Deprivation of REM sleep by operant conditioning

by Scott Searcy Campbell

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology
Montana State University

Abstract:
A process of REM sleep deprivation was tested, whereby a 2000 Hz tone, with an intensity below the awakening threshold of each subject, was presented at the onset of each REM episode and persisted until rapid eye movement ceased. The subjects' task was to terminate the auditory signal by altering some physiological mechanism, (viz., rapid eye movement), resulting in decreased dreaming. A decrease in percent REM was significant, as was an increase in percent deprivation. Likewise, an increase in eye movements/minute REM was significant. The findings were interpreted as lending support to the notion that information processing may occur during sleep, in addition to supporting the hypothesis that REM sleep deprivation may be achieved by means of operant conditioning.

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Date May 26, 1978

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ABSTRACT

A process of REM sleep deprivation was tested, whereby a 2000 Hz tone, with an intensity below the awakening threshold of each subject, was presented at the onset of each REM episode and persisted until rapid eye movement ceased. The subjects' task was to terminate the auditory signal by altering some physiological mechanism, (viz., rapid eye movement), resulting in decreased dreaming. A decrease in percent REM was significant, as was an increase in percent deprivation. Likewise, an increase in eye movements/minute REM was significant. The findings were interpreted as lending support to the notion that information processing may occur during sleep, in addition to supporting the hypothesis that REM sleep deprivation may be achieved by means of operant conditioning.

INTRODUCTION

In 1960, Dement submitted a preliminary report concerning the first year findings of a research project then ongoing at Mount Sinai Hospital. The study involved dream deprivation of human subjects, and it has subsequently been considered landmark research in the field of sleeping and dreaming (Cartwright & Ratzel, 1972; Lewin & Glaubman, 1975; Pivik & Foulkes, 1966; Sampson, 1965).

In that initial report, Dement described a procedure by which the subjects would be kept from dreaming:

> After a few unsuccessful preliminary trials with depressant drugs, it was decided to use the somewhat drastic method of awakening sleeping subjects immediately after the onset of dreaming and to continue this procedure throughout the night, so that each dream period would be artificially terminated right at its beginning. (p. 1705)

Using this procedure, Dement claimed to have found several effects of dream deprivation, including a progressive increase in attempted dream time, anxiety, irritability, difficulty in concentrating, and increased appetite. In the 18 years since Dement's publication, these findings and the interpretations derived from them have been documented by some researchers (Jouvet, 1962, as cited by Lewin & Glaubman, 1975; Sampson, 1965), added to by others (Barker, 1972; Cartwright & Ratzel, 1972; Pivik & Foulkes, 1966), and disputed by still others (Kales, Hoedmaker, Jacobson & Lichtenstein, 1964; Lewin & Glaubman, 1975; Sampson, 1966; West, Janszen, Lester, & Cornelisoon, 1962).

In virtually all of these studies, the method by which dream deprivation has been accomplished is the same procedure employed by Dement almost two decades ago. In a few instances, typically involving non-human organisms, variations of Dement's method have been tested. Yet, Dement's procedure, which was characterized by him as "somewhat drastic," remains the most widely used method of REM sleep deprivation, despite significant problems associated with its application.

The most obvious problem with this method is that the subject must be awakened several times during the first night of testing, and even more frequently on succeeding experimental nights. The question must be asked: What consequences do the multiple awakenings have on the effects attributed to deprivation of dream sleep? Dement's research included a control designed to answer such a question. Six subjects, acting as their own controls, were awakened during NREM (non-rapid eye movement) sleep, the same number of times per night, for the same number of nights, as during the experimental condition (REM sleep interruption). Subsequently, the subjects were found to exhibit none of the psychological effects noted previously, leading Dement to conclude that the stated effects were, indeed, related specifically to the deprivation of REM sleep.

