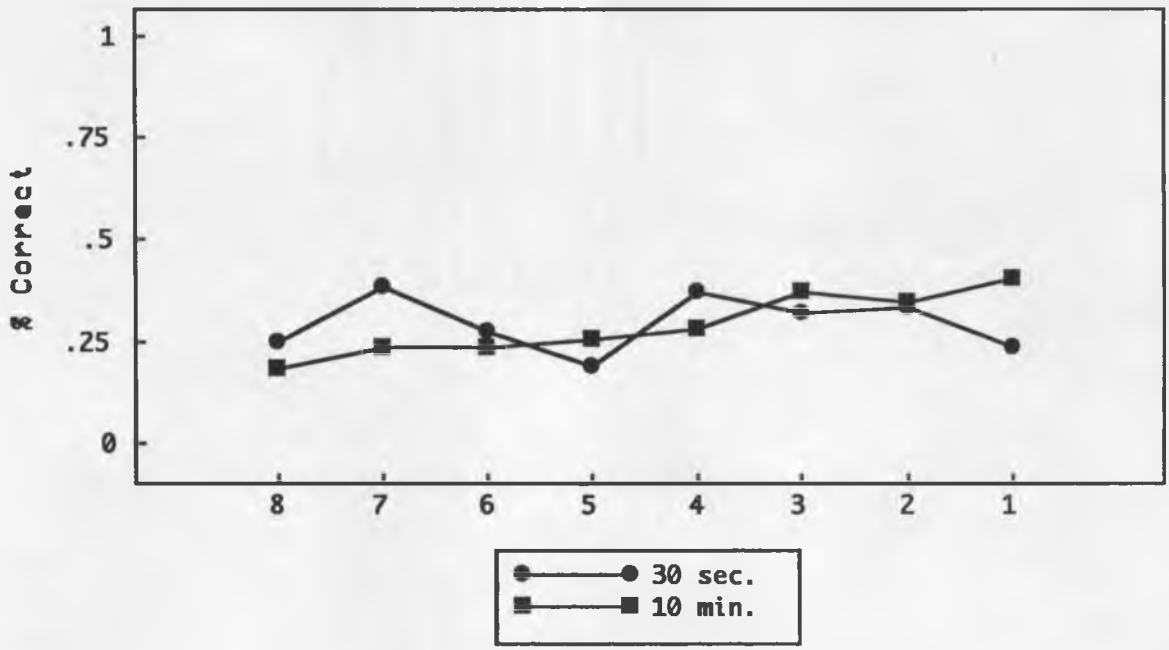


FIGURE 10. MEANS FOR 3-WAY INTERACTION (CONTROL)



Note: See Appendix J for summaries of the t-tests for the free recall, explicit and implicit paired-associate tasks, and the recognition task. See Appendix K for

summaries of the explicit/implicit paired-associate and recognition analyses of variance.

SLEEP STAGES (TEN MINUTE TRIALS) VS. MEMORY PERFORMANCE

To examine the relationship between human-scored sleep stages within the ten minute trials (see Appendix L for exact stagings) and free recall task and recognition task performance, stepwise regression analyses were performed. The independent variables were percentages of Stage 1, 2, slow wave sleep, and wake. There were no significant linear relationships between sleep stages and performance for either of the tasks.

Because one would expect that the subjects' performance would be negatively related to the depth of sleep due to sleep inertia, a subsidiary analysis was performed. Sleep stages 2, 3, and 4 were pooled as a single variable and correlated with the total number of words recalled, adjusted for total number presented before sleep onset. The value of the correlation was -.092. However, examination of the plot indicated a curvilinear relationship. Subjects obtaining either very little or a great deal of stages 2, 3, and 4 performed poorly in the free recall task. This relationship is curvilinear due to only three subjects who both obtained very little of stages 2, 3, and 4 sleep and performed poorly. Without them, there would have been a strong, negative linear relationship ($r = -.591$, $p = .0124$). It is unclear why those three subjects performed poorly, given that they had the smallest percentages of deeper sleep.

DISCUSSION

The results of the present study suggest that the mental or brain activity occurring before, during, and shortly after the onset of sleep impairs memory for auditory events occurring several minutes prior to sleep onset.

Specifically:

1. On the free recall task, subjects in the 30 second sleep condition demonstrated what appeared to be "normal" performance. In trials where subjects were allowed to sleep for ten minutes, however, there was a dramatic failure of unaided recall for the word pairs presented in the three minute period prior to sleep onset. In addition, subjects recalled significantly more words overall in the 30 second trials than in the ten minute trials.
2. In the explicit and implicit paired-associate tasks, there were no significant differences in performance between the 30 second and ten minute trials. However, in the 2x2x2x4 ANOVA, there was the presence of a recency effect in the pooled (explicit and implicit) paired-associate targets. In addition, subjects performed only slightly better for the target than the control word pairs in the implicit task; there was only minimal evidence of priming having taken place. However, subjects' performance on target words was far greater than for control words in the explicit paired-associate task.
3. The recognition data revealed a highly significant difference in the memory for the word pairs presented one minute prior to sleep onset, with the ten minute performance poorer than in the 30 second condition. In addition, subjects performed significantly better on the target words than on the control

words and on the 30 second trials than on the ten minute trials. Furthermore, subjects demonstrated a recency effect for the target words in the 30 second trials, while the same target data for the ten minute trials shows a steady decline right up to sleep onset.

The data from the free recall and recognition tasks in the ten minute trials support a theory that poor stimulus encoding led to the memory deficits observed in the study. If the elaborateness of the encoding progressively decreased prior to sleep onset, then one would have expected the poorest performance in the one word minute prior to sleep onset. This was in fact the case in the recognition data. But the period of impairment extended to the three minute window prior to sleep in the free recall task -- two word pairs more than in the recognition task. A likely explanation for this disparity would be that three and two minutes prior to sleep onset, encoding processes had began to become impaired. Thus, free recall was not possible for these word pairs, due to the impoverished encoding. However, the word pairs were detected on a recognition task, a task quite sensitive to even weak or poorly encoded information. In the case of the word pair immediately prior to sleep onset, there was not even enough information to allow for correct recognition, above the subjects' guessing rate.

Simply positing that there was a failure of proper encoding prior to sleep onset is an interesting, but insufficient description of the results. What needs to be proposed is an underlying reason why encoding failed. One hypothesis involves the fact that the determination of the moment of sleep onset is dependent on the EEG frequency in the general region of the central sulcus,

electrode placement C3. However, it is a common observation that the EEG frequencies from electrodes overlying frontal regions slow and become synchronized before the central EEG. Thus, one might consider frontal lobe contributions to auditory processing and memory functioning going "off-line" sooner than processors in other brain regions. This decrease or cessation of operations may take place before sleep onset is scored in the C3 lead.

Additionally, it could be hypothesized that the overall arousal level declined prior to sleep onset. Subjects may simply have not been paying as much attention to the word pairs presented three minutes before sleep onset. It is unlikely that the subjects did not even hear these word pairs. Attempts were made in the present study to test this hypothesis; subjects were required to repeat each word pair aloud after hearing it, which occurred nearly without fail. Even if subjects had entered Stage 1 NREM a few seconds prior to the presentation of a word pair, they awakened and repeated the pair correctly. Thus, it seems clear that the subjects were at least aware of and heard the word pairs.

The encoding/arousal hypothesis seems applicable here, but it fails to account for the differences found in performance across the two sleep conditions. Why were the deficits not found as well in the 30 second trials? In fact, during the three minute period prior to sleep onset, performance actually increased to its highest levels in the 30 second trials. As the trial conditions were randomly selected, the subjects should have been at equally low arousal levels prior to sleep onset in both sleep conditions. Perhaps the most plausible explanation for the discrepancy would be that upon awakening, subjects in the 30 second trials still had short-term memory for the word pairs upon which to

rely. The recency effects observed in the results suggest the active contribution of short-term memory in the 30 second trials. In contrast, upon being awakened from ten minutes of sleep, subjects no longer had short-term memory to rely upon and had only information held in longer-term storage. As to whether that information was in long-term memory or some intermediate stage is an interesting and important question, but one that is beyond the scope of this paper. One way further research could examine whether or not subjects were relying on short-term memory in the 30 second trials would be to insert a cognitive distraction task (like a digit subtraction task) between the awakening and the free recall task. Thus, one would expect the subjects to evidence the same deficient recall for the word pairs in the three minute period before sleep onset, as short-term memory would have been cleared by the distraction task. Additionally, one would expect, contrary to the findings in the present study, that the subjects would recall the same number of words in both the 30 second and ten minute conditions.

An interesting comparison can be drawn between the present experiment and a study by Bonnet (1983). He conducted a study examining memory for stimuli presented during brief awakenings from sleep. He hypothesized that memory for these events might be related to the stage of sleep prior to awakening (arousal level at encoding), the duration of the awakening (time allowed for consolidation), or both.

In his study, one group (Stage 2) of subjects was awakened from stage 2 NREM sleep and engaged in the Williams Word Memory Test (Williams, Lieseking, & Lubin, 1966), a pre-recorded audio task requiring six minutes to complete. The task involved the presentation of two lists of fifteen words, which

subjects listened to and were asked to write down. Afterward, the subjects' short-term, free recall memory for the lists was tested. After this presentation and testing session, subjects were allowed to return to sleep. A second group (Test) underwent identical procedures, but were instead awakened from stage 4 sleep. A third group of subjects (Test/Delay) was awakened from stage 4 sleep, given the memory task and testing, and then kept awake for eight minutes before being allowed to return to sleep. During this delay after testing, subjects participated in a nonverbal maze task. The task was selected to prevent rehearsal of the words. The fourth group (Delay/Test) was awakened from stage 4, given the maze task, and then given the verbal memory task.

In the morning, all subjects were awakened and tested for both free recall and recognition memory for the word lists heard during the night's awakening. The results indicated that subjects performed significantly better on the short-term recall test when awakened from stage 2 than from stage 4 (Stage 2 vs. Test). Also, subjects performed significantly better on short-term recall when tested was delayed after awakening, versus being tested immediately after awakening (Delay/Test vs. Test/Delay). Long-term free recall performance paralleled short-term performance; subjects recalled more words when testing occurred after awakenings from stage 2 vs. stage 4 sleep and when testing occurred after a delay vs. immediately after awakening. The morning recognition testing revealed no significant differences between the groups.

