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SLEEPING AND WAKING THOUGHT:
THE EFFECTS OF CORTICAL AROUSAL AND EXTERNAL STIMULATION

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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Abstract

SLEEPING AND WAKING THOUGHT:
THE EFFECTS OF CORTICAL AROUSAL AND EXTERNAL STIMULATION

by

Miriam C. Wollman

Adviser: Professor John S. Antrobus

The current research attempted to describe waking thought and REM imagery as quantitative differences in a single set of variables. It was hypothesized that cortical activation and heightened sensory thresholds are sufficient to account for the particular characteristics of the REM mentation report.

Thirty subjects participated in individual sessions where they lay in a sound attenuated, lightproof room with eyes closed.

They were asked for mentation reports:

1. after lying awake with external stimulation (W).

2. after lying awake without external stimulation (WO).

3. after being awakened from REM sleep.

The EEG activity, obtained from left and right mid temporal-parietal and central sites, was recorded for five minute periods before obtaining mentation reports. The absolute power of the EEG activity was calculated for each of six bandwidths.

All transcribed mentation reports were independently scored by two judges, blind to the conditions, on seven content rating scales. These scales include the Total Recall Count (TRC) measure, a count of all words in which the subject was describing his/her experience during the previous interval. The reports were also scored on a Thought Unit (TU) scale. This is a count of the distinct, thematically homogeneous thought sequences.

It was hypothesized that external stimulation would generate intrusions in the subjects thought processes, leading to shorter but more numerous units of thought. It was also hypothesized that within both waking and REM conditions general cortical arousal, measured as greater beta power and lower delta power would relate to amount of recalled content.

Hotelling T squared tests were performed with the different states as the independent variables and the scores on the cognitive scales as the dependent variables. In a comparison of mentation reports of Waking subjects with those subjects awakened from REM, the major distinction was that the Waking subject changes topics more frequently.

EEG power data from both Waking and REM were entered into multiple linear regression equations to predict TRC. No relationships were found between TRC and general cortical activation. Other statistical analyses , including relationships between TRC and scales of visual imagery, are discussed.

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I wish to express my deepest appreciation to Ruth Reinsel, Bob Stein and Kristina Claiborne for judging the 270 mentation reports needed for this study, a long and arduous task.

Ruth Reinsel deserves a special thanks. Her support, encouragement, friendship amd midnight Scrabble games made graduate school a pleasant, enjoyable and worthwile experience.

Freud, 1925 footnote to the Interpretation of Dreams:

"At bottom, dreams are nothing other than a particular form of thinking, made possible by the conditions of the state of sleep."

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Introduction

Dreaming has traditionally been assumed to be a unique state of mental functioning occurring during sleep. The characteristics of dreams have been said to include bizarreness, emotionality and hallucinatory quality (MacKenzie, 1966; Foulkes, 1966). With the advent of psychophysiological monitoring of sleep (Askerinsky and Kleitman, 1953, 1955) dreaming was further assumed to be confined to the specific state of REM sleep. Early research by Dement and Kleitman (1957) found that approximately 85% of awakenings from REM sleep resulted in dream recall, whereas from Stage 2 sleep recall of mentation was much less frequent. Later research found that the frequency of Stage 2 reports judged as "dreaming" ranged from 7% to 54%, depending largely on the definition of "dreaming" which was employed (Kamiya, 1961; Herman, Ellman and Roffwarg, 1978).

The majority of studies which have looked at the "dreamlike" nature of REM and Stage 2 mentation reports have employed global ratings of various aspects such as "visual imagery", "bizarreness", "emotionality" and "hallucinatory quality". It is very difficult to know how judges interpret the dimensions on which they are being asked to make these rather poorly-specifed decisions. Indeed, one judge may use quite different criteria than another in making these global decisions.

Antrobus, Shnee, Offer and Silverman (1976) have attempted to develop an objective technique which would capture the essence of these global judgments. They had judges count the number of words in each of several categories (such as visual nouns, visual adjectives, explicit speech, and specific mentions of affect).

When comparing 73 paired REM/Stage 2 reports (Antrobus, 1983), none of these scales contributed unique variance over and above that accounted for by a simple count of the words in which the subject was describing the experience that had occurred just before waking. This measure, Total Recall Count (TRC), is an edited version of the total report in which verbal intrusions ("ah", "um"), corrections, repetitions and commentary upon the experience are deleted. In this study, global ratings of "dreamlike quality" were compared with the Total Recall Count measure. The global ratings did not add to the total variance beyond that accounted for by the Total Recall Count measure. Antrobus concluded that the fundamental difference between REM and Stage 2 mentation reports is in length; REM reports are consistently found to be longer than Stage 2 reports.

One of the major differences that had previously been found between REM and Stage 2 mentation is that REM mentation is considered more bizarre (e.g. Foulkes, 1962; Rechtschaffen, Verdone and Wheaton, 1963). Bizarreness is dependent on the word length of the report. It refers to the improbable juxtaposition of cognitive elements. Thus a report must be sufficiently long to contain at least two cognitive elements for the quality of bizarreness to be identified. Stage 2 reports, which are less likely to be judged bizarre than are REM reports, are often too short to contain more than one cognitive element. When the variable of report length is controlled, no further differences in bizarreness can be detected (Wollman, Reinsel and Antrobus, 1983; Antrobus, Reinsel and Wollman, 1984).

Editing 35 REM/Stage 2 report pairs to a maximum of 54 words, Wollman et al. (1983) used the Cloze procedure to measure the predictability of the language in the reports. Predictability is the inverse of bizarreness; "bizarre" mentation reports would presumably show low predictability. The reports were prepared for "Clozing" by deleting every fifth word. The forms were then given to 25 judges, who attempted to fill in the missing words. The percent of judge responses that matched the deleted word became the response measure, Percent Correct Score. This variable, which indexes the ability of judges to fill in the deleted words correctly, is a measure of the information transmitted by the context. Results showed no difference in Percent Correct Score between REM and Stage 2 reports. Waking control reports (N=8) were gathered for comparison, and the predictability scores were not distinguishable from either REM or Stage 2 scores. This research lends support to the conclusion that neither REM, Stage 2 or waking reports differ significantly in the quality of bizarreness.

As previously mentioned, the major difference between REM and Stage 2 mentation reports has been found to be the length of the report (Antrobus, 1983; Foulkes, 1982). In a pilot study the length of the mentation from waking fantasy has been found to be longer than from REM sleep (Wollman et al., 1983). REM sleep is similar to the waking state in that it seems to entail a higher degree of arousal than slow wave sleep and Stage 2 sleep. The higher degree of arousal in REM suggests that there will be less decay from short term memory (or nontransfer to long term memory) after REM awakenings leading to longer reports when compared to NREM. If decay is rapid enough, no mentation report may be available as is almost always the case from slow wave sleep and sometimes the case from NREM Stage 2 awakenings. The Waking state, with the highest levels of arousal, should lead to the longest mentation reports.

It is also possible that the difference between the level of arousal during the dream itself and the awake state during which it is to be recalled, makes the dream memory trace unavailable for recall (due to the state dependency of memory) (Lehmann and Koukkou, 1974, 1980, 1981; Lehmann, 1980).

REM has been considered to have a storylike quality, described as the presence of few long thematically homogeneous thought sequences. This kind of thought contiguity seems to require the absence of disruption by external stimuli (Foulkes, 1966; Singer, 1977; Antrobus et al., 1984). Greater stimulus input from the environment might generate intrusions into the private thought sequences, breaking up the storyline, resulting in more and shorter thought sequences.

The high sensory thresholds of REM sleep exclude the processing of many external stimuli (Keefe, Johnson and Hunter, 1971). While individuals are asleep, most of the information available to the individual is coming from long term memory due to the exclusion of external stimuli. While people are awake, on the other hand, information is coming from both internal and external sources (Cartwright, 1981; Singer, 1977; Antrobus et al., 1984).

The differences between waking and sleeping mentation in the length of the report may be due to the differences in arousal in the different states. The differences between waking and sleeping mentation in storylike quality may be due to the different degree of availability of external stimuli for processing.

This is not a new idea. On the basis of his research Zimmerman (1970) proposed that

> "Dreaming is a function of cerebral arousal in the absence of reality contact. Given the loss of reality contact during sleep, dreaming mentation would occur when the level of cerebral arousal exceeds a certain critical point. Levels of cerebral arousal below this point might be sufficient only to sustain thinking. During REM sleep a particular organization of cerebral functioning would usually increase cerebral arousal above the threshold for dreaming for all subjects. During NREM sleep, certain subjects at certain times may exceed the threshold for dreaming." (pp. 547-548)

West (1962,1968) postulated that a major predisposing condition for hallucinatory activity (hallucinatory experiences here including dreams and hypnogogic imagery) is a decrease in awareness of the environment, i.e. a reduction in the level or variety of external sensory input to the brain. A second requirement is the maintenance of an arousal level sufficient to permit awareness.

Stoyva (1973) agrees with West on the conditions under which naturally occurring hallucinatory experiences are likely to arise. Stoyva includes other predisposing conditions to those proposed by West: "In the production of hallucinatory experiences it is important to reduce not only external sensory input but to reduce internal or proprioceptive input as well (p. 404)." These conditions are met by the state of sleep which is associated with higher auditory thresholds (i.e. a reduction in sensory input).

This research directly examines the role of stimulus input on mentation. It attempts to simulate the high thresholds of REM sleep by a reduction of stimulus input. Waking and sleeping mentation reports were elicited after Waking intervals during which there was external noise (external information available to the processing system) as well as when the subject was in a sound attenuated and lightproof room, allowing minimal external stimuli to enter. These reports were compared to reports elicited from REM awakenings. The external stimulation was expected to generate intrusions in the subject's thought processes, leading to shorter but more numerous units of thought.

Cortical arousal level is a second variable which may, at least partially, account for differences between mentation reports from different stages. Measures of cognitive activity elicited from REM awakenings and from the awake condition in which there was minimal available external stimulation were correlated with measures of cortical activation.

Changes in cognitive activity (which could be due to increments or decrements in production, memory, or retrieval processes) were measured by amount of recall in various categories. Cortical arousal level was measured through fast Fourier analysis of the EEG (electroencephalograph). The fast Fourier analysis yields measures of accumulated electrical energy ('power') within prescribed frequency bands over successive time intervals.

Review of Empirical Literature

Role of external stimuli in mentation and recall

A major tenet of the model proposed here is that the quality of an individual's mentation is largely dependent on the level of external stimulation. It is assumed that an individual will continue with a chain of related thoughts and associations until interrupted by an external stimulus. This intrusion generates a different set of associations related to the novel stimulus, thus producing a shift in the "stream of thought". Thus higher levels of ambient stimulation should lead to more numerous topics in the mentation report. Research will be reviewed below which supports the proposition that mentation is affected by external stimulation.

The work on sensory deprivation (e.g. Solomon, 1961) shows that when individuals are awake and under conditions of reduced sensory input, there may be a considerable amount of daydreaming, fantasies and imagery. Pope (1977) found that in a room with little external stimulation as a person shifted from prone to a more vertical body position and to higher activity levels , there was an increase in the frequency of thought shifts, the number of present-oriented thought segments and the time spent with consciousness focussed on the present situation.

Pope postulated that the more active physical posture might lead to greater stimulus input from the environment and therefore generate more intrusions into the subject's private thought sequences. With the more vertical alert posture, aspects of the environment are more likely to catch the subject's attention and trigger off related associations from private memories. Before these associations are fully elaborated, another aspect of the environment catches the attention of the individual, and the cycle begins again.

In Pope's experiment, two conditions were compared: 1) an experimenter present in the room with the subject (giving more external stimulation) and 2) the subject alone in the room (less external stimulation available). Under conditions of higher stimulation (experimenter present), there were more thought shifts and a greater number of thoughts of the present situation.