Likewise, results of a study conducted by Sampson (1965) seem to support the hypothesis that the effects described by Dement are attributable exclusively to dream deprivation. Sampson hypothesized that anxiety, irritability, and so on, were the result of "interruption of the ongoing REM (and dream) process" (p. 79), rather than dream deprivation per se. In an attempt to verify the hypothesis, Sampson developed a method of dream deprivation without dream interruption. The process involved several nights of partial sleep deprivation, whereby a subject was restricted to his/her first 2½ hours of sleep per night. The author reasoned that since only ten to fifteen minutes of REM time occurs during the first 2½ hours of sleep, this method would result in reduction of dream sleep "comparable to that achieved by dream interruption techniques" (p. 79). Applying this process, Sampson failed to confirm his hypothesis, and in so doing added support to Dement's findings. It should be noted, however, that Sampson's partial sleep method of dream deprivation, and likewise any conclusions derived from its use, may be restricted in validity since up to 69% sleep loss results from each experimental session.

Regardless of these findings, and in light of findings to the contrary, it might be argued that a method of REM sleep deprivation involving multiple awakenings or a high percentage of sleep loss may present substantial methodological problems (Fishbein, 1971). And it must be agreed that a method of dream deprivation that does not require multiple awakenings, with normal sleep time, would certainly result in a methodologically cleaner experiment.

The principal drawback to Dement's (1960) method of REM sleep deprivation does not, however, result from the possible confounding influence of multiple awakenings, as such. Rather, a more serious disadvantage to the method of multiple awakenings concerns its tedious nature. Dement reported that "a minute-to-minute all night vigil was required of the experimenter to catch each dream episode immediately at the onset" (p. 1706). This wearisome procedure not only makes dream deprivation studies laborious and time-consuming, but makes them susceptible to an inordinate amount of human error, as well. To stay awake all night is not easy. To stay alert all night with one's attention focused on an apparatus upon which the electronic potentials of a number of physiological measures are recorded seems virtually impossible. Furthermore, when the experimenter does succeed in detecting the onset of a REM sleep period, he must then make the decision to awaken the subject. Since bursts of rapid eye movement may occur during NREM sleep (Sampson, 1965), this is not always easy. The time lost during this deliberation, compounded with occasions in which a REM period begins while the experimenter is distracted from the recording apparatus, results in only 65% to 75% of total dream time actually being deprived (Dement, 1960).

It should be noted that in some animal studies, where a variation of Dement's multiple awakenings procedure is used, the percentage of REM sleep deprivation is slightly higher. For example, a study involving mice conducted by Handwerker and Fishbein (1975) employed the following method. The animal was placed on a platform three centimeters in diameter, situated in a cage filled with water to a level just below that of the platform. Upon entering a REM stage, the animal's ensuing muscle relaxation resulted in its falling from the platform, and consequently being awakened. This method resulted in 80% REM sleep deprivation, with only 11% sleep loss.

Jouvet (1962, as cited by Jouvet, 1967), likewise, demonstrated virtually total REM sleep deprivation, with normal sleep time, by lesioning the pontine region of the brainstems of cats. Both of these methods, however, contain possible areas of bias, the former involving a stress factor (Fishbein, 1971; Handwerker & Fishbein, 1975), and the latter producing the risk of brain damage associated with the surgical procedure. In any event, the limitations of these two procedures, in use with human subjects, are quite apparent.

Undeniably, the ideal dream deprivation technique for animal as well as human subjects would restrict 100% REM activity, while allowing successive nights of uninterrupted sleep. Further, the ideal approach would employ a method whereby human error and subjective decisions on the part of the experimenter could be eliminated, while concurrently making the research task less laborious for both the subjects and the experimenter. It is my view that a process utilizing feedback techniques may provide a way of obtaining a more efficient and less drastic means of REM sleep deprivation.

Biofeedback is the process by which psychophysiological information received from an organism, such as heart rate, EEG (electroencephlograph), respiration, etc., is converted into a symbolic form, and then presented to the organism in that form. This information may be presented as a mechanical symbol (for example, a light flash or an auditory stimulus) or, in fact, it may be "any kind of information that is linked, however indirectly, to a biological activity" (Brown, 1975, p. 9).