Bonnet interpreted the results as supporting a view that arousal level during stimulus presentation (encoding) was the relevant variable for predicting subsequent short-term and long-term free recall performance. He reported that his results did not support a view that short sleep latencies led to interruptions

of trace consolidation. However, there are several problems to be raised regarding his interpretation. It could be argued that subjects in the Delay/Test condition were rehearsing the words as they were falling asleep. On the other hand, subjects in the Test/Delay condition were actively prevented from rehearsing the word lists after presentation. This difference could have masked improved performance in the subjects kept awake after testing. Additionally, the subjects in the Delay/Test and Test/Delay conditions were awakened from stage 4 sleep. It has been shown that "sleep inertia" , a period of profound mental dullness and slowed cognitive processing, often accompanies awakenings from stage 4 sleep. Sleep inertia can last perhaps 20 minutes or more (Dinges, Orne, & Orne, 1985; Stones, 1977; Tilley & Statham, 1989). Thus, the effects of sleep inertia could have masked any favorable effects delayed sleep onset might have had on the consolidation process, and thus, subsequent long-term recall and recognition performance. In conclusion, one can at least find support for an encoding or arousal hypothesis from the Bonnet results.

In contrast, the deficits seen in the present study could have been due to impaired consolidation. Something about sleep per se may have blocked the transfer of information from short-term to long-term memory. Thus, information presented to the subjects four minutes prior to sleep onset had time to enter long-term memory, whereas information presented after that point failed to make it into long-term stores. Again, the fact that the performance appeared unimpaired in the 30 second sleep trials could be explained in at least two ways. First, in those trials, subjects probably had short-term memory to rely upon during testing. Second, perhaps a certain depth or duration of sleep was

necessary to interrupt the flow of information into long-term memory -- and this depth or duration was not reached in only 30 seconds of sleep.

There are some notable problems with a consolidation theory of these memory deficits. First, an all-or-nothing consolidation theory cannot explain the different critical periods in the free recall and recognition tests found in the present study. Consolidation would need to be a gradual process in order to allow for the aforementioned difference. Second, the subjects' memory for word pairs, as tested with the explicit paired associate task, appeared to have been intact right up to sleep onset, as evidenced by the nonsignificant differences between the targets and controls found in the t-testing. Thus, it appeared that consolidation had taken place for all of the word pairs.

Perhaps the most problematic evidence for a consolidation theory was that none of the human-scored sleep data from the ten minute trials correlated significantly with the actual deficits shown in the free recall and recognition tasks. Two caveats should be mentioned that concern this negative finding. It might be that the human-scored data was not the correct level of analysis to detect effects of sleep on consolidation. The spectral data of the subjects' sleep, when analyzed, will provide a more fine-grained analysis of the subjects' sleep, perhaps changing the finding. More importantly, it may be that the presleep EEG activity will correlate with the memory deficits for the word pairs presented three minutes prior to sleep. In contrast, the sleep EEG data may only correlate with the subjects' overall memory performance, across all word pairs. This makes intuitive sense for two reasons. First, if sleep inertia had begun to take place, one would expect deeper sleep to be associated with poorer memory performance. Second, the deeper sleep may simply effect overall consolidation

of the word pairs. Thus, one would expect poorer performance overall, rather than just for the more recent words.

In general, if sleep is viewed as the event that led to the amnesia for the stimuli, as is the case under a consolidation theory, then one would consider retrograde amnesia to have taken place. However, if presleep arousal level was viewed as causal of the memory deficit, then anterograde amnesia would be said to have taken place. However, the results of this study, sans the spectral analysis of the EEG, lend support to a theory that poor encoding associated with the low presleep arousal level led to the memory deficits. It is possible that both the low presleep arousal level and the onset of sleep also added to the effect. Under this explanation, neither of the terms retrograde or anterograde adequately or accurately describe the phenomenon, as no single event or instance in time could be considered causal of the memory deficit. Thus, one could opt for a new term to reflect the ongoing or graded nature of the phenomenon -- ?????grade amnesia.

Turning the focus to the explicit / implicit comparisons, one discovers some interesting findings. First, as mentioned above, it appeared that the subjects' explicit memory, as tested by this cued recall-type task, continued to operate relatively unimpaired right up to sleep onset. Also, when comparing subjects' target to control performance, it was clear that the subjects were performing the task correctly; target performance far exceeded control performance.

However, in the implicit data, the priming effects were much less extensive than expected. In other words, the subjects' target scores were not much higher than their control (guessing) scores. A simple explanation for this

lack of priming involves the concept of interference between multiple memory systems. In normal, awake subjects, it is safe to conclude that no explicit memory task is free from implicit contributions or interference, nor is any implicit task free from explicit contributions. Thus, subjects in the implicit condition may have had the actual target words come to mind first, but sought another word, thinking, "Oh, the instructions were to speak the first word that came to mind, so I'd better not just mention the one that they told me before." Supposition aside, protocol modifications could be employed in further designs to attempt to minimize the cross-system interference most likely observed in this study.

SUGGESTIONS FOR FURTHER RESEARCH

Follow-up studies could be very helpful in elucidating the processes underlying the memory deficits observed in the present study. The following are suggested areas upon which additional studies could focus:

1. The spectral EEG data from the present study should be analyzed. Correlational analyses should examine the relationship between regional EEG power and memory performance. By examining both the EEG data from prior to and after sleep onset, conclusions could be advanced as to what extent presleep brain activity determined subsequent memory performance, versus postsleep activity. In other terms, evidence would be generated to examine the arousal/encoding and consolidation hypotheses of memory dysfunction.

2. The number of sleep conditions should be increased from the present 30 second and ten minute conditions to include fifteen second, one minute, and five minute conditions. If subjects displayed no deficit in free recalling the word

pairs presented three minutes prior to sleep onset when given only one minute of sleep, then the consolidation hypothesis would not be supported. This would counter the observations of Guilleminault and Dement (1977) and Roth et al. (1982), who speculated that consolidation took between three and five minutes to occur.

3. In order to present the subjects with a stimulus that lent itself better to encoding, prose could be used as the verbal stimuli, as opposed to the word pairs of the present study. By providing continuous verbal stimuli, the design would provide better resolution than the present study, which is limited to one minute intervals. To ensure against intrusions from older long-term memories, the stories or other text read would have to be completely foreign to the subjects. Simply asking the subjects to recall the story or text would serve as a free recall test. A number of different coding strategies could be employed to detect graded impairments of recall. Additionally, content or plot items and matched distracters from other stories could be used as items for recognition testing.

4. All subjects should be given a waking test of memory, in the same conditions as the study. Counterbalanced pre- and post-study, lights-on (no sleep) trials could serve this purpose, allowing data on the subjects' normal levels of memory performance.

5. Attempts should be made to test the protocol from the present study on subjects other than "normal" college students. Subjects of different ages should be tested -- perhaps age groups 10-12, 40-50, and 65-75.

6. Running the protocol during daytime naps in narcoleptic subjects could allow for analysis of the effects of REM sleep on memory for auditory events occurring just prior to sleep onset.

7. The protocol could also be used to examine the amnestic properties of medications, especially the benzodiazepine hypnotics. Certain drugs from this class have long been known to produce varying degrees of anterograde amnesia, a phenomenon which may be compound the results found in the present study. Such a design would help separate the sleep and drug effects confounded in the Roth et. al. (1982) study.

8. To test the generalizability of the findings of this study to the major, nocturnal sleep period, it would be important to run this protocol at subjects' normal bedtimes, instead of during afternoon naps. Circadian fluctuations or cumulative sleepiness could effect the results.

APPENDIX A

Human Subjects Committee

THE UNIVERSITY OF
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September 30, 1991

Richard R. Bootzin, Ph.D.
James K. Wyatt, B.A.
Department of Psychology (215C)
The University of Arizona

RE: **HSC A91.88** MEMORY FOR EVENTS OCCURRING PRIOR TO SLEEP ONSET

Dear Investigators:

We received your revised consent form for your above referenced project. The procedures to be followed in this study pose no more than minimal risk to participating subjects. Regulations issued by the U.S. Department of Health and Human Services [45 CFR Part 46.110(b)] authorize approval of this type project through the expedited review procedures, with the condition(s) that subjects' anonymity be maintained. Although full Committee review is not required, a brief summary of the project procedures is submitted to the Committee for their endorsement and/or comment, if any, after administrative approval is granted. This project is approved effective 30 September 1991 for a period of one year.

The Human Subjects Committee (Institutional Review Board) of the University of Arizona has a current assurance of compliance, number M-1233, which is on file with the Department of Health and Human Services and covers this activity.

Approval is granted with the understanding that no further changes or additions will be made either to the procedures followed or to the consent form(s) used (copies of which we have on file) without the knowledge and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

A university policy requires that all signed subject consent forms be kept in a permanent file in an area designated for that purpose by the Department Head or comparable authority. This will assure their accessibility in the event that university officials require the information and the principal investigator is unavailable for some reason.

Sincerely yours,

William F. Denny

William F. Denny, M.D.
Chairman
Human Subjects Committee

WFD:rs
cc: Departmental/College Review Committee

APPENDIX B

TRIAL INSTRUCTIONS SCRIPT

FREE RECALL

OK. Now, I'd like you to tell me any word pairs you heard during this trial.

EXPLICIT CUED RECALL

Now, I'm going to play you the first word of pairs... some of which were played to you and some of which weren't. I want you to tell me what the second word was, if you heard it. If you didn't hear the word or don't remember it, just say, "Don't remember."

IMPLICIT CUED RECALL

Now, we're going to do something different. Just give me the first word that comes to mind after you hear each word.

RECOGNITION

Finally, I'm going to play you some word pairs, some of which were played to you and some of which weren't. I'd like you to tell me if you heard the pair before or not. If you're not sure, guess.

END OF TRIAL

That concludes this trial. You will not be asked about these specific word pairs again, so you do not need to remember them.

Are you ready for the next trial?