A series of studies by Foulkes and his colleagues have looked at the characteristics of waking mentation in a non-stimulating environment (Foulkes and Scott, 1973; Foulkes and Fleisher, 1975). Subjects reclining in a dimly lit room were instructed to relax but remain awake. These subjects gave reports of dramatic, bizarre, visual, and hallucinatory experiences which were accompanied by unambiguous EEG signs of wakefulness.

Antrobus, Singer, and Greenberg (1966) placed subjects under conditions of patterned perceptual deprivation and required that the subjects detect simple auditory stimuli. The rate of the signals or the demands on short term memory made by the tasks were manipulated by the experimenter. Increasing speed of signal presentation, increasing demands upon short term memory and increasing financial reward for accuracy of detection led to reduced reports of task irrelevant cognitive activity, imagery and fantasies.

Antrobus et al. (1966) propose a model to relate the production of spontaneous cognitive events (e.g. fantasies, daydreams) to the individual's response to external stimuli. Under most conditions, in the awake individual, external stimuli have a greater priority for processing than internal stimuli (short term memories, elaborations of recently perceived events and events in long term storage). As the amount and the importance of external stimulation decreases, there is more capacity available in the information processing system for internal processing.

Antrobus (1968) showed that reported spontaneous task irrelevant thought and imagery (daydreaming and mindwandering), at the end of 15 second intervals was a negative, linear function of the information rate of the concurrent auditory task. Antrobus, Singer, Goldstein and Fortgang (1970) have shown that when the demands on the central information processor are low, the processor continuously generates fantasies, images, thoughts and daydreams.

Antrobus, Fein, Goldstein and Singer (1984) found that mindwandering is far more pervasive than usually thought. They concluded that it may compete for time and processing capacity with most experimental tasks and that central decisions are continually made regarding the potential payoff for responding to environmental versus internal sources.

The general picture that emerges from this research is that the cognitive system is continuously constructing events whether it has sensory input or not. If the information in the sensory environment is sufficiently salient or has sufficient learned value to the individual, the processing resources of the cognitive system will be largely devoted to processing that sensory information. Otherwise, the cognitive constructions may continue relatively independent of external stimulation. When patterned visual input is eliminated by closing the eyelids and lying in the understimulated environment of one's bedroom, mentation will become more "dreamlike".

The idea that nonperceptual processing must compete with perceptual processing is in agreement with the model of a central cognitive operator with limited capacity (Kahneman, 1973; Norman and Bobrow, 1975). Besides the assumption of the model that the capacity available to be allocated to all activities (including both internal and external activities) is limited, it is assumed that the limit varies with the individual's level of arousal: more capacity is available when the arousal level is moderately high than when it is low (Antrobus et al., 1984).

Role of arousal in mentation and recall

The model proposed here posits cortical activation as a primary variable associated with cognitive activity. Several studies have reported data which support a relationship between levels of cortical activation, memory performance and qualities of recalled mentation.

In an investigation of learning and EEG (Koukkou and Lehmann, 1968, Koukkou, Madey and Yeager, 1969), short sentences were presented to subjects during slow wave sleep. The EEG was visually assessed for duration of post presentation EEG alpha. In a later study (Lehmann and Koukkou, 1974), the post presentation EEG was computer analyzed into frequency spectra. The different stimulus sentences caused different levels of changes of the EEG patterns for varying times after the presentation. In the morning, the quality of recall of the sentences (spontaneous recall, recognition or no recall/no recognition) was tested. The quality of morning recall was positively correlated with higher amplitude and longer duration of EEG activation.

Lehmann, Dumermuth, Lange and Meier (1981) investigated EEG differences between REM periods that were followed by dream recall and REM periods without dream recall. The experimenters used six leads and examined the power in 2 Hz.

bands from .4-14 Hz. Mean power spectra of REM periods with recall and of REM periods without recall were computed for each of their six subjects, and then averaged across subjects. Average spectra for REM periods with dream recall showed an average of 11% less power (integrated area under the curve) in all examined frequency bands compared to REM periods without dream recall. This was most significant in the left parietal vertex lead. Although these results are in the predicted direction, they must be viewed with caution since they are based on a very small sample size (N=6).

A different approach to the question of arousal was taken by Hersch, Antrobus, Arkin and Singer (1970). They experimentally increased the arousal level of their subjects during Stage 4 sleep by subdermally injecting epinephrine. Subjects served as their own controls and during another Stage 4 period of the same night were injected with an equivalent amount of saline. Subjects were awakened 10 minutes after each injection. Awakenings after the epinephrine injections yielded mentation reports that were rated as more vivid, bizarre, and more perceptual than conceptual in content than those mentation reports following the saline injections.

Zimmerman (1970) measured individual auditory arousal thresholds, a measure of how much sound stimulation is needed in order to awaken the individual. He separated subjects into two extreme groups, a light sleep group (LSG), consisting of subjects easily awakened by an auditory signal and a deep sleep group (DSG), subjects who needed much more intense stimulation in order to be aroused. Subjects in the LSG were also more aroused physiologically while asleep than the DSG subjects as measured by faster heart and respiration rates, higher body temperatures, more awakenings and more gross body movements. Mentation reports were collected during awakenings from both REM and NREM sleep The ratings of the reports included measures of aggression, imaginativeness, physical activity and dreaming vs. thinking. The REM mentation of the two groups did not differ. However, when awakened from NREM sleep, LSG subjects reported dreaming 71% of the time, while DSG subjects reported dreaming after only 21% of the awakenings. Based on these data and the differences in physiological arousal between the two groups, Zimmerman proposed that the level of cerebral arousal must exceed some critical level in order for dreaming to occur.

Zimmerman did not consider sensory thresholds as an independent causal factor of the differences between dreaming and thinking, but used measures of auditory sensory threshold to infer cortical arousal.

The studies summarized in this section fall into two groups. The Koukkou et al. (1968, 1969) and Lehmann et al. (1974, 1981) studies provide evidence of a relationship between EEG activation and memory performance. Hersch et al. (1970) and Zimmerman (1970) suggest that higher physiological arousal levels are associated with more "dreamlike" mentation. These last two studies can not be taken as conclusive since neither has been replicated and Zimmerman confounds cortical arousal with auditory thresholds. The present research is an attempt to examine more specifically the relationship between cortical activation (EEG), report length and other qualities of the mentation.

EEG correlates of sleep mentation

Although researchers have been searching for psychophysiological correlates of sleep mentation for over two decades, within stage EEG correlates of sleep mentation have only barely been studied. Yet many researchers have observed that even within a given sleep stage, where a given EEG pattern is essentially constant, there is a considerable amount of variation in both the incidence and quality of mentation (Pivik, 1978; Foulkes, 1982).

In a preliminary study, Moffitt, Hoffman, Wells, Armitage, Pigeau, and Shearer (1982) found systematic variations in the EEG which related to dream recall success or failure, length of dream report, and dream quality as experienced in the dream report. They measured EEG from left and right hemisphere central locations (C3, C4) and analyzed the data according to five frequency bandwidths, using five minute averages of the preawakening EEG, looking both at specific and average bandwidths as well as hemispheric asymmetries.

As pointed out by the authors, the study can be criticized on several methodological grounds. First, the study used only eight subjects. They were highly selected subjects, coming from a population of 634, and chosen for being high frequency dream recallers (reporting spontaneous morning recall five or more times per week), or low frequency recallers (reporting spontaneous morning recall once per month or less). Second, a large number of statistical tests were performed which greatly increases the probability of attributing false significance to chance findings (type I errors).

In addition, in the statistical analysis, the researchers treated each awakening as if it came from a separate subject, inflating the between subjects degrees of freedom.

Nevertheless, certain trends did emerge in the data. Most of the tests performed indicated significant relationships between mentation recall and beta, their highest frequency band measured. Moffitt et al. (1982) also found that power asymmetries in the beta category were not consistent in direction with asymmetries of total power within a given sleep stage. All of the beta measures (zero cross, first derivative, and power) favored the left hemisphere during Stages Awake, 1, and REM. In Stages 2 and 3, the signs of the ratios in the beta category diverged, with beta power favoring the right hemisphere. In Stage 4, all of the beta measures favored the right hemisphere.

Buchsbaum, Mendelson, Duncan, Coppola, Kelsoe, and Gill (1982) studied the differences between power spectral estimates in Awake, Stages 1-4 and REM sleep periods in four normal volunteers. Data compiled from 16 EEG leads on the left hemisphere and midline were averaged together for nine artifact free 10 second epochs in each of the conditions.

They found the least amount of beta in Stages 1 and REM, highest beta in Stage 2, and a progressive decrease in Stages 3 and 4. These results may be partially due to the non representative selection by Buchsbaum and his colleagues of the 10 second epochs from each stage to be used in their analysis. They only used Stage 2 epochs containing spindle activity and did not include any periods with eye movement activity. These recordings were made during daytime naps. There is some possibility that nocturnal sleep may differ from daytime sleep.

Buchsbaum et al. (1982) also found that waking, Stage 1 and REM showed relatively low delta activity (mean across all leads was 1.01 microvolts). Delta increased progressively in Stage 2 (1.82 microvolts), Stage 3 (2.30 microvolts) and Stage 4 (2.52 microvolts). This corresponds to the progression in amount of recall of mentation with Waking, Stage 1 and REM found to have a relatively high amount of recall and Stages 3 and 4 found to have relatively little if any recall.

In their study of the topographical distribution of EEG delta activity, Findji, Catani, and Liard (1981) found that delta rhythm amplitudes follow the sleep cycles. They found a progressive increase in the amplitude of delta rhythms in proportion to the deepening of NREM sleep, and an abrupt drop in delta amplitude at the moment of passage from NREM sleep into REM sleep.

Cne might postulate an inverse relationship between delta and recall, as in general there is very little or no recall from Stage 4 sleep (Broughton, 1968). Even after episodes of night terrors and somnambulism which are associated with arousal from Stage 4 sleep, dream recall is extremely rare and there is generally no recollection of sleepwalking activities.

In the alpha range, waking state EEG activation has generally been found to be associated with alpha blocking (Morrell, 1966). The reactivity of the alpha rhythm to stimulation poses something of an anomaly. In the waking state, stimulation yields alpha blocking. On the other hand, stimulation presented to a sleeping subject generally produces an increase in alpha, which is taken as an indicator of arousal. In fact, Johnson (1970) argues that the significance of a physiological variable cannot be correctly interpreted without apriori knowledge of the state of consciousness of the individual. Even within states (e.g. REM, Waking), there is a considerable degree of variation in EEG parameters both within and between individuals. Few analyses have looked at within state variations, concentrating instead on the gross differences between the states.

Moffitt and his colleagues conclude that "variance in electrophysiological data does lie within sleep stage boundaries and that given appropriate quantification, it can provide useful information for studies of both dreaming and neurophysiology. Relationships between dream experiences and different EEG frequency categories may shed light on the psychological significance of these frequencies." (Moffitt et al., (1982).

Rationale for the present experiment

The notion that the unique characteristics of dreaming should not be described by a special model of dreaming or sleep mentation, but rather as modifications of models of waking cognition, provides the conceptual basis for the present research. Although the terms "sleep" and "dream" are generally regarded as totally distinct from "waking" and "waking thought" the present research attempts to examine them in terms of a single set of variables: external stimulus input and cortical activation.

In the present study, the level of external stimulation available to waking subjects was varied to see whether a reduction in external stimulation would modify certain aspects of waking cognition in the direction of the dreamlike mentation we obtain upon awakening subjects from REM sleep.

The association of cognitive variables and cortical arousal level (as measured by EEG spectral analysis techniques) was examined in order to see whether cortical arousal level could at least partially account for aspects of mentation derived from both sleeping and waking subjects.

The two major dependent variables for the mentation analysis in this study were Total Recall Count and Thought Units. Total Recall Count is a count of all words in mentation reports in which the subject describes something occurring during the previous period. Thought Units is a count of the distinct, thematically homogeneous thought sequences. These two aspects of mentation have been found to vary in REM and waking subjects, as described in the following section.