A study conducted by Basmajian (1963) involving the fine control of individual motor units is a good example of how effective this process can be. Motor unit potentials were recorded from needle electrodes introduced into the right abductor pullicus brevis, a muscle used in thumb movement. These potentials were presented to the subject in the form of visual and auditory feedback. In half-day sessions, the subjects first learned to maintain slight contractions which were "apparent to themselves only through the response of the apparatus" (p. 440). They next learned to recruit, at will, a single motor unit. Three subjects were able to recruit single units voluntarily, even without the feedback, "but were unable to explain how they could do it" (p. 441). Ten of the eleven subjects, in addition, were able to learn to produce specific rhythms, such as drum beats or roll effects, by recruiting several different units in sequence. Brown (1975) maintains that this process "implies biologically appreciated, non-consciously aware mental associations capable of directly and effectively discriminating and directing physiologic activity" (p. 6).

Indeed, there is considerable evidence derived from the areas of subliminal perception and perceptual defense to indicate that an organism's perceptions and subsequent interpretations of sensory information need not be conscious. Countless investigations have demonstrated that a signal presented at such an intensity as to be below the conscious perception of an alert subject may, nevertheless, result in physiological changes as measured by GSR (galvanic skin response), heart rate, EEG, or blood pressure, indicating that the signal has, in fact, been received by and integrated into the central nervous system (Barratt & Herd, 1964; Libet, Alberts, Wright, & Feinstein, 1967; Riggs & Whittle, 1967; Shevrin, 1975).

Barratt and Herd (1964) found that relaxed subjects who had been presented with an electric shock paired with a subliminal auditory stimulus displayed a "conditioned alpha" response to the stimulus when presented by itself, whereas, control subjects who were similarly stimulated but with no pairing of the shock and the subliminal tone, did not. The authors conclude that "a conditioned response of the alpha rhythm may occur to a subliminal level of stimulation" (p. 18). Shevrin (1975), in analyzing results of a study involving the average evoked response, concurs by stating that "unconscious cognitive processes exist and are of considerable significance" (p. 395). Likewise, Posner and Boies (1971) support this view by concluding from their work involving attention, "conscious awareness is itself rather late in the sequence of mental processing" (p. 407). In addition, Galin (1974) presents evidence from studies involving right and left hemisphere specialization which seem to implicate an anatomical locus for subconscious mental processes. It is Galin's hypothesis that in normal humans, subconscious mental events arising from activity in the right hemisphere may become functionally disconnected from events occurring in the left hemisphere by inhibition of neuronal transmission across the cerebral commissures. Brown (1975) terms the mechanism by which the subliminal process of information analysis takes place, the "integrative subconscious." She says that the integrative subconscious makes it possible for "complex, high level mental activity (to) operate efficiently and effectively via subconscious mechanisms" (p. 2).

Assuming that the information processing associated with biofeedback techniques is a product of the "integrative subconscious," it may be hypothesized that feedback procedures could be effectively employed even during sleep. Indeed, a number of authors support the notion that information processing, accompanied by physiological changes, does occur as a result of auditory stimulation during sleep (Castaldo & Shevrin, 1970; for a review, see Williams, 1973). An example is an investigation carried out by Oswald, Taylor and Treisman (1960). The authors discovered that sleeping subjects displayed different EEG patterns in response to the sound of their own names as compared to other names. Similarly, MacDonald, Schicht, Frazier, Shallenberger and Edwards (1975) found physiological differences, including changes in finger plethysmograph and heart rate, between presentations of "own name" and "other name" during REM sleep. Both studies seem to support the concept of information processing in the absence of behavioral awareness.