APPENDIX C

STUDENT SURVEY QUESTIONNAIRE

Name: _____ ID #: _____ Phone #: _____

SLEEP LABORATORY QUESTIONNAIRE

For the following questions, please answer keeping your average school-year habits in mind:

1. How much sleep do you usually get per night? (Check only one box)
- on weeknights: [ ] less than 5 hours [ ] 5-6 hours [ ] 6-7 [ ] 7-8 [ ] 8-9 [ ] more than 9 hours
- is this amount: [ ] far too little [ ] too little [ ] adequate [ ] too much [ ] far too much
- on weekends: [ ] less than 5 hours [ ] 5-6 hours [ ] 6-7 [ ] 7-8 [ ] 8-9 [ ] more than 9 hours
- is this amount: [ ] far too little [ ] too little [ ] adequate [ ] too much [ ] far too much

2. When do you usually go to bed? (Check only one box)
- on weeknights: [ ] before 9 p.m. [ ] 9-11 p.m. [ ] 11 a.m. - 1 a.m. [ ] 1-3 a.m. [ ] after 3 a.m.
- is this time: [ ] far too early [ ] too early [ ] reasonable [ ] too late [ ] far too late
- on weekends: [ ] before 9 p.m. [ ] 9-11 p.m. [ ] 11 a.m. - 1 a.m. [ ] 1-3 a.m. [ ] after 3 a.m.
- is this time: [ ] far too early [ ] too early [ ] reasonable [ ] too late [ ] far too late

3. When do you usually get up in the morning? (Check only one box)
- on weekdays: [ ] before 5 a.m. [ ] 5-7 a.m. [ ] 7-9 a.m. [ ] 9-11 a.m. [ ] 11 a.m - 1 p.m.
  [ ] 1-3 p.m. [ ] after 3 p.m.
- is this time: [ ] far too early [ ] too early [ ] reasonable [ ] too late [ ] far too late
- on weekends: [ ] before 5 a.m. [ ] 5-7 a.m. [ ] 7-9 a.m. [ ] 9-11 a.m. [ ] after 11 a.m.
  [ ] 1-3 p.m. [ ] after 3 p.m.
- is this time: [ ] far too early [ ] too early [ ] reasonable [ ] too late [ ] far too late

4. How long does it take you to fall asleep at night? (Check only one box)
- at night: [ ] 0-5 minutes [ ] 5-10 mins. [ ] 10-20 mins. [ ] 20-30 mins. [ ] more than 30
- daytime naps: [ ] 0-5 minutes [ ] 5-10 mins. [ ] 10-20 mins. [ ] 20-30 mins. [ ] more than 30
- are these amounts: [ ] far too short [ ] too sort [ ] acceptable [ ] too long [ ] far too long

5. Do you have any problems associated with your sleep? (Check all that apply)
- [ ] insomnia [ ] sleep apnea [ ] loud snoring [ ] extreme daytime sleepiness [ ] narcolepsy

  [ ] nightmares [ ] sleep talking [ ] sleepwalking [ ] tooth grinding or clenching

  [ ] frequent waking up during the night [ ] often wake up too early [ ] often fall asleep

  reading [ ] often fall asleep during class [ ] other (please describe):_____

6. Have you ever sought help with a sleep-related problem?
- [ ] no [ ] yes If yes, what kind of health care worker(s) did you see and what was the result?

  _____

  _____

7. Do you have any problems with your hearing or vision?
- [ ] no [ ] yes If yes, please describe: _____

8. Do you have any problems with your memory?
- [ ] no [ ] yes If yes, please describe: _____

9. Have you ever had a head injury or concussion?
- [ ] no [ ] yes If yes, please describe: _____

10. Is English your first language?
- [ ] yes [ ] no If no, what is your first language? _____

11. MEN ONLY - Do you have a beard?
- [ ] yes [ ] no

12. Do you smoke or chew tobacco?
- [ ] no [ ] yes If yes, how much and how often? _____

13. Are you currently taking any medication, prescription or other, for any reason? [ ] no [ ] yes

Medication?	For What?	Dose?	How Often?
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

14. Will you be able to and are you interested in participating in a sleep experiment? (This would involve
spending one night in the Psychology Department's Sleep Research Laboratory - wearing some electrodes so that we can monitor your sleep) [ ] yes [ ] no

15. Will you be able to keep consistent bedtimes and waketimes for the three nights before you participate come to the sleep laboratory for your study night? [ ] yes [ ] no

16. THANK YOU VERY MUCH FOR ANSWERING THESE QUESTIONS!!! ENJOY INTRO!!!

APPENDIX D
WORD PAIR TABLES

List 1a

1	An	apple	0.175	17	Child	baby	0.173
2	Mountain	hill	0.213	25	See	saw	0.211
3	My	mine	0.143	28	Playing	working	0.142
4	Sit	down	0.271	23	Very	much	0.271
5	Swift	fast	0.452	21	Fruit	apple	0.45
6	Or	nor	0.191	22	Farther	away	0.19
7	Scissors	sharp	0.104	24	Is	are	0.103
8	Us	we	0.51	30	Always	never	0.507
9	City	town	0.232	27	House	home	0.23
10	Was	is	0.248	18	Closer	nearer	0.247
11	Easier	harder	0.419	32	Quickly	fast	0.416
12	Mutton	lamb	0.317	29	Bible	god	0.316
13	Street	road	0.118	19	Memory	mind	0.117
14	I	me	0.383	20	Stand	sit	0.383
15	Because	of	0.163	31	Red	white	0.163
16	Doors	windows	0.358	26	Shoes	feet	0.358

List 1b

List 2b

1	Mountain	hill	0.213	22	See	saw	0.211
2	Because	of	0.163	17	Red	white	0.163
3	An	apple	0.175	32	Child	baby	0.173
4	Doors	windows	0.358	28	Shoes	feet	0.358
5	Was	is	0.248	30	Closer	nearer	0.247
6	Or	nor	0.191	23	Farther	away	0.19
7	City	town	0.232	21	House	home	0.23
8	I	me	0.383	25	Stand	sit	0.383
9	Us	we	0.51	26	Always	never	0.507
10	Street	road	0.118	20	Memory	mind	0.117
11	My	mine	0.143	24	Playing	working	0.142
12	Mutton	lamb	0.317	18	Bible	god	0.316
13	Scissors	sharp	0.104	19	Is	are	0.103
14	Easier	harder	0.419	31	Quickly	fast	0.416
15	Swift	fast	0.452	27	Fruit	apple	0.45
16	Sit	down	0.271	29	Very	much	0.271

List 1c

List 2c

1	Mutton	lamb	0.317	18	Bible	god	0.316
2	Doors	windows	0.358	32	Shoes	feet	0.358
3	City	town	0.232	31	House	home	0.23
4	Was	is	0.248	29	Closer	nearer	0.247
5	Because	of	0.163	25	Red	white	0.163
6	Swift	fast	0.452	19	Fruit	apple	0.45
7	Sit	down	0.271	21	Very	much	0.271
8	Scissors	sharp	0.104	30	Is	are	0.103
9	An	apple	0.175	27	Child	baby	0.173
10	Mountain	hill	0.213	28	See	saw	0.211
11	Or	nor	0.191	22	Farther	away	0.19
12	Us	we	0.51	24	Always	never	0.507
13	Street	road	0.118	23	Memory	mind	0.117
14	Easier	harder	0.419	26	Quickly	fast	0.416
15	I	me	0.383	17	Stand	sit	0.383
16	My	mine	0.143	20	Playing	working	0.142

List 1d

List 2d

1	City	town	0.232	21	House	home	0.23
2	Swift	fast	0.452	26	Fruit	apple	0.45
3	Doors	windows	0.358	23	Shoes	feet	0.358
4	Us	we	0.51	22	Always	never	0.507
5	Because	of	0.163	17	Red	white	0.163
6	I	me	0.383	25	Stand	sit	0.383
7	My	mine	0.143	30	Playing	working	0.142
8	Scissors	sharp	0.104	27	Is	are	0.103
9	Mutton	lamb	0.317	31	Bible	god	0.316
10	An	apple	0.175	28	Child	baby	0.173
11	Mountain	hill	0.213	29	See	saw	0.211
12	Street	road	0.118	20	Memory	mind	0.117
13	Or	nor	0.191	24	Farther	away	0.19
14	Sit	down	0.271	18	Very	much	0.271
15	Easier	harder	0.419	32	Quickly	fast	0.416
16	Was	is	0.248	19	Closer	nearer	0.247

List 2a

1	Child	baby	0.173
2	Closer	nearer	0.247
3	Memory	mind	0.117
4	Stand	sit	0.383
5	Fruit	apple	0.45
6	Farther	away	0.19
7	Very	much	0.271
8	Is	are	0.103
9	See	saw	0.211
10	Shoes	feet	0.358
11	House	home	0.23
12	Playing	working	0.142
13	Bible	god	0.316
14	Always	never	0.507
15	Red	white	0.163
16	Quickly	fast	0.416

List 2b

1	Red	white	0.163
2	Bible	god	0.316
3	Is	are	0.103
4	Memory	mind	0.117
5	House	home	0.23
6	See	saw	0.211
7	Farther	away	0.19
8	Playing	working	0.142
9	Stand	sit	0.383
10	Always	never	0.507
11	Fruit	apple	0.45
12	Shoes	feet	0.358
13	Very	much	0.271
14	Closer	nearer	0.247
15	Quickly	fast	0.416
16	Child	baby	0.173

List 2c

1	Stand	sit	0.383
2	Bible	god	0.316
3	Fruit	apple	0.45
4	Playing	working	0.142
5	Very	much	0.271
6	Farther	away	0.19
7	Memory	mind	0.117
8	Always	never	0.507
9	Red	white	0.163
10	Quickly	fast	0.416
11	Child	baby	0.173
12	See	saw	0.211
13	Closer	nearer	0.247
14	Is	are	0.103
15	House	home	0.23
16	Shoes	feet	0.358

List 2d

1	Red	white	0.163
2	Very	much	0.271
3	Closer	nearer	0.247
4	Memory	mind	0.117
5	House	home	0.23
6	Always	never	0.507
7	Shoes	feet	0.358
8	Farther	away	0.19
9	Stand	sit	0.383
10	Fruit	apple	0.45
11	Is	are	0.103
12	Child	baby	0.173
13	See	saw	0.211
14	Playing	working	0.142
15	Bible	god	0.316
16	Quickly	fast	0.416