Preliminary studies

In two preliminary studies (Antrobus et al., 1984), daytime mentation was compared to mentation elicited from REM and NREM awakenings in a between subjects design. The experiments addressed the methodological question of the effect of the waking report interval duration on the report attributes. The report interval in sleep is indeterminate. Subjects in dream studies are commonly awakened five to ten minutes after REM onset, as defined polygraphically. However it is not valid to assume that the onset of the subjective "dream" experience coincides in time with the onset of REM sleep. Thus the choice of an appropriate waking control interval for mentation reports becomes problematic. If the indices of the mentation report, such as Total Recall Count (TRC), Thought Units (TU) and the ratio TRC/TU increase systematically with the report interval (time between successive reports) then it would be impossible to determine an appropriate waking standard with which to compare the REM and Stage 2 reports. If, however, imagery and thought generated earlier in the report interval are progressively lost as the report interval increases in duration, TRC and/or TU may asymptote to a constant maximum limit. That is, increasing the report interval beyond some point in time may no longer be accompanied by further increases in TRC and TU.

These two experiments employed low levels of auditory ambient stimulation and no visual illumination. In Experiment 1, ambient street sound was moderately attenuated but no laboratory speech could be perceived. This was called the Moderate Stimulation environment. In Experiment 2, both light and sound were maximally attenuated. This was called the Minimal Stimulation environment. Twelve volunteer subjects participated in the first experiment. They were asked to lie down in the experimental room, keeping their eyes open, the lights were turned off and the door closed. Subjects were contacted by intercom for mentation reports at intervals varying randomly around a mean of 5 minutes, with a range from 2 to 8 minutes. Mentation reports were solicited by standardized questions as follows: 1) "Please tell me everything that was going through your mind before I called you" and 2) "Was there anything else?" The subjects' reports were tape recorded and transcribed without addition of punctuation.

Mentation reports were analyzed using the word count variables of the Psycholinguistic Coding Manual (Antrobus, Schnee, Offer and Silverman, 1977). The rating scales of this manual were developed as a method of reliably counting the words in several classes relevant to sleep mentation reports. Each category (e.g. visual nouns, spatial relations, explicit speech) is given a formal definition followed first by unequivocal and then borderline examples together with commentary. Judges were required to score a separate test set of 50 reports and obtain a correlation greater than .90 with criterion scores on Total Recall Count, the most complex of the variables.

The transcribed mentation reports were given to 2 independent judges who first counted the total number of words in the report (Total Word Count, TWC). The reports were then edited to remove non-content material such as interjections (ums and ahs), redundant words, disclaimers, corrected words and all commentary on the experience, the report, or the current status of the subject. What remains after the editing process is exclusively a description of the experience that had occurred during the mentation interval. A count was then made of the number of words in the content-edited reports (Total Recall Count or TRC). Since word count scores are generally positively skewed, the TWC and TRC scores were normalized by the log10 (X+1) transformation (Kirk, 1968) and averaged between the two judges. All data analyses were conducted on the log transformed scores.

All transcribed mentation reports were also scored by three judges on a thought unit scale modelled after the "Structural Coding System for Verbal Output" devised by Klinger (1971). Each Thought Unit contains a distinct, thematically homogeneous thought sequence. "Two contiguous thought segments are considered to be one unit if there is no way to distinguish them thematically. Since verbal ability and mode of expression vary from subject to subject, the coder disregards sheer length and looks for complete thoughts bordered on either side by thematically different segments." (Klinger, 1971, p. 97)

In addition, a ratio was computed to index the average number of words per Thought Unit (log TRC / log TU). The mean trial interval for this set was approximately 5 min.

To provide a pool of sleep reports for comparison to the waking data, 50 REM and 50 NREM mentation reports were chosen from a collection of paired reports from sleep laboratories across the United States. Each pair of REM/NREM reports was contributed by a single subject and was drawn from approximately the same time of night. TRC showed little increase over the longer intervals although TU did tend to increase. The decrement over interval size in TRC/TU suggests that while subjects report about the same amount of information each time they are interrupted, they tend to condense, or perhaps, forget information from earlier time periods, as the recall interval increases.

Student's T-tests were conducted to compare the REM reports (N=50) and the Waking reports (N=12). TRC was significantly higher in Waking than in REM. Significantly more Thought Units were present in Waking mentation reports. Total Recall Count per Thought Unit (ratio log TRC/log TU) was significantly ($p < .01$) higher in REM sleep than in Waking.

Similarly, t-tests were computed between all variables for Waking and Stage 2 reports. Again, TRC was significantly higher in Waking. Mentation reports contained significantly more Thought Units in Waking than in Stage 2. TRC/TU was also significantly greater in Waking .

Since REM and NREM reports were drawn from the same subjects, correlated t-tests were computed between these measures. TRC was significantly higher in REM reports. Although Thought Units were slightly, but significantly more numerous in REM reports, the ratio of TRC/TU was also significantly higher in REM reports than in Stage 2.

This first experiment demonstrated that mentation reports obtained during the Waking state in an environment similar to that of the sleep laboratory, can be used to make meaningful comparisons with sleep mentation reports. Although all of the Waking variables changed as a function of recall interval size, REM and Stage 2 values differed from Waking values, regardless of which interval was compared. That TRC was higher in Waking than REM and Stage 2 suggested that the cognitive system that creates and stores the mentation is more active in Waking despite the EEG spectral similarities with REM.

The second experiment was made possible by the construction of high sound attenuation acoustic sleep chambers that permitted a more powerful test of the effects of ambient sound on TU and TRC/TU. It was predicted that TU should be lower, and therefore, TRC/TU higher in the acoustic chambers of Experiment 2 than the moderately sound attenuated chambers of Experiment 1. A second goal of this experiment was to determine if the interval duration results of Experiment 1 were indeed reliable. Fourteen young adults participated in afternoon sessions. The experimental session was less than one hour in duration and included 7 mentation reports.

Interval length was systematically manipulated using seven conditions: 15 secs, 30 secs, 1 min, 3 mins, 5 mins, 7 mins, and 9 mins. Order of presentation was randomized using a Latin square design such that each interval occurred equally often (twice) in each position within the sequence of mentation reports.

The transcribed mentation reports were given to two independent judges and were rated for the same word count variables as in Experiment 1.

The results showed that as trial duration increases, subjects recall more topics and more words. However the number of words per topic decreases over time. The results suggest that as the recall interval increases, subjects either forget, summarize or possibly restrict the length of the narrative to socially appropriate bounds.

Independent groupt T-tests were performed between the two waking conditions as well as between the minimally stimulated waking condition and the sleep conditions. Since the REM and Stage 2 reports were drawn from the same subjects in a repeated measures design, correlated T-tests were performed between the REM and Stage 2 conditions.

TRC was higher in the moderately stimulated environment of Experiment 1 than the minimally stimulated environment of Experiment 2. Minimal stimulation was effective in decreasing the number of Thought Units. TRC/TU was significantly higher in the less stimulated environment at all intervals. Finally, Stage 1 REM with a TRC/TU ratio of 3.70 was significantly higher than even the minimally stimulated Waking environment. Stage 2, with a ratio of 2.07 was significantly lower than REM. The results showed that even moderate magnitudes of ambient auditory stimulation are sufficient to disrupt the train of thought in the waking state. The fact that the REM TRC/TU ratio is higher than that obtained in a waking minimal stimulation environment indicates that the REM report comes from a state of both high cortical activation and minimal perceptual response to environmental stimuli. That REM TRC lies midway between Stage 2 and Waking suggests that the cortical activation associated with the generation and storage of this mentation also lies midway between Stage 2 and Waking.

The mentation reports were also compared on the more global constructs of Dreamlike Quality and Bizarreness. A multiple regression comparison of Waking and REM showed that TU is the best discriminator of the two conditions. The semipartial correlation of TRC, corrected for the contribution of TU (unlike the ratio TRC/TU, the TRC semipartial correlation is independent of TU), does not does not add significantly to TU (F (1,53) = 2.12, n.s.). This analysis suggests that the major distinction between Waking and Stage 1 REM mentation is that the Waking subject changes topics more frequently, presumably because spontaneous sequences of thought are interrupted by brief orientations to external stimuli.

By contrast TU makes little distinction between Stage 1 REM and 2 reports, despite the much longer reports in Stage 1 REM. This lack of difference may reflect the similar auditory arousal thresholds in REM and Stage 2 sleep (Rechtschaffen, Hauri and Zeitlin, 1966; Bonnet and Johnson, 1978). In summary, TU would seem to be the best discriminator of both Stage 2 and REM from Waking.

The current study: An extension of the previous research

The current research project extends the analyses of the preliminary studies and incorporates several methodological improvements.

1) The two preliminary studies compared REM and Waking reports that came from different subjects. The subjects who participated in the moderate stimulation environment of Experiment 1 were not the same subjects as those participating in the minimal stimulation environment of Experiment 2. The present experiment compared REM and different waking conditions in a within subject design in order to increase the statistical power of the design.

Subjects lay in a sound attenuated, lightproof room with eyes closed.

Subjects were asked for mentation reports:

1. after lying awake with external stimulation (W).

2. after lying awake without external stimulation (WO).

3. after being awakened from REM sleep.

Each subject served as his/her own control, going through all treatment conditions.

2) Since cortical activity is an integral part of the theoretical underpinnings of this approach, cortical arousal level was directly measured via spectral analysis. In both sleeping and waking subjects a decrease in power in bands < 8 Hz., specifically a decrease in delta power, and an increase in power in bands > 12 Hz., specifically, an increase in beta power, will be taken as indicators of increased arousal. For waking subjects, a decrease in power in the 8-12 Hz. band will also be taken as an indicator of increased arousal.

3) REM sleep has neurological characteristics distinguishing it from Waking other than cortical activation levels. Therefore, this research also asks whether within REM sleep itself as well as within Waking, intervals of greater cortical activation are associated with independent measures of cognitive activity.

Hypotheses and Statistics

1. Mentation reports obtained after REM awakenings will be characterized by fewer Thought Units than mentation reports from waking subjects in a stimulus reduced environment. Even in a stimulus reduced waking environment, ambient levels of stimulation are still higher than during sleep. Mentation from waking subjects with external stimulation will have a greater number of Thought Units than mentation from waking subjects without external stimulation or subjects awakened from REM.

Hotelling T squared tests will be performed with the different states (REM, waking with external stimulation (W) and waking without external stimulation (WO)) as the independent variables and Total Recall Count and Thought Units (averaged across reports in each state for each subject) as the dependent variables. Once Total Recall Count has been partialled out the main difference remaining between conditions will be in the Thought Unit variable.

2. There is an association between cortical activation level and cognitive activation.

A. The power (measured in picowatts) in the beta band (16 Hz. to 30 Hz.) will be linearly associated with log Total Recall Count. This will be tested

1) in REM

2) in the waking without stimulation condition

B. The wattage in the delta band (.5 Hz. to 4 Hz.) will be inversely associated with log Total Recall Count. This will be tested

1) in REM

2) in the waking without stimulation condition

C. The wattage in the alpha band (8 Hz. to 12 Hz.) will be inversely associated with log Total Recall Count

1) in the waking without stimulation condition

These hypotheses will be tested for EEG data obtained from both the last minute and the last five minutes preceding the mentation reports.

Multiple linear regressions will be performed with Total Recall Count as the dependent variable and the EEG measures and subjects as the independent variables. The EEG variables will account for significant proportions of the Total Recall Count variance once subject variance has been partialled out.

Method

Subjects

Thirty subjects (17 males and 13 females) completed the experimental procedures. Three additional subjects were dropped because they failed to complete the entire experimental protocol.

The subjects were either undergraduate or graduate students at the City College of New York or acquaintances of City College students. The subjects volunteered to participate in the experiment after hearing about it through classroom announcements, from others who had heard it announced or directly from the experimenter. The announcement stated that subjects were needed for a sleep experiment and that subjects were likely to have an interesting experience.