Further evidence is supplied by Evans, Gustafson, O'Connell, Orne and Shor (1970), in a study of sleeping subjects' behavioral responses to verbal commands. Some subjects responded in a pre-determined manner to verbal suggestions which had been administered during Stage I sleep. For example, when a subject entered Stage I sleep, the experimenter administered a suggestion such as, "Whenever I say the word 'pillow' the pillow will feel uncomfortable until you move it." Later in the same sleep stage the cue word 'pillow' was repeated, in an effort to elicit the correct response. A total of 21.2% of all cue words administered were responded to correctly. This figure, however, "fails to capture the dramatic quality of some of the responses and the extent to which they appeared to be purposive reactions" (p. 183).

Results of investigations concerned with both auditory awakening thresholds and habituation during sleep indicate that signals with intensities below that required to awaken the subjects can bring on changes in a number of physiological measures, as well as subjectively appreciated responses (Castaldo & Shevrin, 1970; MacDonald & Carpenter, 1975; Rechtschaffen, Hauri, & Zeitlin, 1966). Rechtschaffen, et al. (1966), in testing a method of determining auditory awakening threshold, found that subjects incorporated into their dreams a tone that was below awakening threshold. Further, MacDonald and Carpenter (1975) detected changes in skin resistance, skin potential, finger plethysmograph, and heart rate as the result of a stimulus estimated to be only ten to fifteen dB above background noise, too faint to awaken any of the 46 subjects.

Could the subawakening stimulation which gives rise to these physiological alterations be used as feedback to condition the mechanism involved? For instance, could rapid eye movement be converted into a tone below the awakening threshold, and then be presented to the organism, resulting in the elimination of those eye movements? From the evidence reviewed above, it seems clear that sleeping subjects can react physiologically to an auditory signal without showing signs of behavioral arousal. It seems equally apparent that biofeedback techniques may be effective at a subconscious level. It may be hypothesized, therefore, that a sleeping subject might be capable of altering a physiological mechanism as a result of feedback, although that feedback is in the form of an auditory signal with an intensity below that required to awaken the subject.

The following describes a method of operant conditioning in which rapid eye movement during sleep is the physiological measure to be altered and in which feedback consists of a 2000 Hz tone presented at an intensity below the awakening threshold of each subject. Although Stoyva and Kamiya (1968) argue quite convincingly that dreaming is only "a hypothetical construct, not directly accessible to public observation" (p. 199), it is a fact that approximately 85% of the time REM sleep occurs, dreaming is reported by awakened subjects (Dement & Wolpert, 1958; Wolpert & Trosman, 1958; Wolpert, 1960). Thus, if sleep accompanied by rapid eye movement is terminated, dreaming should be substantially reduced.

The subject's task in the present experiment was to terminate the auditory stimulus by altering some physiological activity. The only alteration resulting in the termination of the tone was the suppression of rapid eye movement. Consequently, if the subject's "integrative subconscious" was successful in arresting the auditory signal, that subject would concurrently effect the termination of his/her dreams.

Method

Subjects

The subjects were two male and two female undergraduates, 18-25 years old, recruited through an advertisement placed in the student newspaper. Each was screened by means of a simple questionnaire to insure apparent good health, normal sleep patterns, conscientiousness in following experimental instructions, and ability to recall having dreamed. Subjects were informed as to the nature of the experiment and were given a brief explanation of theory and apparatus to be employed. Each subject was observed for a baseline period of up to three nights, followed by six experimental nights. The subjects were instructed to sleep only during the experimental sessions, to take no medication during the experimental period, and to abstain from the consumption of alcohol at least six hours prior to their anticipated bedtime. Importance and reasoning behind such restrictions was explained to each subject. For participating, each subject was paid $20.00