List 1a

17	An	apple	0.175
26	Was	is	0.248
29	Street	road	0.118
30	I	me	0.383
21	Swift	fast	0.452
22	Or	nor	0.191
20	Sit	down	0.271
23	Scissors	sharp	0.104
18	Mountain	hill	0.213
32	Doors	windows	0.358
25	City	town	0.232
19	My	mine	0.143
28	Mutton	lamb	0.317
24	Us	we	0.51
31	Because	of	0.163
27	Easier	harder	0.419

List 1b

18	Because	of	0.163
28	Mutton	lamb	0.317
29	Scissors	sharp	0.104
26	Street	road	0.118
23	City	town	0.232
17	Mountain	hill	0.213
22	Or	nor	0.191
27	My	mine	0.143
24	I	me	0.383
25	Us	we	0.51
31	Swift	fast	0.452
20	Doors	windows	0.358
32	Sit	down	0.271
21	Was	is	0.248
30	Easier	harder	0.419
19	An	apple	0.175

List 1c

31	I	me	0.383
17	Mutton	lamb	0.317
22	Swift	fast	0.452
32	My	mine	0.143
23	Sit	down	0.271
27	Or	nor	0.191
29	Street	road	0.118
28	Us	we	0.51
21	Because	of	0.163
30	Easier	harder	0.419
25	An	apple	0.175
26	Mountain	hill	0.213
20	Was	is	0.248
24	Scissors	sharp	0.104
19	City	town	0.232
18	Doors	windows	0.358

List 1d

21	Because	of	0.163
30	Sit	down	0.271
32	Was	is	0.248
28	Street	road	0.118
17	City	town	0.232
20	Us	we	0.51
19	Doors	windows	0.358
29	Or	nor	0.191
22	I	me	0.383
18	Swift	fast	0.452
24	Scissors	sharp	0.104
26	An	apple	0.175
27	Mountain	hill	0.213
23	My	mine	0.143
25	Mutton	lamb	0.317
31	Easier	harder	0.419

List 3a

1	Am	I	0.244
2	Lift	carry	0.208
3	Find	lose	0.19
4	Hand	foot	0.228
5	Hungry	food	0.413
6	Take	give	0.116
7	Cabbage	lettuce	0.14
8	Now	then	0.378
9	Come	go	0.355
10	Doctor	nurse	0.173
11	Hammer	nail	0.449
12	Square	round	0.315
13	A	an	0.159
14	Carry	hold	0.102
15	Cottage	house	0.264
16	Faster	slower	0.494

List 3b

1	Now	then	0.378
2	Carry	hold	0.102
3	Hand	foot	0.228
4	Am	I	0.244
5	Faster	slower	0.494
6	Lift	carry	0.208
7	Cabbage	lettuce	0.14
8	Square	round	0.315
9	Doctor	nurse	0.173
10	Cottage	house	0.264
11	Hungry	food	0.413
12	A	an	0.159
13	Come	go	0.355
14	Find	lose	0.19
15	Take	give	0.116
16	Hammer	nail	0.449

List 3c

1	Carry	hold	0.102
2	A	an	0.159
3	Find	lose	0.19
4	Faster	slower	0.494
5	Doctor	nurse	0.173
6	Hungry	food	0.413
7	Cabbage	lettuce	0.14
8	Come	go	0.355
9	Take	give	0.116
10	Cottage	house	0.264
11	Square	round	0.315
12	Am	I	0.244
13	Hammer	nail	0.449
14	Hand	foot	0.228
15	Lift	carry	0.208
16	Now	then	0.378

List 3d

1	Doctor	nurse	0.173
2	Now	then	0.378
3	Faster	slower	0.494
4	Square	round	0.315
5	Am	I	0.244
6	Come	go	0.355
7	Lift	carry	0.208
8	Hungry	food	0.413
9	Find	lose	0.19
10	Cabbage	lettuce	0.14
11	Hammer	nail	0.449
12	A	an	0.159
13	Cottage	house	0.264
14	Carry	hold	0.102
15	Hand	foot	0.228
16	Take	give	0.116

List 4a

29	Justice	law	0.243
21	Hardly	ever	0.205
17	Numbers	letters	0.19
18	Stove	hot	0.226
27	Green	grass	0.412
26	What	question	0.11
22	People	crowd	0.139
23	Spider	web	0.378
24	We	they	0.355
25	Deep	shallow	0.171
31	This	that	0.444
30	Carpet	rug	0.311
28	Citizen	man	0.155
20	Slowly	quickly	0.102
19	Thief	steal	0.264
32	Hotter	colder	0.49

List 4b

32	Spider	web	0.378
28	Slowly	quickly	0.102
31	Stove	hot	0.226
26	Justice	law	0.243
25	Hotter	colder	0.49
19	Hardly	ever	0.205
27	People	crowd	0.139
20	Carpet	rug	0.311
18	Deep	shallow	0.171
23	Thief	steal	0.264
22	Green	grass	0.412
21	Citizen	man	0.155
24	We	they	0.355
29	Numbers	letters	0.19
17	What	question	0.11
30	This	that	0.444

List 4c

31	Slowly	quickly	0.102
23	Citizen	man	0.155
22	Numbers	letters	0.19
19	Hotter	colder	0.49
20	Deep	shallow	0.171
25	Green	grass	0.412
17	People	crowd	0.139
27	We	they	0.355
30	What	question	0.11
32	Thief	steal	0.264
29	Carpet	rug	0.311
26	Justice	law	0.243
24	This	that	0.444
21	Stove	hot	0.226
18	Hardly	ever	0.205
28	Spider	web	0.378

List 4d

27	Deep	shallow	0.171
28	Spider	web	0.378
23	Hotter	colder	0.49
26	Carpet	rug	0.311
17	Justice	law	0.243
29	We	they	0.355
22	Hardly	ever	0.205
31	Green	grass	0.412
24	Numbers	letters	0.19
21	People	crowd	0.139
25	This	that	0.444
32	Citizen	man	0.155
30	Thief	steal	0.264
18	Slowly	quickly	0.102
19	Stove	hot	0.226
20	What	question	0.11

List 4a

1	Numbers	letters	0.19
2	Stove	hot	0.226
3	Thief	steal	0.264
4	Slowly	quickly	0.102
5	Hardly	ever	0.205
6	People	crowd	0.139
7	Spider	web	0.378
8	We	they	0.355
9	Deep	shallow	0.171
10	What	question	0.11
11	Green	grass	0.412
12	Citizen	man	0.155
13	Justice	law	0.243
14	Carpet	rug	0.311
15	This	that	0.444
16	Hotter	colder	0.49

List 4b

1	What	question	0.11
2	Deep	shallow	0.171
3	Hardly	ever	0.205
4	Carpet	rug	0.311
5	Citizen	man	0.155
6	Green	grass	0.412
7	Thief	steal	0.264
8	We	they	0.355
9	Hotter	colder	0.49
10	Justice	law	0.243
11	People	crowd	0.139
12	Slowly	quickly	0.102
13	Numbers	letters	0.19
14	This	that	0.444
15	Stove	hot	0.226
16	Spider	web	0.378

List 4c

1	People	crowd	0.139
2	Hardly	ever	0.205
3	Hotter	colder	0.49
4	Deep	shallow	0.171
5	Stove	hot	0.226
6	Numbers	letters	0.19
7	Citizen	man	0.155
8	This	that	0.444
9	Green	grass	0.412
10	Justice	law	0.243
11	We	they	0.355
12	Spider	web	0.378
13	Carpet	rug	0.311
14	What	question	0.11
15	Slowly	quickly	0.102
16	Thief	steal	0.264

List 4d

1	Justice	law	0.243
2	Slowly	quickly	0.102
3	Stove	hot	0.226
4	What	question	0.11
5	People	crowd	0.139
6	Hardly	ever	0.205
7	Hotter	colder	0.49
8	Numbers	letters	0.19
9	This	that	0.444
10	Carpet	rug	0.311
11	Deep	shallow	0.171
12	Spider	web	0.378
13	We	they	0.355
14	Thief	steal	0.264
15	Green	grass	0.412
16	Citizen	man	0.155

List 3a

19	Find	lose	0.19
20	Hand	foot	0.228
31	Cottage	house	0.264
30	Carry	hold	0.102
18	Lift	carry	0.208
23	Cabbage	lettuce	0.14
24	Now	then	0.378
25	Come	go	0.355
26	Doctor	nurse	0.173
22	Take	give	0.116
21	Hungry	food	0.413
29	A	an	0.159
17	Am	I	0.244
28	Square	round	0.315
27	Hammer	nail	0.449
32	Faster	slower	0.494

List 3b

31	Take	give	0.116
25	Doctor	nurse	0.173
22	Lift	carry	0.208
24	Square	round	0.315
28	A	an	0.159
27	Hungry	food	0.413
26	Cottage	house	0.264
29	Come	go	0.355
21	Faster	slower	0.494
20	Am	I	0.244
23	Cabbage	lettuce	0.14
18	Carry	hold	0.102
30	Find	lose	0.19
32	Hammer	nail	0.449
19	Hand	foot	0.228
17	Now	then	0.378

List 3c

23	Cabbage	lettuce	0.14
31	Lift	carry	0.208
20	Faster	slower	0.494
21	Doctor	nurse	0.173
30	Hand	foot	0.228
19	Find	lose	0.19
18	A	an	0.159
29	Hammer	nail	0.449
22	Hungry	food	0.413
28	Am	I	0.244
24	Come	go	0.355
32	Now	then	0.378
27	Square	round	0.315
25	Take	give	0.116
17	Carry	hold	0.102
26	Cottage	house	0.264

List 3d

21	Am	I	0.244
30	Carry	hold	0.102
31	Hand	foot	0.228
32	Take	give	0.116
26	Cabbage	lettuce	0.14
23	Lift	carry	0.208
19	Faster	slower	0.494
25	Find	lose	0.19
27	Hammer	nail	0.449
20	Square	round	0.315
17	Doctor	nurse	0.173
18	Now	then	0.378
22	Come	go	0.355
29	Cottage	house	0.264
24	Hungry	food	0.413
28	A	an	0.159