The ages of the subjects ranged from 16 to 41 with a mean age of 25.37. All subjects were native English speakers.

Subjects agreed to be free of all drugs and alcohol at least two days prior to the experiment.

In addition, all subjects had a consistent sleep schedule, i.e. sleeping and waking regularly at approximately the same time, generally spending at least six and one half hours in bed, finding it easy to fall asleep and having no known difficulty sleeping when not in their usual bed.

Bio-potential recording apparatus

A Grass Model 78 polygraph was used for EEG, electromyograph (EMG) and electro-oculograph (EOG) recordings. Grass silver cup electrodes were used for scalp placements and were attached using Offner electrode paste. Beckman Instrument Company silver chloride miniature disk electrodes were used for all other sites and were attached using Beckman adhesive collars and surgical tape. All resistances were less than 5K ohms.

EEG: For the purpose of scoring sleep stages, EEG was recorded from scalp electrodes placed both at C3 (left central, using the 10-20 system) and at C4 (right central) and referred to electrically linked electrodes placed at the left and right mastoid bones (A1, A2) (Rechtschaffen and Kales, 1968).

EEG was also recorded from left and right mid temporal-parietal sites (midpoints between T3 and P3, and T4 and P4, by the 10-20 system) referenced to vertex (Cz). These electrode placements have consistently been found to show task related hemispheric asymmetries (Ehrlichman and Weiner, 1980) and have been used as the placements in studies of EEG asymmetry and sleep mentation (Ehrlichman, Antrobus and Weiner, 1982).

EOG: Standard right and left outer canthi locations, referred to the electrically linked mastoids (Rechtschaffen and Kales, 1968) and to each other (bipolar EOG) were used to help score sleep stages.

EMG: Submental electrodes were used to aid in the scoring of stage REM sleep.

An electrode was placed on the forehead to serve as a ground.

For the REM and WO conditions, the four EEG channels were recorded using a Vetter Analogue Tape Recorder, during the five minute period prior to asking the subject for a mentation report. The frequency characteristics of the taped EEG were then analyzed using a Nicolet Med-80 Frequency Analysis Package.

For each successive sweep, the absolute power (in picowatts) was calculated for the delta (.5 Hz. to 4 Hz.), theta (4 Hz. to 8 Hz.), alpha (8 Hz. to 12 Hz.), sigma (12 Hz. to 16 Hz.), beta (16 Hz. to 30 Hz.) and high (35 Hz. to 45 Hz.) bands.

The sweep time was 1.75 seconds with a time resolution of 6.827 msec. per point and 256 points per sweep for each electrode placement. Each sweep was taken and spectrally transformed. Within each band the total power for the last minute (the last 34 sweeps) and the last five minutes (170 sweeps) before the request for a mentation report were averaged separately.

Eye movement activity

Eye movements were scored by having two independent judges count the number of three second intervals , in the 60 seconds prior to each REM awakening, that contained at least one rapid eye movement. Rapid eye movements were defined as having a pen deflection of at least 31 microvolts (with a callibration signal of 50 microvolts) at an angle of between 88 and 92 degrees.

Sleep room

The sleep room is a sound attenuated, electrically shielded, lightproof chamber, approximately 10x15 feet. There is a two way intercom system for communication between the experimental and sleep rooms.

For the waking conditions, the subject lay supine in the bed in the same room which was used for subsequent sleep awakenings.

External stimuli tape

The external stimuli tape included recordings of small portions of radio broadcasts. The broadcasts interrupted white noise every 20-30 seconds and lasted from 10-15 seconds with an average length of 10 seconds. The portions came from many different types of radio broadcasts and included portions of talk shows, news, sports, advertisements, music programs, etc. from a variety of New York AM and FM radio stations.

Procedure

Adaptation session

On a day preceding the experimental sessions, subjects were asked to come to the sleep laboratory for approximately one hour in order to get adjusted to the experimental situation.

Upon the subject's arrival, the experimenter showed the subject around the laboratory, trying to get the subject to feel as comfortable as possible.

The subject was then taken to a sleep room, the same room which was used for the subsequent experimental sessions. Half of the subjects were block randomly assigned to the external stimuli free condition first and the external stimuli condition second and the second half of the subjects were assigned to the conditions in the opposite order, the external stimuli condition first and the external stimuli free condition second. The same order was later utilized for the experimental session.

During both waking conditions, white noise (50 db) was introduced into the subject's room, through a speaker, in order to mask sounds produced by the subject's movements. During the external stimuli condition, portions of radio broadcasts interrupted the white noise.

After the subject was in bed, the lights were turned off, the door closed and all further communication utilized the intercom system.

The experimenter read the instructions to the subjects as they are written in Instructions to Subjects (see Appendix A).

Mentation reports were elicited from subjects after six intervals, three with external stimuli and three without external stimuli. In each condition the intervals were of the following lengths: three minutes, six minutes and nine minutes, the order of the intervals being block randomized across subjects.

The subject was interrupted using the Procedure for Elicitation of Mentation Reports (Appendix B).

After the session, the experimenter thanked the subject for participating and made an appointment for the waking experimental session.

Experimental sessions

Waking conditions

Subjects were asked to come to the laboratory for approximately three hours for the waking part of the experiment. This provided time for the application of the electrode montage and the waking conditions part of the experiment.

After electrode placement, the subject was taken to the experimental sleep room, the same room which was used for the subsequent sleep recordings.

After the subject was in bed, the lights were turned off, the door was closed and all further communication utilized the intercom system.

The experimenter read the instructions to the subjects as they are written in Instructions to Subjects (see Appendix A).

Waking interruptions for mentation reports

A. Criteria used for interrupting waking subjects for mentation reports in the external stimulus free (WO) condition:

Mentation was elicited from subjects after six ordered intervals of the following lengths: three, six, nine, six, three and six minutes. The subject was interrupted using the Procedure for Elicitation of Mentation Reports (Appendix B).

As mentioned, previously reported data from the City College Sleep Laboratory have shown that the amount of uninterrupted time lying awake in a quiet room affects the content of the report, specifically, by increasing the number of Thought Units. Therefore, only the three six minute intervals were used for later analysis.

The other intervals were not used in the analysis, but were included with the six minute intervals, so that the subject would not develop an expectation regarding when he/she would be called.

For the six minute intervals, one minute after the interval began, the experimenter started to record the EEG onto the Vetter Analogue Tape Recorder. After five more minutes, the subject was interrupted using the Procedure for Elicitation of Mentation Reports (Appendix B).

If there were any gross body movements, observable artifacts, or if the subject fell asleep during this period, he/she was immediately interrupted and asked for a mentation report. After the completion of the report, the experimenter requested that the subject try not to move around if there had been a gross body movement or the experimenter requested that the subject try to remain awake, if he/she had fallen asleep. Mentation reports elicited from these periods were not included in the data analysis.

B. Criteria used for interrupting waking subjects for mentation reports in the external stimuli condition:

Mentation was elicited from subjects after six intervals. The intervals were the same as those mentioned in Section A. The subjects were interrupted using the Procedure for Elicitation of Mentation Reports (Appendix B).

As in the external stimulus free condition, only the three six minute intervals were used for later analyses.

After the waking conditions had been completed, the experimenter disconnected the subject, thanked him/her for participating in the daytime session and made an appointment for the nighttime session.

Sleeping condition

The subjects were instructed to arrive at the sleep laboratory approximately two hours before their usual bedtime. This provided time for the application of the electrode montage and an approximate one hour break before the subject was connected in the sleep chamber.

After the subject was in bed, the lights were turned off, the door was closed and all further communication utilized the intercom system.

Pre-sleep instructions to subjects

The instructions given to the subjects were as follows: "I am interested in studying any and all forms of mental content, such as thoughts, images, feelings, dreams, and anything else that might go through your mind. I would like you to lay down in bed, close your eyes, relax and let yourself fall asleep.

During the course of the night you will be awakened several times. I am going to ask you the same standardized questions as I asked you before. Please try to answer the questions as completely and in as much detail as possible.

Do you have any questions?

(The experimenter answered any questions that the subject might have.)

Good night. Sleep well. I'll be talking to you soon."

<u>REM awakenings for mentation reports</u>

Criteria used for awakening subjects from Stage REM:

At least five minutes after two of the three measured electrographic parameters (the EEG, EOG, and EMG) showed polygraphic changes which indicated the presence of REM sleep (the standard two out of three criterion system set forth by Rechtschaffen and Kales (1968)), the experimenter recorded the EEG onto the Vetter Analogue Tape Recorder. Following five additional minutes of uninterrupted REM sleep, the subject was awakened using the Procedure for Elicitation of Mentation Reports (Appendix B). If there were any gross body movements or observable artifacts during this period, the awakening was not made, and the subject was required to emit an additional minute of uninterrupted REM before the experimenter restarted five minutes of recording.

REM awakenings were made from three REM periods following at least an initial 90 minutes of uninterrupted sleep.

Debriefing

In the morning, while the electrodes were being removed, the subjects were asked about the experimental situation. The questions included:

> What do you think was the purpose of the experiment?
>
> Why do you think we played the parts of radio broadcasts?
>
> How did you feel about the material on the radio?
>
> What strategy did you use in trying to remember what was going through your mind?

The subjects responses were recorded.

After the subject answered the questions, the experimenter discussed the purpose of the experimental procedures.

Analysis of the data

Scoring mentation reports

All transcribed mentation reports were independently scored by three judges on seven scales in the Psycholinguistic Coding Manual (Antrobus et al., 1976). The Psycholinguistic Coding Manual is a series of scales devised to score various qualities of mentation reports.

Reports were scored on the Total Recall Count measure, a count of all words in phrases in which the subject was describing something that had occurred during the presentation period in response to the two questions, "Tell me what was going through your mind before I called you" and "Was there anything else?". The reports were also scored on the four scales for the measurement of visual imagery: Visual Nouns, Visual Modifiers, Visual Action, and Spatial Relations as well as on the two scales for measuring aural experience: Explicit Speech and Implicit Speech.

The word count scores were positively skewed. They were therefore normalized by the log (X+1) transformation (Kirk, 1968) before being used. The four scales measuring visual imagery were arithmetically summed to form a combined visual scale. The two scales measuring aural experience were summed to form a combined auditory scale.

All transcribed mentation reports were further divided into Thought Units according to the method described by Klinger (1971). For the examples of how to divide protocols which were given to the judges see Appendix C.

Each judge counted the number of Thought Units found in each mentation report. A measure of interjudge reliability was computed for each scale. The scores of the three judges were averaged for each mentation report and these averages were used in the analyses.

Reliabilities of Variables

The mean correlation for each of the three possible judge pairs was computed using the Fisher r to z transformation. The reliability of the mean of the three judges was then calculated using the Spearman-Brown equation. These inter-judge reliabilities are presented in Table 1.

TABLE 1

Judge Reliabilities

Variable name	*Transformation*	*across Conditions*	*REM*	*WO*	*W*
Total Word Count	log (x+1)	1.00	1.00	1.00	1.00
Total Recall Count	log (x+1)	.92	.96	.95	.87
Thought Units		.85	.77	.81	.87
Visual	log (x+1)	.83	.95	.79	.70
Auditory	log (x+1)	.81	.86	.83	.76
Visual Nouns	log (x+1)	.79	.95	.73	.66
Visual Modifiers	log (x+1)	.78	.88	.79	.63
Visual Action	log (x+1)	.74	.83	.69	.65
Spatial Relations	log (x+1)	.69	.85	.56	.43
Implicit Speech	log (x+1)	.69	.68	.47	.70
Explicit Speech	log (x+1)	.79	.86	.97	.68

WO - waking condition *without* external stimulation

W - waking condition *with* external stimulation

Results and Discussion

Differences between Conditions in Cognitive Variables

The judges' scores for each of the mentation reports were averaged across the three occasions for each condition, REM, WO and W, for each subject.