Apparatus

Electrodes monitoring eye movement and EEG were plugged into a three channel Grass Instruments Model 7 Physiograph. Although standards outlined by Rechtschaffen and Kales (1968) recommend paper speed of at least 10 mm/sec, budget restrictions permitted a paper speed of only 6 mm/sec for recording potentials from the electrodes. Connected to the physiograph channel monitoring eye movements, by means of the J6 output, was a REM alarm. The REM alarm is an apparatus designed to detect the onset of rapid eye movement, via information supplied by the physiograph, and to transform the electrical impulses into an auditory stimulus to be presented to the sleeping subject. The stimulus was a tone of approximately 2000 Hz with an intensity of from 15 to 25 dB (see Procedure). The tone was to commence with the onset of rapid eye movement, and continue as long as rapid eye movement persisted; that is, as long as an eye movement potential of at least 100 μv amplitude was detected once each second. The auditory signal was amplified by means of a Maico Instruments audio system and was presented through two loudspeakers located on each side of the bed. A microphone was located near the subject's head to allow communication between experimenter and subject. The bed was situated in an eight foot by six foot soundproof room adjoining the monitoring room.

Procedure

The subject reported to the sleep laboratory approximately one half hour prior to his/her usual bedtime. At that time, the subject was asked to evaluate his/her day, the previous night's sleep, present state of mind, and so on. To detect rapid eye movement, potentials were recorded from Grass Instruments E52 silver cup electrodes implanted in Grass Instruments EC2 electrode cream slightly lateral to the outer canthus of each eye. The reference electrode was a clip type, located on one ear lobe. Changes in muscle tone were to be detected by two silver cup electrodes placed over muscle areas around the chin. However, this procedure proved to be virtually useless in determining REM sleep onset and was discarded after only a few nights. As a result, EEG was recorded on two channels, from electrodes placed on the scalp in the C3 and C4 positions. Again, reference electrodes were clip type, located on the ears. All electrode placements followed the 10-20 System of electrode placement and guidelines suggested by Rechtschaffen and Kales (1968).

The initial night in the lab was primarily for purposes of adaptation, to familiarize the subject with the apparatus to be employed, and to eliminate what is known as the "first night effect" (Agnew, Webb, & Williams, 1966). The authors report that "the first night of laboratory sleep contains more awake periods and less Stage I-REM sleep. There is a delay in the onset of Stages IV and REM and the sleep is more changeable" (p. 263). These effects typically disappear by the second night in the lab.

Portions of the first baseline night were spent determining the appropriate intensity of the tone to be presented at the onset of each REM period. The volume of the tone had to be of sufficient intensity to result in physiological responses, yet below the intensity required to awaken the subject. Studies concerned with auditory awakening thresholds report intensities of around 70 dB above background noise to be the approximate intensity at which subjects may respond physiologically while remaining asleep (Castaldo & Shevrin, 1970; Rechtschaffen, Hauri, & Zeitlin, 1966). Of course, the very nature of these investigations made if necessary to determine the <u>highest</u> intensity at which subjects remained asleep, rather than any intensity which would result in physiological changes in the absence of behavioral arousal.

MacDonald and Carpenter (1975), while conducting research involving habituation of the orienting response in sleep, found that their subjects responded physiologically to a tone approximately 15 dB over background noise, while remaining asleep. At this intensity, however, the authors noted significant habituation to the stimulus, specifically for heart rate and finger plethysmograph. Although habituation of such responses did not appear to present any potential problem in this study, a slightly more intense tone (25 dB) was used as a reference point from which to determine the appropriate intensity for each subject, in an effort to make habituation less likely.

On the first baseline night, a 25 dB tone was presented for 20 sec shortly after the onset of the first REM sleep period. If, at that time, no behavioral arousal was observed, it was assumed that the 25 dB intensity would be appropriate for the succeeding experimental nights. This conclusion was reevaluated throughout the remainder of that night. If, on the other hand, the initial 25 dB tone awakened a subject, intensity was decreased by steps of ten dB during subsequent REM stages until no behavioral arousal was noted. That intensity was then considered appropriate for that subject for succeeding nights in the lab. Two subjects, (Subject #1 and Subject #4), required this procedure. After decreasing the intensity of the tone one step (10 dB), both subjects remained asleep during the next 20 sec presentation.

On subsequent nights the subject retired at his/her normal bedtime and was allowed to sleep as long as eight hours each night. On each experimental night the subject was given the following instructions immediately before retiring: "Each time you start to dream, a tone will be presented, I would like you to terminate the tone by altering some physiological activity."