List 5a

1	Butter	yellow	0.109
2	Kittens	cats	0.373
3	Children	kids	0.188
4	Priest	church	0.225
5	Have	not	0.153
6	By	near	0.134
7	Thirsty	water	0.432
8	Oh	my	0.17
9	Joy	happy	0.26
10	Short	tall	0.411
11	Bath	clean	0.354
12	They	them	0.308
13	Comfort	soft	0.101
14	Running	fast	0.242
15	Where	there	0.205
16	Light	dark	0.488

List 5b

1	Thirsty	water	0.432
2	Children	kids	0.188
3	By	near	0.134
4	Priest	church	0.225
5	Light	dark	0.488
6	Have	not	0.153
7	They	them	0.308
8	Butter	yellow	0.109
9	Oh	my	0.17
10	Bath	clean	0.354
11	Joy	happy	0.26
12	Where	there	0.205
13	Running	fast	0.242
14	Kittens	cats	0.373
15	Comfort	soft	0.101
16	Short	tall	0.411

List 5c

1	Comfort	soft	0.101
2	Short	tall	0.411
3	Kittens	cats	0.373
4	Where	there	0.205
5	Thirsty	water	0.432
6	Joy	happy	0.26
7	They	them	0.308
8	Light	dark	0.488
9	Bath	clean	0.354
10	Priest	church	0.225
11	By	near	0.134
12	Children	kids	0.188
13	Butter	yellow	0.109
14	Running	fast	0.242
15	Oh	my	0.17
16	Have	not	0.153

List 5d

1	Have	not	0.153
2	Bath	clean	0.354
3	Light	dark	0.488
4	Joy	happy	0.26
5	Where	there	0.205
6	Oh	my	0.17
7	By	near	0.134
8	Comfort	soft	0.101
9	Children	kids	0.188
10	Kittens	cats	0.373
11	Thirsty	water	0.432
12	Short	tall	0.411
13	Priest	church	0.225
14	They	them	0.308
15	Running	fast	0.242
16	Butter	yellow	0.109

List 6a

32	Cars	trucks	0.107
20	Sickness	health	0.369
24	Sheep	wool	0.187
29	How	now	0.221
18	Wish	dream	0.149
27	Get	got	0.132
17	Chair	table	0.428
30	As	is	0.169
28	Command	order	0.254
21	Buying	selling	0.41
23	Anger	mad	0.35
25	Rough	smooth	0.304
31	Lamp	shade	0.099
22	Stomach	food	0.242
19	Therefore	because	0.203
26	Sour	sweet	0.487

List 6b

17	Chair	table	0.428
24	Sheep	wool	0.187
27	Get	got	0.132
29	How	now	0.221
26	Sour	sweet	0.487
18	Wish	dream	0.149
25	Rough	smooth	0.304
32	Cars	trucks	0.107
30	As	is	0.169
23	Anger	mad	0.35
28	Command	order	0.254
19	Therefore	because	0.203
22	Stomach	food	0.242
20	Sickness	health	0.369
31	Lamp	shade	0.099
21	Buying	selling	0.41

List 6c

21	Lamp	shade	0.099
27	Buying	selling	0.41
18	Sickness	health	0.369
30	Therefore	because	0.203
25	Chair	table	0.428
23	Command	order	0.254
31	Rough	smooth	0.304
24	Sour	sweet	0.487
26	Anger	mad	0.35
28	How	now	0.221
22	Get	got	0.132
17	Sheep	wool	0.187
29	Cars	trucks	0.107
20	Stomach	food	0.242
19	As	is	0.169
32	Wish	dream	0.149

List 6d

32	Wish	dream	0.149
18	Anger	mad	0.35
31	Sour	sweet	0.487
26	Command	order	0.254
23	Therefore	because	0.203
22	As	is	0.169
20	Get	got	0.132
24	Lamp	shade	0.099
27	Sheep	wool	0.187
19	Sickness	health	0.369
17	Chair	table	0.428
21	Buying	selling	0.41
25	How	now	0.221
28	Rough	smooth	0.304
30	Stomach	food	0.242
29	Cars	trucks	0.107

List 6a

1	Chair	table	0.428
2	Wish	dream	0.149
3	Therefore	because	0.203
4	Sickness	health	0.369
5	Buying	selling	0.41
6	Stomach	food	0.242
7	Anger	mad	0.35
8	Sheep	wool	0.187
9	Rough	smooth	0.304
10	Sour	sweet	0.487
11	Get	got	0.132
12	Command	order	0.254
13	How	now	0.221
14	As	is	0.169
15	Lamp	shade	0.099
16	Cars	trucks	0.107

List 5a

23	Thirsty	water	0.432
21	Have	not	0.153
31	Where	there	0.205
18	Kittens	cats	0.373
26	Short	tall	0.411
30	Running	fast	0.242
27	Bath	clean	0.354
19	Children	kids	0.188
28	They	them	0.308
32	Light	dark	0.488
22	By	near	0.134
25	Joy	happy	0.26
20	Priest	church	0.225
24	Oh	my	0.17
29	Comfort	soft	0.101
17	Butter	yellow	0.109

List 6b

1	Chair	table	0.428
2	Wish	dream	0.149
3	Therefore	because	0.203
4	Sickness	health	0.369
5	Buying	selling	0.41
6	Stomach	food	0.242
7	Anger	mad	0.35
8	Sheep	wool	0.187
9	Rough	smooth	0.304
10	Sour	sweet	0.487
11	Get	got	0.132
12	Command	order	0.254
13	How	now	0.221
14	As	is	0.169
15	Lamp	shade	0.099
16	Cars	trucks	0.107

List 5b

17	Thirsty	water	0.432
22	Have	not	0.153
28	Where	there	0.205
30	Kittens	cats	0.373
32	Short	tall	0.411
29	Running	fast	0.242
26	Bath	clean	0.354
18	Children	kids	0.188
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19	By	near	0.134
27	Joy	happy	0.26
20	Priest	church	0.225
25	Oh	my	0.17
31	Comfort	soft	0.101
24	Butter	yellow	0.109

List 6c

1	Sheep	wool	0.187
2	Sickness	health	0.369
3	As	is	0.169
4	Stomach	food	0.242
5	Lamp	shade	0.099
6	Get	got	0.132
7	Command	order	0.254
8	Sour	sweet	0.487
9	Chair	table	0.428
10	Anger	mad	0.35
11	Buying	selling	0.41
12	How	now	0.221
13	Cars	trucks	0.107
14	Therefore	because	0.203
15	Rough	smooth	0.304
16	Wish	dream	0.149

List 5c

28	Children	kids	0.188
19	Kittens	cats	0.373
31	Oh	my	0.17
30	Running	fast	0.242
17	Comfort	soft	0.101
27	By	near	0.134
22	Joy	happy	0.26
24	Light	dark	0.488
21	Thirsty	water	0.432
25	Bath	clean	0.354
18	Short	tall	0.411
26	Priest	church	0.225
29	Butter	yellow	0.109
20	Where	there	0.205
23	They	them	0.308
32	Have	not	0.153

List 6d

1	Chair	table	0.428
2	Anger	mad	0.35
3	Sickness	health	0.369
4	Get	got	0.132
5	Buying	selling	0.41
6	As	is	0.169
7	Therefore	because	0.203
8	Lamp	shade	0.099
9	How	now	0.221
10	Command	order	0.254
11	Sheep	wool	0.187
12	Rough	smooth	0.304
13	Cars	trucks	0.107
14	Stomach	food	0.242
15	Sour	sweet	0.487
16	Wish	dream	0.149

List 5d

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18	Bath	clean	0.354
26	Kittens	cats	0.373
23	By	near	0.134
28	Short	tall	0.411
22	Oh	my	0.17
21	Where	there	0.205
24	Comfort	soft	0.101
29	Priest	church	0.225
20	Joy	happy	0.26
25	Children	kids	0.188
30	They	them	0.308
32	Butter	yellow	0.109
31	Running	fast	0.242
19	Light	dark	0.488
17	Have	not	0.153

List 7a

1	Quiet	loud	0.253
2	Trouble	bad	0.107
3	The	boy	0.129
4	Eagle	fly	0.095
5	Fingers	hand	0.341
6	Salt	pepper	0.408
7	Religion	god	0.238
8	Loud	soft	0.423
9	At	home	0.184
10	Guns	shoot	0.201
11	There	here	0.368
12	To	from	0.22
13	Bitter	sour	0.149
14	Beautiful	ugly	0.169
15	Dream	sleep	0.485
16	River	water	0.286

List 8a

28	Speak	talk	0.252
32	Although	because	0.107
17	Who	is	0.128
18	Black	dark	0.094
22	Live	die	0.332
26	Stem	flower	0.398
21	Moon	star	0.236
25	Eating	food	0.423
24	With	without	0.181
29	Why	because	0.196
23	It	is	0.363
19	Appear	see	0.218
30	For	what	0.148
27	However	but	0.165
20	Tobacco	smoke	0.482
31	So	what	0.286

List 7b

1	At	home	0.184
2	There	here	0.368
3	Eagle	fly	0.095
4	Salt	pepper	0.408
5	Loud	soft	0.423
6	To	from	0.22
7	Beautiful	ugly	0.169
8	Fingers	hand	0.341
9	Trouble	bad	0.107
10	The	boy	0.129
11	River	water	0.286
12	Guns	shoot	0.201
13	Quiet	loud	0.253
14	Religion	god	0.238
15	Dream	sleep	0.485
16	Bitter	sour	0.149

List 8b

28	With	without	0.181
18	It	is	0.363
30	Black	dark	0.094
17	Stem	flower	0.398
26	Eating	food	0.423
31	Appear	see	0.218
23	However	but	0.165
32	Live	die	0.332
21	Although	because	0.107
22	Who	is	0.128
20	So	what	0.286
19	Why	because	0.196
27	Speak	talk	0.252
25	Moon	star	0.236
29	Tobacco	smoke	0.482
24	For	what	0.148

List 7c

1	Beautiful	ugly	0.169
2	Quiet	loud	0.253
3	Fingers	hand	0.341
4	Guns	shoot	0.201
5	River	water	0.286
6	The	boy	0.129
7	Dream	sleep	0.485
8	There	here	0.368
9	Loud	soft	0.423
10	Trouble	bad	0.107
11	Bitter	sour	0.149
12	To	from	0.22
13	Salt	pepper	0.408
14	Religion	god	0.238
15	Eagle	fly	0.095
16	At	home	0.184