Each subject's responses to the question of how alert he/she felt before being called was also averaged across the three occasions for each condition.

Hotelling's one sample T squared tests were performed on the differences between the REM and WO, WO and W and REM and W conditions.

Differences between the REM and WO condition

The first hypothesis stated that mentation reports obtained after REM awakenings would be characterized by fewer Thought Units than mentation reports from subjects in a stimulus reduced environment.

Table 2 presents the differences between the REM and WO conditions in the cognitive variables. Thought Units and Total Recall Count account for significant proportions of the variance of the difference between the REM and WO conditions. In the WO condition, as hypothesized, subjects produce more Thought Units and recall. Alertness and Total Word Count also account for significant proportions of the variance of the difference between the two conditions. The summary visual and auditory variables are not significantly different between the two conditions, although each is higher during REM. None of the individual visual and auditory variables (not included in Table 2) account for a significant proportion of the REM-WO variance.

Incremental MANOVA tests (Rao, 1973; Antrobus, 1983) were performed to determine whether the significant T squared tests were all describing the same difference or whether some of the dependent variables would add to the REM-WO difference already described by another dependent variable. It was hypothesized that once Total Recall Count was partialled out, the main difference between the conditions would be in the Thought Unit variable. Indeed, the Thought Unit variable adds significantly ($p < .01$) to the variance accounted for by Total Recall Count.

Additional incremental MANOVA tests were performed to determine if other variables would independently add to the variance accounted for by Thought Units or Total Recall Count. Total Word Count does not add significantly to the

REM-WO variance already accounted for by either Thought Units or Total Recall Count. Total Recall Count does not add significantly to the variance already accounted for by Thought Units. Total Recall Count does not add significantly to the variance accounted for by Total Word Count. The Visual and Auditory variables do not add significantly to the variance accounted for by Thought Units. These and other incremental MANOVA tests are presented in Table 3.

The major difference in word count variables between the REM and WO conditions is in the Thought Unit variable, which is higher in the WO condition. Once the variance accounted for by Thought Units is removed, no other variable accounts for a significant proportion of the REM-WO variance.

TABLE 2

Differences between the REM and WO Conditions

Variable	Source	df	SS	MS	F	Pr≥F	R2	Mean
Total	Model	1	1.30	1.30	8.43	.007	.225	-.208
Word	Error	29	4.47	.15				
Count	Total	30	5.77					
Total	Model	1	2.81	2.81	12.25	.0015	.297	-.306
Recall	Error	29	6.66	.23				
Count	Total	30	9.47					
Thought	Model	1	29.12	29.12	32.60	.0001	.529	-.985
Units	Error	29	25.90	.89				
	Total	30	55.02					
Visual	Model	1	1.56	1.56	2.11	.157	.068	.228
	Error	29	21.43	.74				
	Total	30	22.99					
Auditory	Model	1	.71	.71	1.30	.26	.043	.154
	Error	29	15.76	.54				
	Total	30	16.46					
Alertness	Model	1	1809.12	1809.12	209.17	.0001	.878	-7.77
	Error	29	250.82	8.65				
	Total	30	2059.93					

TABLE 3

Incremental MANOVA Tests for the differences between REM and WO

1. Increment due to Total Word Count over Thought Units:

Total Word Count + Thought Units	$F(1/29) = 34.48$
Thought Units	$F(1/29) = 32.60$
Increment	$F(1/28) = .855$

2. Increment due to Thought Units over Total Word Count:

Total Word Count + Thought Units	$F(1/29) = 34.48$
Total Word Count	$F(1/29) = 8.43$
Increment	$F(1/28) = 19.48$**

3. Increment due to Total Word Count over Total Recall Count:

Total Word Count + Total Recall Count	$F(1/29) = 12.26$
Total Recall Count	$F(1/29) = 12.25$
Increment	$F(1/28) = .007$

4. Increment due to Total Recall Count over Total Word Count:

Total Word Count + Total Recall Count	$F(1/29) = 12.26$
Total Word Count	$F(1/29) = 8.43$
Increment	$F(1/28) = 2.86$

5. Increment due to Thought Units over Alertness:

Thought Units + Alertness	$F(1/29) = 248.17$
Alertness	$F(1/29) = 209.17$
Increment	$F(1/28) = 4.585$*

6. Increment due to Total Recall Count over Alertness:

Total Recall Count + Alertness	$F(1/29) = 247.67$
Alertness	$F(1/29) = 209.17$
Increment	$F(1/28) = 4.55$*

7. Increment due to Total Recall Count over Thought Units:

Total Recall Count + Thought Units	$F(1/29) = 39.87$
Thought Units	$F(1/29) = 32.60$
Increment	$F(1/28) = 3.30$

8. Increment due to Thought Units over Total Recall Count:

Total Recall Count + Thought Units	$F(1/29) = 39.87$
Total Recall Count	$F(1/29) = 12.25$
Increment	$F(1/28) = 18.75$**

9. Increment due to Visual over Thought Units:

Visual + Thought Units	$F(1/29) = 37.92$
Thought Units	$F(1/29) = 32.60$
Increment	$F(1/28) = 2.42$

* $p < .05$

** $p < .01$

Differences between the WO and W conditions

It was hypothesized that mentation from waking subjects with external stimulation would have a greater number of Thought Units than mentation reports from subjects in a stimulus reduced environment. Hotelling's one sample T squared tests were performed on the differences between the WO and W conditions. As shown in Table 4, the Thought Unit scale approaches significance with $p = .054$, with subjects producing more Thought Units during the W than WO condition. Total Word Count, Total Recall Count, Visual and Auditory do not account for significant proportions of the variance between the WO and W conditions.

Again, the major difference between the two conditions in content variables is in the Thought Unit variable. The external stimulation generated intrusions in the subjects' thought processes leading to a greater number of Thought Units. One might have expected the mentation reports from waking subjects with external stimulation available to show an even greater difference in Thought Units when compared with the mentation reports in the stimulus reduced environment, but even in a stimulus reduced environment, there is stimulation available to subjects.

TABLE 4

Differences between the WO and W Conditions

Variable	Source	df	SS	MS	F	Pr>F	R2	Mean
Total	Model	1	.01	.01	.21	.65	.007	-.02
Word	Error	29	1.86	.06				
Count	Total	30	1.87					
Total	Model	1	.10	.10	1.29	.266	.042	-.058
Recall	Error	29	2.30	.08				
Count	Total	30	2.41					
Thought	Model	1	1.60	1.60	4.03	.054	.122	-.23
Units	Error	29	11.51	.40				
	Total	30	13.11					
Visual	Model	1	.65	.65	1.92	.18	.062	.147
	Error	29	9.82	.34				
	Total	30	10.47					
Auditory	Model	1	.24	.24	1.35	.26	.04	-.089
	Error	29	5.10	.18				
	Total	30	5.34					
Alertness	Model	1	18.99	18.99	8.10	.0081	.218	-.796
	Error	29	68.00	2.35				
	Total	30	86.98					

<u>Differences between the REM and W conditions</u>

As predicted by the model, REM and W were the two most divergent conditions in the present experiment with Alertness, Thought Units, Total Recall Count, Total Word Count and Visual all significantly different between the two conditions (see Table 5).

Among the cognitive variables, Thought Units accounts for 53% of the REM-W variance, Total Recall Count accounts for 32% and Total Word Count accounts for 20% of the REM-W variance with W being higher on each of these measures. Visual accounts for 15% of the variance with the visual count being higher for REM than W reports.

Incremental MANOVA tests were performed to determine whether some of the dependent variables could add to the variance already accounted for by other dependent variables. Selected incremental MANOVA tests are presented in Table 6.

It was hypothesized that the major difference between the two conditions would be in the Thought Unit variable. Total Recall Count does not add significantly to the variance already accounted for by Thought Units. The Visual and Auditory variables do not add significantly to the variance accounted for by Thought Units. Total Word Count does not add significantly to the REM-W variance already accounted for by either Thought Units or Total Recall Count.

The major difference in word count variables between the REM and W conditions is in the Thought Unit variable. Once the variance accounted for by Thought Units is removed, no other variable accounts for a significant proportion of the REM-W variance.

The Alertness measure accounts for 90% of the REM-W variance. As might be expected, subjects reported their preinterruption alertness level as having been higher when interrupted from the waking condition than when interrupted from REM. Both Thought Units and Total Recall Count individually add significantly (at $< .05$ level) to the variance accounted for by Alertness.

TABLE 5

Differences between the REM and W Conditions

Variable	Source	df	SS	MS	F	Pr>F	R2	Mean
Total	Model	1	1.58	1.58	7.36	.011	.202	-.23
Word	Error	29	6.23	.22				
Count	Total	30	7.80					
Total	Model	1	3.99	3.99	13.32	.001	.32	-.37
Recall	Error	29	8.69	.30				
Count	Total	30	12.63					
Thought	Model	1	44.36	44.36	33.10	.0001	.53	-1.22
Units	Error	29	38.87	1.34				
	Total	30	83.23					
Visual	Model	1	4.22	4.22	5.14	.03	.151	.375
	Error	29	23.81	.82				
	Total	30	128.03					
Auditory	Model	1	.13	.13	.24	.63	.008	.06
	Error	29	15.48	.53				
	Total	30	15.60					
Alertness	Model	1	2198.78	2198.78	261.6	.0001	.90	-8.56
	Error	29	243.75	8.41				
	Total	30	2442.53					

TABLE 6

Incremental MANOVA Tests for the differences between REM and W

1. Increment due to Total Word Count over Thought Units:	
Total Word Count + Thought Units	F(1/29) = 33.27
Thought Units	F(1/29) = 33.10
Increment	F(1/28) = .077
2. Increment due to Total Word Count over Total Recall Count:	
Total Word Count + Total Recall Count	F(1/29) = 14.75
Total Recall Count	F(1/29) = 13.32
Increment	F(1/28) = .946
3. Increment due to Thought Units over Alertness:	
Thought Units + Alertness	F(1/29) = 335.77
Alertness	F(1/29) = 261.60
Increment	F(1/28) = 7.146*
4. Increment due to Total Recall Count over Alertness:	
Total Recall Count + Alertness	F(1/29) = 353.75
Alertness	F(1/29) = 261.60
Increment	F(1/28) = 8.879*
5. Increment due to Total Recall Count over Thought Units:	
Total Recall Count + Thought Units	F(1/29) = 37.28
Thought Units	F(1/29) = 33.10
Increment	F(1/28) = 1.88
6. Increment due to Visual over Thought Units:	
Visual + Thought Units	F(1/29) = 39.82
Thought Units	F(1/29) = 33.10
Increment	F(1/28) = 3.03
7. Increment due to Auditory over Thought Units:	
Auditory + Thought Units	F(1/29) = 37.55
Thought Units	F(1/29) = 33.10
Increment	F(1/28) = 2.01

* $p < .05$

Cortical Activation and Mentation

Eye movement activity during REM

Eye movement activity has been found to contaminate the delta bandwidth in fast Fourier analysis (Lopes da Silva, 1982; Chen, Drangshol, Dworkin and Clark, 1983). Therefore, eye movement activity and the EEG measures were correlated to test for possible eye movement artifacts in the EEG measures.

Eye movements were scored by having two independent judges count the number of three second intervals , in the 60 seconds prior to each REM awakening, that contained at least one rapid eye movement. Rapid eye movements were defined as having a pen deflection of at least 31 microvolts (with a callibration signal of 50 microvolts) at an angle of between 88 and 92 degrees. The number of intervals with eye movements ranged from 0 to 20 with a mean of 7.45 and a standard deviation of 5.4.

The correlation between judges' ratings of number of intervals containing eye movements was .94. The judges ratings were averaged for each trial and these averages used in subsequent analyses. The significant relationships are presented in Table 7.

As can be seen from Table 7, the significant relationships are from the central electrode placements. There were no significant relationships from the temporal-parietal placements. The relationships are with the delta and theta bandwidths, with total power reflecting the contributions from the delta and theta bandwidths.

These relationships are for nonstandardized EEG data. When looking at nonstandardized data, results include both between subject and within subject variance. In this case, the between subject variance would include the possibility that subjects vary in the amount of EEG activity or eye movement activity that they generally produce. The within subject variance would include the variation in EEG and eye movement activity from trial to trial. In order to study the within subject variability from trial to trial, the between subject differences can be eliminated by setting each subject's mean to a standard mean.

When the mean for each subject is set to a standard mean, all the relationships between EEG activity and eye movements become insignificant. This is therefore a general effect, individuals with a greater average level of eye movement activity are producing more delta and theta power. It is not specific. For any individual, producing more eye movements on one trial does not mean that there will be more delta and theta on that trial.

TABLE 7

Relationships between Eye Movement Activity and EEG Measures

	Five minute EEG averages		One minute EEG averages	
Variable	C3-A1A2	C4-A1A2	C3-A1A2	C4-A1A2
Delta		.24*	.21*	.27**
Theta	.29**	.38***	.23*	.34***
Total	.26*	.32**	.25*	.28**

* p < .05

** p < .01

*** p < .001

**** p < .0001

EEG differences between conditions

Repeated measures F tests were performed to look at the differences in EEG measures between the REM and WO conditions. As can be seen in Table 8 there is significantly more delta in REM and significantly more alpha, sigma, beta and high power in the waking condition. This is true whether one is looking at the five or the one minute EEG averages.

TABLE 8

Difference between REM and WO Conditions in EEG Measures

Five Minute EEG Averages

Variable	df	F	Pr>F	R2	
Mean*					
Delta	1,26	49.76	.0001	.66	19.96
Theta	1,26	1.39	.25	.05	4.03
Alpha	1,26	21.00	.0001	.45	-.25
Sigma	1,26	25.94	.0001	.56	-5.86
Beta	1,26	32.84	.0001	.56	-3.89
High	1,26	5.40	.028	.17	-.46
Total	1,26	.72	.41	.03	-7.44

One Minute EEG Averages

Delta	1,26	24.29	.0001	.48	17.28
Theta	1,26	1.13	.30	.04	3.6
Alpha	1,26	20.03	.0001	.43	-19.48
Sigma	1,26	19.88	.0001	.51	-5.45
Beta	1,26	19.14	.0002	.42	-3.10
High	1,26	.00	.98	.00	-.007
Total	1,26	.22	.65	.01	-4.10

* + sign means more power in REM than WO

Relationships between EEG and content disregarding conditions

The mean of each subject for each content and EEG measure was computed for each condition. Pearson product-moment correlations between the EEG measures and the content measures were calculated for each electrode placement disregarding the conditions. Surprisingly, there were no significant relationships between the Total Recall Count measure and any of the EEG measures. This is despite the fact that 56 correlations were performed. There were also no significant relationships ($p<.05$) between the summary visual measure or any of its component scales and the EEG measures. A total of 280 correlations were performed looking at the relationships between the visual scales and the EEG measures. There were no significant relationships between the summary Auditory scale and the EEG measures. There was one significant relationship between Explicit Speech, a component scale of the Auditory scale, and an EEG measure, but considering the 168 correlations performed looking at the relationships between auditory scales and EEG measures, this too seems insignificant.

The significant relationships between the EEG measures and the Thought Unit scale for each electrode placement are presented in Table 9. The significant relationships between the EEG measures and the Alertness ratings for each electrode placement are presented in Table 10. Many of these relationships are significant and there is a definite pattern among them. There is a negative relationship between the delta measures and both the Thought Unit scale and the Alertness measure. There is a negative relationship between theta and the Alertness measure. There are significant positive relationships between alpha, sigma, and beta and both the Thought Unit scale and the Alertness ratings.

These results correspond to the significant differences between conditions in both EEG and content variables. Subjects have more delta during REM than WO and also have REM reports containing fewer Thought Units than their WO reports. Subjects awakened from REM feel less alert than subjects in the Waking condition. With the significant differences between stages, when looking across stages, higher delta would relate to fewer Thought Units and a lessened feeling of alertness. On the other hand, subjects produce more alpha, sigma and beta during Waking than during REM and at the same time produce a greater number of Thought Units and feel more alert. Correspondingly an increase in these EEG measures correlates with an increase in these content variables.

Alpha, sigma, and beta correlate with both Thought Units and Alertness despite the fact that the alertness measure and Thought Unit scale are independent of each other. The correlations between Alertness and Thought Units for each stage are small and insignificant.

These relationships between the EEG measures and the content measures across the REM and WO stages were also calculated with the EEG measures averaged across electrode sites, giving one global EEG measure for each bandwidth. Again, there were significant positive relationships between alpha, sigma, beta and the Thought Unit scale. There were significant negative relationships between delta and theta and Alertness as well as significant positive relationships between sigma and beta and Alertness. These relationships held for both the five and one minute averages (see Table 11).

TABLE 9

EEG Variables and Thought Units

Significant Relationships Disregarding Conditions

Five minute EEG averages:

Variable	TP1-Cz	TP2-Cz	C3-A1A2	C4-A1A2
Delta		-.25*		
Theta				
Alpha	.43***	.42***	.36**	.32**
Sigma			.27*	.28*
Beta	.38**	.34**	.50****	.52****
Total				

One minute EEG averages:

Variable	TP1-Cz	TP2-Cz	C3-A1A2	C4-A1A2
Delta		-.27*		
Theta				
Alpha	.40**	.37**	.35**	.33**
Sigma			.29*	.32**
Beta	.26*		.45**	.47***
Total				

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

TABLE 10

EEG Variables and Alertness

Significant Relationships Disregarding Conditions

Five minute EEG averages:

Variable	TP1-Cz	TP2-Cz	C3-A1A2	C4-A1A2
Delta	-.51****	-.53****	-.37**	-.37**
Theta	-.41**	-.41**		
Alpha	.30*	.36**	.33**	.33**
Sigma			.29*	.31*
Beta	.26*	.27*	.46****	.47****
Total				

One minute EEG averages:

Variable	TP1-Cz	TP2-Cz	C3-A1A2	C4-A1A2
Delta	-.47***	-.51****	-.34**	-.33**
Theta	-.37**	-.38**		
Alpha	.27*	.33**	.34**	.34**
Sigma			.32**	.35**
Beta			.41***	.42***

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

TABLE 11

Alertness, Thought Units, and EEG Variables

Significant Relationships Disregarding Conditions

Five minute EEG averages:

Variable	Thought Units	Alertness
Delta		-.51****
Theta		-.28*
Alpha	.39**	.36**
Sigma	.29*	.31*
Beta	.52***	.45***
Total		

One minute EEG averages:

Variable	Thought Units	Alertness
Delta		-.48****
Theta		-.26*
Alpha	.38**	.35**
Sigma	.27*	.281*
Beta	.45***	.38**
Total		

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

Subject variance

Thirty subjects were studied in this experiment. EEG activity certainly differs from subject to subject, with some subjects generally producing more or less power in certain bandwidths than other subjects.

Content data might also differ from subject to subject. Some subjects might have a tendency to speak more or less or to speak in more or less detail than other subjects. If this were true, then relationships found between the EEG data and the content data within conditions would reflect not only the variance within subjects across trials, but also the variance between subjects.

Multiple linear regressions were performed to see whether the subject factor predicted a significant proportion of the variance in the EEG and content data. As can be seen in Table 12, every EEG variable was significantly associated with subject variance.

As in the EEG measures, subject variance predicted a significant proportion of the variance in all content measures. As can be seen in Table 13, the subject factor predicted between 69 and 95 percent of the content variance depending on which particular measure was studied.

Because of the strong differences between subjects, in order to study the relationship between EEG and content variables within subjects (across trials), subject variance would have to be partialled out. This was accomplished by setting each subject's mean in each condition to a standard mean of zero. All within condition analyses were performed on data in which each subject's mean was set to a standard mean of zero.

TABLE 12

Subject Variance Predicting EEG Data

REM

	Five minute Averages				One Minute Averages		
Variable	df	F	Pr>F	R2	F	Pr>F	R2
Delta	29,55	25.95	.0001	.93	30.91	.0001	.94
Theta	29,55	56.01	.0001	.97	59.78	.0001	.97
Alpha	29,55	73.85	.0001	.98	50.09	.0001	.96
Sigma	29,55	41.84	.0001	.96	33.82	.0001	.95
Beta	29,55	23.34	.0001	.93	7.37	.0001	.79
High	29,55	1.90	.02	.50	1.94	.017	.50
Total	29,55	27.86	.0001	.94	43.18	.0001	.96

WO

	Five minute Averages				One Minute Averages		
Variable	df	F	Pr>F	R2	F	Pr>F	R2
Delta	29,59	35.33	.0001	.95	12.63	.0001	.86
Theta	29,59	84.00	.0001	.98	24.59	.0001	.92
Alpha	29,59	75.00	.0001	.97	8.99	.001	.82
Sigma	29,59	20.14	.0001	.91	29.94	.0001	.94
Beta	29,59	23.13	.0001	.92	11.03	.0001	.84
High	29,59	1.67	.047	.45	2.91	.0003	.59
Total	29,59	86.26	.0001	.98	41.74	.0001	.95

TABLE 13

Subject Variance Predicting Word Count Data

REM

Variable	df	F	Pr≥F	R2
Total Word Count	29,56	33.16	.0001	.95
Total Recall Count	29,56	17.90	.0001	.90
Thought Units	29,53	13.35	.0001	.90
Visual	29,56	7.45	.0001	.79
Auditory	29,56	3.82	.0001	.84

WO

Variable	df	F	Pr≥F	R2
Total Word Count	29,58	40.70	.0001	.95
Total Recall Count	29,58	33.70	.0001	.94
Thought Units	29,58	8.57	.0001	.81
Visual	29,58	12.11	.0001	.86
Auditory	29,58	4.54	.0001	.69

The significant differences between the means of the subjects might be reflected in the subjects' variances across trials. Means and variances are often correlated. If the variances of some subjects are different from those of other subjects, and correlations are performed across subjects, then some subjects would contribute more to the correlations than other subjects.

Subjects' means and standard deviations were correlated across trials for each variable. As can be seen in Table 14, almost all the correlations were significant at $p < .0001$.

Therefore, all within condition analyses were performed on data where each subject's mean was set to a standard of zero and each subject's standard deviation set to a standard of one as well as being performed with the mean set to zero and the standard deviation unchanged.

TABLE 14

Relationships between Each Subject's Mean and STD

EEG data

Variable	Five Minute EEG Averages	One Minute EEG Averages
Delta	.75****	.80****
Theta	.86****	.87****
Alpha	.99****	.97****
Sigma	.92****	.88****
Beta	.89****	.90****
High	.99****	.98****
Total	.83****	.87****

Relationships between each subject's mean and STD

content data

Variable	r
Total Word Count	.11
Total Recall Count	-.53**
Thought Units	.71****
Visual	.71****
Auditory	.90****
Alertness	-.10

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

Relationships between EEG and content variables within stages

EEG activity was averaged across the four sites for each trial for each subject to get a general measure of EEG activity. EEG was correlated with content variables both within the REM and the WO conditions. Table 15 presents the relationships between EEG activity and content variables during REM, with each subject's mean set to a standard of zero for each variable. Table 16 presents the same relationship but with each subject's variance standardized as well, to a common standard deviation of one. Tables 17 and 18 present the same relationships, respectively, in the Waking condition.

Relationships between EEG and content variables within REM

The content variables that show the most consistent relationship with the EEG during REM are the visual variables, most specifically, Visual Modifiers, a subscale of the visual scale. Visual Modifiers show a significant negative relationship with delta, theta and sigma during REM. Total Word Count (not included in tables) shows no significant relationships and Total Recall Count only significantly correlates with sigma and only for the five minute preawakening EEG data and then only when the subjects' means have been standardized and standard deviations have not been, a not very consistent result. Thought Units positively correlate with delta.