List 8c

19	However	but	0.165
21	Speak	talk	0.252
23	Live	die	0.332
28	Why	because	0.196
25	So	what	0.286
29	Who	is	0.128
20	Tobacco	smoke	0.482
22	It	is	0.363
27	Eating	food	0.423
17	Although	because	0.107
18	For	what	0.148
26	Appear	see	0.218
30	Stem	flower	0.398
31	Moon	star	0.236
32	Black	dark	0.094
24	With	without	0.181

List 7d

1	Religion	god	0.238
2	There	here	0.368
3	Salt	pepper	0.408
4	Guns	shoot	0.201
5	Beautiful	ugly	0.169
6	At	home	0.184
7	Loud	soft	0.423
8	Trouble	bad	0.107
9	Dream	sleep	0.485
10	To	from	0.22
11	Fingers	hand	0.341
12	Quiet	loud	0.253
13	River	water	0.286
14	The	boy	0.129
15	Bitter	sour	0.149
16	Eagle	fly	0.095

List 8d

28	Moon	star	0.236
27	It	is	0.363
25	Stem	flower	0.398
24	Why	because	0.196
26	However	but	0.165
22	With	without	0.181
19	Eating	food	0.423
21	Although	because	0.107
17	Tobacco	smoke	0.482
30	Appear	see	0.218
31	Live	die	0.332
29	Speak	talk	0.252
32	So	what	0.286
23	Who	is	0.128
18	For	what	0.148
20	Black	dark	0.094

List 8a

1	Who	is	0.128
2	Black	dark	0.094
3	Appear	see	0.218
4	Tobacco	smoke	0.482
5	Moon	star	0.236
6	Live	die	0.332
7	It	is	0.363
8	With	without	0.181
9	Eating	food	0.423
10	Stem	flower	0.398
11	However	but	0.165
12	Speak	talk	0.252
13	Why	because	0.196
14	For	what	0.148
15	So	what	0.286
16	Although	because	0.107

List 8b

1	Stem	flower	0.398
2	It	is	0.363
3	Why	because	0.196
4	So	what	0.286
5	Although	because	0.107
6	Who	is	0.128
7	However	but	0.165
8	For	what	0.148
9	Moon	star	0.236
10	Eating	food	0.423
11	Speak	talk	0.252
12	With	without	0.181
13	Tobacco	smoke	0.482
14	Black	dark	0.094
15	Appear	see	0.218
16	Live	die	0.332

List 8c

1	Although	because	0.107
2	For	what	0.148
3	However	but	0.165
4	Tobacco	smoke	0.482
5	Speak	talk	0.252
6	It	is	0.363
7	Live	die	0.332
8	With	without	0.181
9	So	what	0.286
10	Appear	see	0.218
11	Eating	food	0.423
12	Why	because	0.196
13	Who	is	0.128
14	Stem	flower	0.398
15	Moon	star	0.236
16	Black	dark	0.094

List 8d

1	Tobacco	smoke	0.482
2	For	what	0.148
3	Eating	food	0.423
4	Black	dark	0.094
5	Although	because	0.107
6	With	without	0.181
7	Who	is	0.128
8	Why	because	0.196
9	Stem	flower	0.398
10	However	but	0.165
11	It	is	0.363
12	Moon	star	0.236
13	Speak	talk	0.252
14	Appear	see	0.218
15	Live	die	0.332
16	So	what	0.286

List 7a

19	The	boy	0.129
20	Eagle	fly	0.095
28	To	from	0.22
31	Dream	sleep	0.485
23	Religion	god	0.238
21	Fingers	hand	0.341
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22	Salt	pepper	0.408
30	Beautiful	ugly	0.169
17	Quiet	loud	0.253
26	Guns	shoot	0.201
29	Bitter	sour	0.149
32	River	water	0.286
18	Trouble	bad	0.107

List 7b

20	Salt	pepper	0.408
18	There	here	0.368
28	Guns	shoot	0.201
27	River	water	0.286
25	Trouble	bad	0.107
26	The	boy	0.129
23	Beautiful	ugly	0.169
32	Bitter	sour	0.149
30	Religion	god	0.238
21	Loud	soft	0.423
29	Quiet	loud	0.253
17	At	home	0.184
31	Dream	sleep	0.485
19	Eagle	fly	0.095
22	To	from	0.22
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List 7c

26	Trouble	bad	0.107
27	Bitter	sour	0.149
17	Beautiful	ugly	0.169
23	Dream	sleep	0.485
18	Quiet	loud	0.253
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29	Salt	pepper	0.408
30	Religion	god	0.238
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List 7d

25	Dream	sleep	0.485
31	Bitter	sour	0.149
23	Loud	soft	0.423
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24	Trouble	bad	0.107
22	At	home	0.184
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18	There	here	0.368
17	Religion	god	0.238
28	Quiet	loud	0.253
26	To	from	0.22
27	Fingers	hand	0.341
29	River	water	0.286

List 9a

1	Over	under	0.387
2	Lion	tiger	0.216
3	Whiskey	drink	0.328
4	Woman	girl	0.094
5	Ocean	water	0.362
6	His	hers	0.479
7	Jump	high	0.164
8	Working	hard	0.146
9	Tell	me	0.251
10	Dark	night	0.181
11	Whistle	train	0.106
12	Head	hair	0.194
13	Butterfly	moth	0.124
14	Cry	baby	0.284
15	On	off	0.423
16	And	but	0.233

List 9b

1	Cry	baby	0.284
2	His	hers	0.479
3	And	but	0.233
4	Butterfly	moth	0.124
5	Over	under	0.387
6	Working	hard	0.146
7	On	off	0.423
8	Whiskey	drink	0.328
9	Whistle	train	0.106
10	Ocean	water	0.362
11	Dark	night	0.181
12	Jump	high	0.164
13	Tell	me	0.251
14	Woman	girl	0.094
15	Lion	tiger	0.216
16	Head	hair	0.194

List 9c

1	Dark	night	0.181
2	Woman	girl	0.094
3	Working	hard	0.146
4	Cry	baby	0.284
5	Head	hair	0.194
6	Tell	me	0.251
7	Lion	tiger	0.216
8	Over	under	0.387
9	Butterfly	moth	0.124
10	Ocean	water	0.362
11	Whiskey	drink	0.328
12	On	off	0.423
13	Jump	high	0.164
14	And	but	0.233
15	Whistle	train	0.106
16	His	hers	0.479

List 9d

1	Tell	me	0.251
2	Dark	night	0.181
3	Whistle	train	0.106
4	Whiskey	drink	0.328
5	Ocean	water	0.362
6	Head	hair	0.194
7	And	but	0.233
8	Lion	tiger	0.216
9	Jump	high	0.164
10	Butterfly	moth	0.124
11	Over	under	0.387
12	On	off	0.423
13	Cry	baby	0.284
14	His	hers	0.479
15	Woman	girl	0.094
16	Working	hard	0.146

List 10a

22	In	out	0.385
25	Window	glass	0.216
28	Thinner	fatter	0.321
20	Yellow	color	0.092
29	Only	one	0.359
31	Needle	thread	0.457
27	Music	song	0.164
23	Earth	dirt	0.143
19	Blue	sky	0.25
18	Soldier	man	0.177
32	Cheese	mouse	0.106
30	Become	became	0.192
24	Of	course	0.12
17	Afraid	fear	0.278
21	Heavy	light	0.422
26	Broader	wider	0.232

List 10b

25	Afraid	fear	0.278
24	Needle	thread	0.457
20	Broader	wider	0.232
31	Of	course	0.12
17	In	out	0.385
29	Earth	dirt	0.143
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List 10c

28	Soldier	man	0.177
26	Yellow	color	0.092
30	Earth	dirt	0.143
29	Afraid	fear	0.278
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4	Yellow	color	0.092
5	Heavy	light	0.422
6	In	out	0.385
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8	Of	course	0.12
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15	Needle	thread	0.457
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32	And	but	0.233
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19	Whiskey	drink	0.328
21	Ocean	water	0.362
28	Head	hair	0.194
22	His	hers	0.479
27	Whistle	train	0.106

List 10b

1	In	out	0.385
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3	Cheese	mouse	0.106
4	Broader	wider	0.232
5	Yellow	color	0.092
6	Only	one	0.359
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9	Afraid	fear	0.278
10	Become	became	0.192
11	Soldier	man	0.177
12	Blue	sky	0.25
13	Earth	dirt	0.143
14	Heavy	light	0.422
15	Of	course	0.12
16	Thinner	fatter	0.321

List 9b

21	Over	under	0.387
28	Jump	high	0.164
25	Whistle	train	0.106
19	And	but	0.233
30	Woman	girl	0.094
26	Ocean	water	0.362
31	Lion	tiger	0.216
18	His	hers	0.479
17	Cry	baby	0.284
32	Head	hair	0.194
27	Dark	night	0.181
29	Tell	me	0.251
22	Working	hard	0.146
23	On	off	0.423
20	Butterfly	moth	0.124
24	Whiskey	drink	0.328

List 10c

1	Window	glass	0.216
2	Broader	wider	0.232
3	Of	course	0.12
4	In	out	0.385
5	Heavy	light	0.422
6	Needle	thread	0.457
7	Only	one	0.359
8	Cheese	mouse	0.106
9	Music	song	0.164
10	Yellow	color	0.092
11	Blue	sky	0.25
12	Soldier	man	0.177
13	Afraid	fear	0.278
14	Earth	dirt	0.143
15	Become	became	0.192
16	Thinner	fatter	0.321

List 9c

23	Lion	tiger	0.216
30	And	but	0.233
25	Butterfly	moth	0.124
24	Over	under	0.387
28	On	off	0.423
32	His	hers	0.479
26	Ocean	water	0.362
31	Whistle	train	0.106
29	Jump	high	0.164
18	Woman	girl	0.094
22	Tell	me	0.251
17	Dark	night	0.181
20	Cry	baby	0.284
19	Working	hard	0.146
21	Head	hair	0.194
27	Whiskey	drink	0.328