Relationships between EEG and content variables within Waking

As during REM, the content variables that show the only consistent relationships with the EEG during Waking are the visual variables, specifically Visual Modifiers. Depending on which standardization method is used and whether one is looking at the five minute or one minute EEG averages, Visual Modifiers correlate negatively with some or all of theta, sigma, alpha, and beta. No matter which standardization method is used, there is a negative relationship between Visual Modifiers and alpha.

Total Recall Count has a negative relationship with beta for the five minute EEG averages. There are very few other significant relationships and none of them are consistent, e.g. for both the five and one minute EEG averages.

Although only the summary tables for EEG averaged across the four electrode placements are included here, the summary statistics are representative of the individual placements. When correlations are performed separately for each placement, the major significant relationships are negative relationships between the visual scales and the EEG bands irrespective of placement for both REM and Waking.

TABLE 15

Relationships between EEG Activity and Content Variables during REM

(Each subject's mean set to a standard mean of 0)

Five minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall				-.22*		
Thoughts	.29**				.26**	
Modifiers	-.23*	-.22*		-.24*		-.22*
Visual						
Auditory						
Alertness		-.22*				

One minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall						
Thoughts	.25*					.26**
Modifiers	-.28**					
Visual						
Auditory						
Alertness						

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

TABLE 16

Relationships between EEG Activity and Content Variables during REM

(Each subject's mean and std set to a standard mean of 0 and a std of

Five minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall						
Thoughts	.30**	.22*				
Modifiers	-.25*			-.25*		-.23*
Visual	-.38***					-.23*
Auditory						
Alertness						

One minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall						
Thoughts						
Modifiers	-.26**					
Visual	-.34***					
Auditory					-.21*	
Alertness						

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

TABLE 17

Relationships between EEG Activity and Content Variables during WO

(Each subject's mean set to a standard mean of 0)

Five minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall					-.23*	
Thoughts						
Modifiers		-.22*	-.36***		-.28**	-.33**
Visual		-.36***				
Auditory						
Alertness						

One minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall						
Thoughts						
Modifiers			-.28**	-.30**	-.29**	-.27**
Visual			-.25*			
Auditory	.25*					
Alertness				.21*		

* p < .05

** p < .01

*** p < .001

**** p < .0001

TABLE 18

Relationships between EEG Activity and Content Variables during WO

(Each subject's mean and std set to a standard mean of 0 and a std of

Five minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall					-.21*	
Thoughts						
Modifiers			-.31**			-.26**
Visual						
Auditory						
Alertness					.22*	

One minute EEG averages

Variable	Delta	Theta	Alpha	Sigma	Beta	Total
Total Recall						
Thoughts		-.26**				
Modifiers			-.32**	-.36***		-.26**
Visual						
Auditory	.25*	.22*				
Alertness		-.21*			.20*	

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

Attempts to replicate general findings and issues

Eye movement activity

To address the continuing controversy regarding the relationship between eye movement activity and dream content. eye movement activity was correlated with the various content variables. Correlations were performed with the Total Recall Count scale, Thought Unit Scale, Visual and Auditory scales and the Alertness measure. There were no significant relationships between any content variable and eye movement activity.

Time of night effect

Dreams elicited from later REM periods have been found to contain more activity than dreams elicited from earlier periods (Foulkes, 1966). It is possible (Schwartz, Weinstein and Arkin, 1978) that awakenings made from later REM periods are preceded by some REM deprivation. REM deprivation has been shown to increase "dreamlikeness" of REM mentation reports within the night (Pivik and Foulkes, 1966). Cartwright (1975) attempted to collect REM mentation reports from early and late REM periods without confounding later reports with the effects of some REM deprivation. She found very little difference between the earlier and the later reports on the Foulkes DF Scale. However the judges agreed that on eight of the ten pairs she collected, the fourth REM was dreamier than the first REM. In their review of the "time of night" question Schwartz et al. conclude that nothing conclusive can be said about the changes in mentation quality across the night.

In the present study, subjects were awakened and asked for reports from three different REM periods during the night. The time of night effect was measured by having the report number correlated with the different content variables. These correlations were done with the content variables unstandardized, with each subject's mean set to zero and with each subject's mean set to zero and standard deviation set to one.

The significant results are presented in Table 19. The Total Recall Count, Visual, and Auditory ratings all show significant positive relationships with report number with later reports having more recall. All of the component visual and auditory scales showed significant positive relationships as well. The Total Word Count measure is significantly related to report number only when each subject's mean is set to zero and standard deviation unchanged. The Thought Unit scale shows no relationship with report number, later reports having the same number of Thought Units as reports given earlier in the night. The Alertness rating shows no relationship with report number, subjects don't feel more or less alert after being awakened from REM as the night progresses.

TABLE 19

The Relationship between Report Number and Content Variables

Variable	Unstandardized	Mean=0	Mean=0, STD=1
Total Word Count		.25*	
Total Recall Count	.25*	.37***	.36***
Thought Units			
Visual	.24*	.34***	.24*
Auditory	.23*	.33***	.32**
Alertness			

* $p < .05$

** $p < .01$

*** $p < .001$

**** $p < .0001$

General Discussion

Although waking thought and REM imagery have been regarded as quite distinct, the current research attempted to describe them as quantitative differences in a single set of variables. A model of dreaming and related forms of spontaneous mentation cannot be constructed exclusively from sleep report data. Rather, it must be built upon models that have been developed from the more extensive data bases that exist in experimental studies of waking cognitive processes.

It has been proposed (Antrobus et al., 1984) that cortical activation and heightened sensory thresholds are sufficient to account for the particular characteristics of the REM dream report; that these two variables modify certain characteristics of normal waking thought to produce dreamlike mentation; and that no additional special cognitive operations are required to account for dreamlike mentation in REM.

This research considered whether the process of REM mentation as distinguished from waking mentation in understimulated and noisy contexts, can be accounted for by these two factors, perceptual thresholds and cortical activation, which modify waking cognitive processes.

The data presented here support the position that the auditory distraction characteristic of the waking environment continually interrupts what might otherwise be a continuous associative flow of cognitive events.

In a comparison of mentation reports of Waking subjects with those subjects awakened from REM, the major distinction was that the Waking subject changes topics more frequently. This result is consistent with the prediction of the model that spontaneous sequences of thought are interrupted by brief orientations to external stimuli.

When additional external stimulation was included in the waking environment, there were an even greater number of Thought Units. The increase in number of Thought Units approached significance with a p value of .054. Thought Units was the best discriminator of the two waking conditions as well as the Waking and REM conditions. Although Total Recall Count is greater in Waking than in REM, it was the number of Thought Units that was the best discriminator of the two states.

By contrast, the two preliminary studies showed that Thought Units made little distinction between REM and Stage 2 reports despite the much longer reports in REM. Sleep, including both REM and Stage 2, is associated with higher thresholds than Waking. We can conclude, as hypothesized, that auditory stimulation is sufficient to disrupt the train of thought in the waking state.

The second part of this model hypothesizes that differences between REM and Waking mentation can be accounted for by general cortical activation. The cortical activation model assumes that the cortex is more active in Waking than in REM and more active in REM than in Stage 2. As we were able to see from the comparison of power in EEG bands from REM and Waking, The EEG is indeed more active during Waking than REM. There is significantly more delta in REM and significantly more sigma, beta and high frequency power in the Waking condition (Table 8). The major discriminator of REM and Stage 2 mentation has been found to be the greater length of the REM report (TRC) (Antrobus, 1983). Mentation reports from Waking subjects have been found to be even longer than REM reports. Since Total Recall Count is not dependent on any particular imagery or affective modality, the REM superiority in all mentation variables when compared with Stage 2 was attributed to higher general cortical activation.

The hypothesis that the cognitive features of Waking and REM are distinguished by cortex wide differences in activation was studied in this experiment. This research attempted to determine whether the association of EEG spectral parameters and cognitive characteristics are consistent both between and within states.

In view of the postulated relationship, it was surprising, when looking across REM and Waking, that there were no significant relationships between Total Recall Count and any EEG measure. There was however a significant negative relationship between delta power and Thought Units. There were significant positive relationships between alpha, sigma, beta and the Thought Unit scale. This corresponds to the major discriminators of the two states in both EEG and content measures, Waking being lower than REM in delta and higher in alpha, sigma, beta and Thought Units.

The lack of a relationship between EEG measures and Total Recall Count across REM and Waking does not support the general cortical activation model. Attributing the REM superiority in recall to general cortical activation when comparing REM and Stage 2 mentation (Antrobus, 1983) may have been a false attribution. The differences that Antrobus found in Total Recall Count between REM and Stage 2 that we have been calling general cortical activation may not be due to general activation at all, but may be due to unique differences between these states. The present study measured EEG in REM and Waking and did not measure EEG in Stage 2. Additional research would be needed to resolve the question of the relationship between EEG measures of cortical activity and recall across REM and Stage 2.

This study further attempted to control for the major differences between stages by holding stage constant and comparing mentation reports within subject from intervals of higher and lower cortical activation as measured by EEG power in specified bands. This is equivalent to asking whether, for any given subject, increasing power in any given EEG band would be associated with an increase in Total Recall Count.

The main hypothesis that cortical activation would associate with greater Total Recall Count within states was not substantiated. Greater cortical activation did not relate to Total Recall Count within conditions. This is in agreement with the results of a study conducted by Antrobus, Ehrlichman, Weiner and Wollman (1983). The study compared mentation from REM periods with high and low total activation. EEG was integrated over a 2 Hz. to 12 Hz. band. Total Recall Count was expected to increase as total EEG activation increased. However, Total Recall Count did not vary between the high and low activation conditions. The Antrobus et al. (1983) study was limited in that the EEG measures consisted only of a single broad frequency band. This limitation has been corrected in the present study by breaking up the single global EEG parameter into separate bandwidths. It was expected that the narrower bandwidths would be more sensitive to changes in specific regions of the frequency spectrum. In spite of this methodological improvement, the present study leads to the same conclusion as the previous study: that there is no relationship between Total Recall Count and general cortical activation as measured by the EEG.

While Total Recall Count per se was not related to cortical activation, significant relationships were found between EEG activity and some of the component subscales of the Total Recall Count variable. The scales measuring visual imagery were found to be correlated with EEG activity within REM and Waking. It is surprising that the component scales of Total Recall Count would correlate with EEG while the overall measure does not. Perhaps visual imagery is more directly related to what the EEG measures than is Total Recall Count.

Finding a relationship between EEG and visual imagery but not finding a relationship between EEG and Total Recall Count seriously suggests that a model with general cortical activation as the only necessary factor to account for differences in total recall is not an adequate model. There may be other forms of cortical or subcortical activity relating to visual imagery which are either specific to a given stage (e.g. REM) or which are active in all stages, possibly in differing degrees.

A specific example of these postulated activating factors is provided by Hobson and McCarley (1977). They have proposed that pontine-geniculate-occipital activity provides an additional and unique form of cortical activation that accounts for the high intensity of visual imagery during REM sleep. This may not be obvious when comparing REM and Stage 2 mentation. The magnitude of the difference in general cortical activation may be so large as to obscure the smaller differences due to other forms of activation. When comparing REM and Waking, the difference in availability of external stimulation for processing may be so large that it obscures other more subtle forms of cortical activation. These separate activators may be more apparent when studying variability within stages.

The idea that specific activation factors are needed to explain the differences in mentation reports is supported by the study of Ehrlichman, Antrobus, and Weiner (1982). When comparing mentation reports from REM awakenings with relative left or right hemispheric dominance, a significant difference between left and right dominant awakenings occurred for the visual scales. This was despite the fact that TRC showed no response to hemispheric dominance.

Summary

The present model postulated two factors to account for differences in mentation between states. As hypothesized, external auditory stimulation did increase the number of Thought Units in Waking as compared to REM. However the second factor, general cortical activation, did not relate to cognitive activation as operationalized by Total Recall Count. A more stringent test of the cortical activation model was to see if relationships between EEG and mentation could be found within states, holding other variables (such as stimulation) constant. These analyses did not support the general activation model either.

The failure to find a relationship between or within stages might be due to any or all of three possibilities:

A) Total Recall Count may not be a good measure of cognitive activation. Total Recall Count has been found to vary with subject factors (e.g. motivation to report (Antrobus, Fein, Jordan, Ellman and Arkin, 1978) and individual differences in verbal production).

B) The concept of general cortical activation has been criticized (Duffy, 1972; Hamilton, Hockey and Rejman, 1977). Unidimensional formulations of the concept of activation do not adequately model the data (Lacey, 1967). It may be necessary to consider activation as a multidimensional phenomenon (Thayer, 1978).

C) There may be other factors which account for unique variance in different stages. For instance, in REM there are several varieties of phasic events which may be correlated with aspects of mentation. Middle ear muscle activity has been found to be associated with bizarre and discontinuous mentation (Ogilvie, Hunt, Sawick and Samahalski, 1982). Periorbital integrated potentials have also been found to be associated with increased bizarreness in both REM and NREM mentation (Rechtschaffen, Watson, Wincor, Molinari and Barta, 1972) although other investigators have not consistently found the same results (Pivik, 1978). These phasic REM events may be seen as analogous to the external auditory stimulation condition which increases the discontinuity of mentation. These endogenous neural events may intrude upon the ongoing neural activity, thus disrupting the thought sequence and resulting in an increase in discontinuity. In both Waking and REM, tonic levels of EMG activity show a range of variation which may correlate with mental processes. In Waking, Jones and Lewis (1980) found that relaxation was associated with improved performance on a recall task. This finding may be relevant to the subject's task in the sleep lab where dream recall is attempted after a period of reduced EMG levels in REM sleep. Capiocco and Petty (1981) have related fluctuations in EMG activity to affect and information processing tasks in human subjects.

In conclusion, while external stimulation does affect the stream of thought, a general cortical activation model is not sufficient to account for the observed data in this study. In the future it may be more fruitful to investigate other cortical and/or subcortical forms of activation which account for unique variance in human cognitive processing.

Appendix A

Instructions to Subjects

I am interested in studying any and all forms of mental content, such as thoughts, images, feelings, dreams and anything else that might go through your mind. I would like you to lay down in bed, close your eyes, and relax without falling asleep. Try to relax and not move around too much. Most people feel uncomfortable with the room so quiet so I am going to be piping in white noise which will sometimes have parts of radio broadcasts mixed in. Every once in a while, after intervals of varying lengths, you will hear me call your name.

When you hear me call your name please respond. I will ask you three standardized questions. The first question is "Tell me everything that was going through your mind before I called you".

After you answer that question I will ask you "Was there anything else or was there any more detail about what you told me?". If you had nothing to report I will ask you, "Do you feel that something was there that you can't remember or was there really nothing to report?". I want as much detail as possible in the reports. Please try to answer the questions as completely and in as much detail as possible. If you have any questions to ask me, please try to wait until after you've finished your report.

At times you may feel that you do not want to tell me about something that was going through your mind. If you decide not to tell me something, please let me know that there was something that was going through your mind but that you've decided to withhold it. Of course I would like as much detail as possible about anything that was going through your mind, so please tell me as much as you are willing to tell.

After you answer those questions I will ask "If zero is dead asleep and ten is the boundary between waking and sleeping, can you give me some number to show how alert you were just before I called you?"

Do you have any questions?

(The experimenter answered any questions the subject might have.)

Let's try this once to see if you understand. Just lie there quietly and I'll ask you the questions in a little while.

(The experimenter waits three minutes and then calls the subject. After the subject answers, the experimenter asks the three questions. After the subject finishes answering the experimenter says ...)

Thank you. The questions are standardized so I will always ask them the same way. I won't forget that you're in the bedroom and I will let you know when we are finished with this part of the experiment.

Do you have any questions? (The experimenter answered any questions the subject might have.) We are starting now. Close your eyes, lie quietly and I'll be talking to you soon.

(After the subject finishes each report, the experimenter will say, "Thank you, I will talk to you again later.". After the last report, the experimenter will say, "Thank you. We are now finished with this part of the experiment.".

Appendix B

Procedure for Elicitation of Mentation Reports

The experimenter elicited mentation reports by calling the subject's name. When the subject answered, the experimenter said, "Tell me everything that was going through your mind before I called you.". If no reply was given by the subject within 10 seconds, the question was repeated.

Ten seconds after the subject finishes reporting, the experimenter asked, "Was there anything else or was there any more detail about what you told me?".

If there was no report in response to the first question, the experimenter asked, "Do you feel something was there that you just can't remember or was there really nothing to report?".

Ten seconds after the subject finshes reporting, the experimenter asked, "If zero is dead asleep and ten is the boundary between waking and sleeping, can you give me some number to show how alert you were just before I called you?"

Ten seconds after the subject finished talking the experimenter said, "Thank you. I'll talk to you again later.".

All mentation reports were tape recorded on cassettes and typed transcripts were made from the recorded tapes. The typed transcripts were not punctuated, but they included notations for long pauses.

Appendix C

THOUGHT UNIT SCALE

The Thought Unit Scale used in the City College Sleep Laboratory is a modified version of Klinger's (1971) Structural Coding System for Verbal Output. The modified version of this scale has been applied to mentation reports obtained from wakefulness and after awakenings from sleep stages. In what follows, we loosely quote from Klinger's description of his Structural Coding System for Verbal Output, then present examples of the application of this coding system to mentation reports.

> The task is "to divide each protocol into separate units distinct in thematic thought content . . . (Each thought unit) by definition contains a distinct, thematically homogeneous thought sequence. The homogeneity consists of what the subject reports he is thinking about in one particular interval: noticing particular external objects, thinking about a particular past experience, anticipating particular aspects of the future, or concentrating on a particular abstract notion. Two contiguous thought segments are considered to be one unit if there is no way to distinguish them thematically. Since verbal ability and mode of expression vary from subject to subject, the coder must disregard sheer length and look for complete thoughts bordered on either side by thematically different segments." (Klinger, 1971, p. 97)

The division of a mentation report into thought units is illustrated in the following reports. The omission of punctuation is deliberate, so that the transcriber/typist does not impose his/her own ideas of verbal structure on the mentation sequence.

The following examples are drawn from a pool of waking and sleeping mentation reports from the sleep laboratory of the City College of New York. In these examples, individual thought units are separated by slash marks (/). Underlined words represent words included in the Total Recall Count (see Psycholinguistic Coding Manual, Total Recall Count Scale). The Recall Count is intended to be a count of words in which the subject was describing the experience that had occurred during the interval prior to being asked for a mentation report. This procedure yields an edited version of the total report in which verbal intrusions (ah, um), corrections, repetitions and commentary upon the experience are deleted.

The following two examples are mentation reports elicited after awakenings from REM sleep.

Example 1.

> Um about uh 5 minutes before you called me there was a guy in the room with me and uh I couldn't imagine what he was doing here I had no thought that I might be dreaming or anything like that uh and I had just made a request to him to go to the bathroom and he was just kind of joking with me and talking and he was kind of like your assistant and he worked just like a psychiatric resident that works at PI / um also I had a dream in which I was just having just a conversation you know a woman that I know out in New Jersey just talking to her about about just various things about about our work / job that sort of thing let's let's see I was surprised that you called me because I thought I was awake for the past 15 minutes / or so uh that's about it

The previous mentation report contained three thought units, as indicated by the slash marks. The next report consists of only one thought unit.

Example 2.

A dream with a baby oh yes I remember this what this was a strange adventure it was someplace up in the country and I was with friends and some parts of my family and we were in what looked like a bungalow colony you know what that is and there was a fence that divided one bungalow colony from another and apparently the one that we were staying in was for a better class of people than the one on the other side of the fence and we had gone on a hike and during the hike it had rained very heavily and we were getting lost and when we returned because the roads were washed out we found that we had come down the hill on the other side of the fence and we were in eyesight of our own bungalow but we weren't able to get to it because of the rain and we came onto the porch of another bungalow from that group on the other side and the characters that lived in that bungalow reminded me of the Queen of Hearts and the the evil Queen of Hearts and someone else from Alice in Wonderland's mad tea party they were people they weren't dressed in costumes but that was the personality that I detected and it was that baby who was crying a lot and when I picked him up and held him he stopped crying but when his mother the evil Queen came came along and took the baby back she tended to abuse it and I remember my grandmother was along on the trip she was the the Queen was very hospitable to all of us though she wasn't she didn't seem to mind us being there and if you didn't wake me up I think she was going to help us get back to our place / that's all I can remember

The following three reports were obtained from waking subjects.

Example 3.

OK I was thinking about I was thinking about my refrigerator at my house with all of the food in it / and I was thinking about uh the rain and looking out the window when it was raining out and watching the lightning and thunder / and I was just thinking about a book that my father gave me a long time ago when I was younger when he brought it back from Alaska about Alaskan folk stories and I remember reading that and uh I was thinking if he brought me back anything else when he was there / and uh that's about it

Example 4.

OK I was trying to think if I could see I was still trying to see if I could see my hand if there was any light coming from around me looking straight up / and uh I was thinking about seeing that computer I keep forgetting the name of it Wylbur / I guess something like that and uh I was thinking about an um instrument that I'm buying called a Chapman stick which has ten strings it's like a bass and a guitar together I was thinking about that and playing that and about going to the store to put more money down on it I'm almost paid off on buying it / and uh I was thinking about eating / and that's it mm I was thinking about the paper clip holding the microphone above my head / that's about it

The previous example contains five thought units. The references to playing the Chapman stick and putting more money down on it at the store are considered part of the same thought unit since they are connected by the common theme of "guitar". The following example contains three thought units, as indicated by the slash marks.

Example 5.

A lot of creative dreaming I don't know what it is about this environment that inspires such creativity I certainly don't feel this way at home uh first I started imagining seals at the zoo where they sit up on this stone obelisk that comes out of the water there's only one seal that I saw however he was striped red and white and he was balancing a striped ball on his nose and he kept bouncing it to someone else it could've been another seal I don't know but I only saw one in the picture and then it got cold again and and the water in in the seal pond they don't really call it in the zoo with the cage with the fence around it and the obelisk the water began to freeze over / and I started to feel that wintery scene again and there were I guess there were wolves or dogs barking with big big teeth and they barked for awhile and that only lasted a few seconds though / and after that I started to feel like I guess I guess every once in a while I get get a bit of insomnia it's certainly not a frequent thing but it may happen once every four months or five months like there's one month that you feel you just can't get to sleep I suppose it happens to everybody and I I felt like that right now I said I wish I wish I could get to sleep why can't I what is it that's keeping me awake then I felt very dissatisfied about why I couldn't go to sleep / and that's about when you called me that's all

The final example, also obtained from a waking subject, illustrates discontinuous reporting . The report actually contains two thought units, "getting her hair done" and "going dancing", but the second thought unit is followed by a continuation of the "hairdresser" theme when the experimenter asks for further detail or clarification.

<u>Example 6</u>.

Subject: I was thinking of that um I have to go to the hairdresser on Saturday and do I have enough money for it / and how was my night going to be um on Saturday night which I'm on because I'm planning on dancing / and that's about it

Experimenter: Was there anything else, or can you give me any further details?

Subject: Yeah um yeah um there's two hairdressers that I usually go to and I was just deciding on deciding which one I want to go to / and that's it

In this report there are actually two thought units, not three. The amplification given in response to the experimenter's question is thematically part of the first thought unit, and should not be counted as a separate thought unit in its own right.

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