List 10d

1	Thinner	fatter	0.321
2	Become	became	0.192
3	Cheese	mouse	0.106
4	In	out	0.385
5	Blue	sky	0.25
6	Soldier	man	0.177
7	Needle	thread	0.457
8	Of	course	0.12
9	Earth	dirt	0.143
10	Window	glass	0.216
11	Broader	wider	0.232
12	Yellow	color	0.092
13	Music	song	0.164
14	Heavy	light	0.422
15	Only	one	0.359
16	Afraid	fear	0.278

List 9d

20	Whiskey	drink	0.328
22	Head	hair	0.194
19	Whistle	train	0.106
27	Over	under	0.387
17	Tell	me	0.251
18	Dark	night	0.181
30	His	hers	0.479
26	Butterfly	moth	0.124
32	Working	hard	0.146
24	Lion	tiger	0.216
23	And	but	0.233
31	Woman	girl	0.094
25	Jump	high	0.164
28	On	off	0.423
21	Ocean	water	0.362
29	Cry	baby	0.284

APPENDIX E
LABORATORY TIMELINE

1:00 - 1:15 p.m.	Subject arrives - Orientation
1:15 - 1:30 p.m.	Hookup Begins
1:30 - 1:45 p.m.	
1:45 - 2:00 p.m.	
2:00 - 2:15 p.m.	
2:15 - 2:30 p.m.	Subject Cals - LIGHTS OUT
2:30 - 2:45 p.m.	SLEEP
2:45 - 3:00 p.m.	SLEEP
3:00 - 3:15 p.m.	SLEEP
3:15 - 3:30 p.m.	SLEEP
3:30 - 3:45 p.m.	SLEEP
3:45 - 4:00 p.m.	SLEEP
4:00 - 4:15 p.m.	SLEEP
4:15 - 4:30 p.m.	SLEEP
4:30 - 4:45 p.m.	SLEEP
4:45 - 5:00 p.m.	SLEEP
5:00 - 5:15 p.m.	LIGHTS ON
5:15 - 5:30 p.m.	Unhook - Debrief
5:30 - 5:45 p.m.	CLEANUP
5:45 - 6:00 p.m.	CLEANUP

Tech Sets Up: Noon
Subject Arrives: 1:00 p.m.
Subject Leaves: 5:30 p.m.
Tech Leaves: 6:00 p.m.

APPENDIX F

RESEARCH CONSENT FORM

Title: MEMORY FOR EVENTS OCCURING PRIOR TO SLEEP ONSET

YOU ARE BEING ASKED TO READ THE FOLLOWING MATERIAL TO ENSURE THAT YOU ARE INFORMED OF THE NATURE OF THIS RESEARCH STUDY AND OF HOW YOU WILL PARTICIPATE IN IT, IF YOU CONSENT TO DO SO. SIGNING THIS FORM WILL INDICATE THAT YOU HAVE BEEN SO INFORMED AND THAT YOU GIVE YOUR CONSENT. FEDERAL REGULATIONS REQUIRE WRITTEN INFORMED CONSENT PRIOR TO PARTICIPATION IN THIS RESEARCH STUDY SO THAT YOU KNOW THE NATURE AND THE RISKS OF YOUR PARTICIPATION AND CAN DECIDE TO PARTICIPATE OR NOT PARTICIPATE IN A FREE AND INFORMED MANNER.

We would like to invite you to volunteer to take part in the research project named above. The purpose of to investigate memory for events that occur prior to the onset of sleep. If you agree to participate, you will have sensors attached to your face and scalp measure eye movements, chin muscle activity, and brain waves during a series of brief, afternoon naps. These naps will take place during a single afternoon, in the Psychology Department's Sleep Research Laboratory. Before each nap, you will be listening to simple, verbal material, played over a stereo speaker. After you are woken up from each nap, you will complete three, simple tests of memory. The total time you will be in the laboratory that afternoon will be approximately five hours.

To stabilize your sleep/wake cycle and to facilitate napping on the day of the study, you will be asked to maintain a sleep schedule for the three nights preceding the study: eight (8) hours of sleep for the third and second nights prior to the study and six (6) hours of sleep on the night prior to the study. You will also be asked to refrain from napping on those days.

We do not foresee any psychological or mental harm in participating in this study. You may experience slight skin discomfort after sensor/electrode removal. However, this risk is both infrequent and, when it does occur, quite transient.

The benefits of your participation will be primarily indirect. You will receive credits toward your experimental participation requirement for Psychology

101. In addition, you will be helping advance what is known about the functioning of memory at the transition from wakefulness to sleep. You will also get a chance to see what your sleep looks like on an EEG machine.

If you have any questions concerning your rights as a research subject, you may call the Human Subjects Committee office at 626-6721.

IN GIVING MY CONSENT BY SIGNING THIS FORM, I AGREE THAT THE METHODS, INCONVENIENCES, RISKS, AND BENEFITS HAVE BEEN EXPLAINED TO ME AND MY QUESTIONS HAVE BEEN ANSWERED. I UNDERSTAND THAT I MAY ASK QUESTIONS AT ANY TIME AND THAT I AM FREE TO WITHDRAW FROM THE PROJECT AT ANY TIME WITHOUT CAUSING BAD FEELINGS OR AFFECTING MY MEDICAL CARE. MY PARTICIPATION IN THIS PROJECT MAY BE ENDED BY THE INVESTIGATOR OR BY THE SPONSOR FOR REASONS THAT WOULD BE EXPLAINED. NEW INFORMATION DEVELOPED DURING THE COURSE OF THIS STUDY WHICH MAY AFFECT MY WILLINGNESS TO CONTINUE IN THIS RESEARCH PROJECT WILL BE GIVEN TO ME AS IT BECOMES AVAILABLE. I UNDERSTAND THAT THIS CONSENT FORM WILL BE FILED IN AN AREA DESIGNATED BY THE HUMAN SUBJECTS COMMITTEE WITH ACCESS RESTRICTED TO THE PRINCIPAL INVESTIGATOR, RICHARD BOOTZIN, PH.D., OR AN AUTHORIZED REPRESENTATIVE OF THE DEPARTMENT. I UNDERSTAND THAT I DO NOT GIVE UP ANY OF MY LEGAL RIGHTS BY SIGNING THIS FORM. A COPY OF THIS SIGNED CONSENT FORM WILL BE GIVEN TO ME.

_____ _____

Subject's Signature Date

I have carefully explained to the subject the nature of the above project. I hereby certify that to the best of my knowledge the person who is signing this consent form understands clearly the nature, demands, benefits, and risks involved in his/her participation and his/her signature is legally valid. A medical problem or language or educational barrier has not precluded this understanding.

_____ _____

Investigator's Signature Date

APPENDIX G

POLYSOMNOGRAPHY MONTAGE

CHANNEL	LEADS	HF FILTER	LF FILTER	SENSITIVITY
1	TIME	--	--	--
2	AUDIO	--	--	--
3	FP1/A2	35	.3	50μV/cm
4	C3/A2	35	.3	50μV/cm
5	T3/A2	35	.3	50μV/cm
6	O1/A2	35	.3	50μV/cm
7	ROC/A1	35	.3	50μV/cm
8	LOC/A2	35	.3	50μV/cm
9	CHIN EMG	70	10	20μV/cm
10	--	--	--	--
11	SPARE EEG	35	1.0	50μV/cm
12	--	--	--	--

APPENDIX H

Subject Calibrations Script

"NOW please lie quietly, with your arms at your sides, and keep your eyes open and look straight ahead"
- tech marks "EYES OPEN" on polygraph
- wait 30 seconds
- tech then performs 60-cycle checks on each active polygraph channel

"Now please close your eyes"
- tech marks "EYES CLOSED" on polygraph
- wait 30 seconds (making sure subject does not fall asleep)
- tech then switches to backup leads and performs 60-cycle checks

"Now please open your eyes"
- check video screen for compliance

"And without moving your head, please look to the left... right... left... right... and straight ahead"
- check video and mark "L" near EOG channels on polygraph, then "R"... "L"... "R"... "STR"

"Now please look up... down...up...down... and straight ahead"
- check video and mark "U" near EOG channels on polygraph, then "D"... "U"... "D"... "STR"

"Now please blink your eyes slowly five times"
- mark "5 BLINKS" near EOG channels and underscore each blink

"Now please grit your teeth"
- mark "GRIT" below EMG channel

"And now, how about a big yawn"
- mark "YAWN" below EMG channel

Assuming all went well, the tech then proceeds with the LIGHTS OUT procedures

APPENDIX I

NUMBER OF WORDS PER TRIAL

	Trial	Trial	Trial	Trial	Trial	
Subject	1	2	3	4	5	
1	12	16	13	8	5	
2	16	16	16	16	.	
3	6	9	4	10	16	
4	9	11	7	12	7	
5	11	16	16	16	11	
6	16	16	6	7	16	
7	14	16	16	16	.	
8	7	16	11	16	7	
9	16	7	7	16	16	
10	16	15	16	16	15	
11	16	16	16	10	14	
12	10	12	16	16	12	
13	4	6	5	.	4	
14	16	14	16	16	16	
15	14	15	8	7	9	
16	.	11	16	15	16	
17	14	16	16	9	16	
18	16	16	11	16	15	
19	10	16	8	7	8	
20	9	7	5	8	16	
						Total/Avg.
Sum	232	267	229	237	219	1184
Avg	12.211	13.350	11.450	12.474	12.167	12.333

APPENDIX J

T-TEST SUMMARIES

FREE RECALL TASK

30 second vs. 10 minute

Word/Minute Prior to Sleep Onset:

	10	9	8	7	6	5	4	3	2	1
df	12	14	15	18	18	19	19	19	17	17
Mean X-Y	0.006	0.122	-0.042	0.026	-0.053	0.05	0.004	0.279	0.185	0.338
Paired t value	0.049	0.781	-0.32	0.209	-0.497	0.495	0.044	3.364	2.811	3.195
Prob. (2-tail)	0.9619	0.4476	0.7537	0.8367	0.6253	0.6264	0.9653	0.0033	0.012	0.0053

EXPLICIT PAIRED-ASSOCIATE TASK

30 second vs. 10 minute, adjusted

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	7	6	8	8	9	8	7	8
Mean X-Y	0.039	0.25	0.035	-0.028	0.031	-0.361	0.039	-0.083
Paired t value	0.202	0.655	0.14	-0.092	0.138	-1.554	0.182	-0.471
Prob. (2-tail)	0.8456	0.537	0.8919	0.9289	0.8931	0.1588	0.8611	0.6499

30 second vs. 10 minute, targets

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	7	6	8	8	9	8	7	8
Mean X-Y	0.062	0.286	0.056	0	0.05	-0.333	0.062	-0.056
Paired t value	0.314	0.795	0.217	0	0.218	-1.512	0.284	-0.316
Prob. (2-tail)	0.7627	0.4571	0.8337	.	0.8321	0.169	0.7849	0.7599

30 second vs. 10 minute, controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	7	6	8	8	9	8	7	8
Mean X-Y	0.024	0.036	0.021	0.028	0.019	0.028	0.024	0.028
Paired t value	1	1	1	1	1	1	1	1
Prob. (2-tail)	0.3506	0.3559	0.3466	0.3466	0.3434	0.3466	0.3506	0.3466

30 second condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	17	10	17	11	17	11	17	11
Mean X-Y	0.608	0.54	0.663	0.276	0.469	0.193	0.358	0.318
Paired t value	5.204	3.284	7.588	1.842	4.472	1.351	3.224	2.444
Prob. (2-tail)	0.0001	0.0082	0.0001	0.0926	0.0003	0.2038	0.005	0.0326

10 minute condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	7	11	9	13	11	13	9	13
Mean X-Y	0.484	0.391	0.525	0.433	0.427	0.504	0.262	0.469
Paired t value	2.479	2.507	3.215	3.185	2.968	3.896	1.964	3.876
Prob. (2-tail)	0.0423	0.0292	0.0106	0.0072	0.0128	0.0018	0.0811	0.0019

IMPLICIT PAIRED-ASSOCIATE TASK

30 second vs. 10 minute, adjusted

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	4	8	6	9	7	9	7	6
Mean X-Y	0.25	0.174	-0.116	-0.3	0.031	0.244	-0.156	0.188
Paired t value	0.57	0.79	-0.561	-1.994	0.147	1.433	-0.737	1.036
Prob. (2-tail)	0.599	0.4522	0.5953	0.0773	0.8869	0.1857	0.485	0.34

30 second vs. 10 minute, targets

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	4	8	6	9	7	9	7	6
Mean X-Y	0.4	0.056	0	-0.4	0.125	0.15	-0.062	0.071
Paired t value	1	0.263	0	-2.449	0.607	1.152	-0.314	0.548
Prob. (2-tail)	0.3739	0.7995	.	0.0368	0.563	0.2789	0.7627	0.6036

30 second vs. 10 minute, controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	4	8	6	9	7	9	7	6
Mean X-Y	0.15	-0.118	0.116	-0.1	0.094	-0.094	0.094	-0.116
Paired t value	3.207	-1.341	3.357	-1.238	2.51	-1.138	2.51	-1.036
Prob. (2-tail)	0.0327	0.2168	0.0153	0.2471	0.0404	0.2847	0.0404	0.34

30 second condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	8	17	10	17	10	17	10	16
Mean X-Y	0.333	0.198	0.182	0.174	0.136	0.146	0.227	0.206
Paired t value	1.696	1.802	1.324	1.807	0.865	1.599	1.473	1.9
Prob. (2-tail)	0.1283	0.0892	0.2149	0.0885	0.4072	0.1284	0.1716	0.0756

10 minute condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	10	9	12	10	13	11	13	9
Mean X-Y	0.239	0.019	0.216	0.449	0.009	-0.156	0.33	0.075
Paired t value	1.379	0.124	1.392	4.366	0.082	-1.147	2.492	0.531
Prob. (2-tail)	0.198	0.9042	0.1893	0.0014	0.936	0.2757	0.027	0.6083

RECOGNITION TASK

30 second vs. 10 minute, adjusted

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	15	18	18	19	19	19	17	16
Mean X-Y	0.156	-0.184	0.054	0.012	0.018	-0.12	0.054	0.392
Paired t value	1.431	-1.249	0.325	0.084	0.123	-1.312	0.376	3.896
Prob. (2-tail)	0.1728	0.2277	0.7486	0.9338	0.9033	0.2052	0.7114	0.0013

30 second vs. 10 minute, targets

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	15	18	18	19	19	19	17	17
Mean X-Y	0.094	-0.026	0.096	-0.058	0.108	-0.175	0.037	0.176
Paired t value	1.379	-0.268	0.944	-0.597	1.378	-2.018	0.383	0.2406
Prob. (2-tail)	0.1881	0.7916	0.3577	0.5577	0.1842	0.0579	0.7064	0.0278

30 second vs. 10 minute, controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	15	18	18	19	19	19	17	16
Mean X-Y	-0.062	0.158	0.042	-0.07	0.09	-0.055	-0.017	-0.206
Paired t value	-0.62	1.332	0.436	-0.594	0.697	-0.519	-0.138	-2.538
Prob. (2-tail)	0.5445	0.1995	0.6679	0.5597	0.4943	0.6098	0.8919	0.0219

30 second condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	18	18	19	19	19	19	19	18
Mean X-Y	0.704	0.474	0.552	0.587	0.552	0.332	0.467	0.64
Paired t value	7.238	4.189	5.343	5.62	5.329	2.538	4.151	6.857
Prob. (2-tail)	0.0001	0.0006	0.0001	0.0001	0.0001	0.0201	0.0005	0.0001

10 minute condition, target vs. controls

Word/Minute Prior to Sleep Onset:

	8	7	6	5	4	3	2	1
df	15	18	18	19	19	19	17	17
Mean X-Y	0.656	0.658	0.474	0.575	0.533	0.452	0.354	0.25
Paired t value	5.547	6.479	3.508	6.328	5.332	4.707	2.859	2.133
Prob. (2-tail)	0.0001	0.0001	0.0025	0.0001	0.0001	0.0002	0.0109	0.0478

APPENDIX K

ANOVA SUMMARIES

EXPLICIT/IMPLICIT PAIRED-ASSOCIATE ANOVA

Source of Variation	df	Sum of Squares	Mean Square	F	p	Epsilon Correction
Subjects	19	4.477	.236			
E	1	2.128	2.128	14.222	.0013	
Error	19	2.842	.150			1.00
T	1	16.483	16.483	98.679	.0000	
Error	19	3.174	.167			1.00
ET	1	2.815	2.815	20.490	.0002	
Error	19	2.610	.137			1.00
S	1	.001	.001	.006	.9403	
Error	19	1.890	.099			1.00
ES	1	.204	.204	1.539	.2299	
Error	19	2.516	.132			1.00
TS	1	.028	.028	.192	.6665	
Error	19	2.787	.147			1.00
ETS	1	.001	.001	.006	.9392	
Error	19	2.135	.112			1.00
I	3	.536	.179	2.465	.0715	
Error	57	4.130	.072			.85
EI	3	.250	.083	1.033	.3850	
Error	57	4.603	.081			.92
TI	3	.547	.182	2.497	.0688	
Error	57	4.164	.073			.85
ETI	3	.250	.083	1.038	.3826	
Error	57	4.584	.080			.91
SI	3	.130	.043	.512	.6753	
Error	57	4.815	.084			.84
ESI	3	.494	.165	2.303	.0867	
Error	57	4.073	.071			.75
TSI	3	.117	.039	.464	.7084	
Error	57	4.809	.084			.85
ETSI	3	.493	.164	2.300	.0870	
Error	57	4.072	.071			.76

RECOGNITION ANOVA

Source of Variation	df	Sum of Squares	Mean Square	F	p	Epsilon Correction
Subjects	19	11.550	.608			
T	1	39.686	39.686	92.688	.0000	
Error	19	8.135	.428			1.00
S	1	.242	.242	5.691	.0276	
Error	19	.807	.042			1.00
TS	1	.197	.197	1.707	.2069	
Error	19	2.195	.116			1.00
I	7	.608	.087	.672	.6958	
Error	133	17.203	.129			.70
TI	7	.915	.131	1.249	.2805	
Error	133	13.915	.105			.71
SI	7	1.024	.146	1.137	.3441	
Error	133	17.111	.129			.62
TSI	7	1.234	.176	2.207	.0375	
Error	133	10.624	.080			.72

APPENDIX L

SLEEP SCORING SUMMARY

Subj. #	Trial #	Epoch # (1-20)																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	0	1	1	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2
1	5	1	1	2	0	0	0	1	2	1	1	1	2	0	1	1	2	2	2	2	2
2	3	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
3	1	1	1	1	1	1	2	2	2	0	0	0	0	0	1	1	1	1	1	1	1
3	3	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1
3	5	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
4	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2
4	3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
6	1	1	1	1	2	2	2	2	2	2	2	2	2	2	0	0	1	2	0	0	0
6	4	1	0	1	0	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7	2	1	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
8	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0
8	5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	3	1	2	2	2	2	2	2	2	2	2	3	2	2	2	3	2	2	3	3	2
10	2	1	1	2	2	0	0	1	0	0	1	1	1	2	2	1	1	1	1	1	1
11	5	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
12	2	1	.	1	1	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2
12	5	1	0	0	1	1	0	0	1	1	1	1	2	2	2	2	2	2	3	2	2
13	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13	3	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	1	5	5	5	2
13	5	2	2	2	2	2	2	2	2	2	2	3	3	4	4	4	4	4	4	4	4
14	2	1	1	1	1	1	1	1	1	1	2	2	2	1	2	2	2	2	2	2	2
15	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
15	3	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	3	2
16	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2
16	4	2	2	0	1	2	2	2	2	2	2	2	1	1	2	2	2	0	2	2	2
17	4	1	0	0	1	1	1	1	1	1	2	2	0	0	1	1	1	2	2	2	2
18	3	1	1	0	1	1	1	2	2	2	0	0	0	1	1	1	2	2	2	2	2
18	4	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	2
19	1	1	1	2	0	1	2	2	2	2	2	2	2	3	2	2	0	0	0	0	1
20	2	1	1	1	1	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
20	3	1	1	1	1	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2

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