Each morning, immediately upon awakening, the subject was asked to recall whether he/she had dreamed, how he/she would evaluate the previous night's sleep, and how he/she felt physically and emotionally. Prior to leaving the laboratory the subject was reminded of experimental restrictions concerning naps, use of medication, and consumption of alcohol.

Results

Since the goal of the study was to eliminate periods of rapid eye movement, measurements and evaluations were made in those terms. Scoring of REM stages (Table 1) followed closely the guidelines described by Rechtschaffen and Kales (1968). The only alteration in this method of scoring involved the onset and termination of the REM stages. A REM stage was defined as beginning with the first burst of REM activity and concluding with the last burst of rapid eye movement (Sampson, 1965). Scoring of the REM periods was verified by a second, independent scorer.

Absolute spikes (Table 2) were determined by counting individual eye movement potentials which reached or exceeded 100 μv in amplitude, while EEG channels were recording low voltage, mixed frequency activity.

Table 1

Percent REM and Percent Deprivation (in parentheses) for

Each Subject on Each Night

Subject	Night: Baseline	1	2	3	4	5	6
1	18.27 (0)	4.23 (76.9)	7.11 (61.1)	5.47 (70.1)	3.48 (80.9)	3.87 (78.8)	11.48 (37.2)
2	18.98 (0)	14.45 (23.9)	12.98 (31.6)	11.89 (37.4)	14.89 (21.6)	15.89 (16.3)	14.43 (23.9)
3	9.94 (0)	2.82 (71.6)	11.66 (-17.3)	11.47 (-15.4)	8.94 (10.1)	7.58 (23.7)	1.79 (82.0)
4	15.88 (0)	6.73 (57.6)	5.60 (64.7)	6.90 (56.6)	9.03 (43.1)	10.24 (35.5)	8.71 (45.2)
$\overline{X}$	15.77 (0)	7.06 (57.5)	9.34 (35.0)	8.93 (37.2)	9.09 (38.9)	9.39 (38.6)	9.10 (47.1)

Note. Total mean percent REM for experimental nights = 8.82

Total mean percent deprivation for experimental nights = 42.4

Table 2

Spikes/Minute REM and Absolute Spikes (in parentheses) for

Each Subject on Each Night

	Night						
Subject	Baseline	1	2	3	4	5	6
1	11.25 (830)	13.33 (224)	15.21 (511)	9.13 (219)	13.56 (179)	10.00 (156)	11.15 (542)
2	8.25 (505)	12.79 (783)	7.53 (402)	11.59 (452)	9.51 (622)	9.90 (677)	11.97 (740)
3	5.70 (195)	8.70 (94)	10.32 (446)	8.68 (328)	8.20 (251)	10.22 (282)	9.97 (58)
4	10.00 (594)	11.49 (324)	11.79 (276)	11.49 (317)	12.01 (418)	13.25 (493)	13.30 (431)
$\overline{X}$	8.80 (531)	11.58 (356)	11.21 (409)	10.22 (329)	10.82 (368)	10.84 (402)	11.60 (443)

Note. Total mean spikes/minute REM for experimental nights = 11.05

Total mean absolute spikes for experimental nights = 385

The 100 µv criterion was employed because that was the level at which eye movements activated the REM alarm. Eye movement recordings were calibrated such that bursts of rapid eye movement always measured at least 100 µv and often far exceeded that amplitude.

Data were analyzed using the following measures: 1) Percent REM, which was defined as the percentage of total sleep time spent in REM sleep. 2) Percent Deprivation, defined as the quotient of the percentage of REM time on each experimental night divided by the percentage of REM time of the baseline period, subtracted from 100%. 3) Absolute Spikes, defined as the total number of eye movements per night, which exceeded 100 µv amplitude concurrent with low voltage, mixed frequency EEG readings. 4) Spikes/Minute REM, defined as the number of eye movements per minute of REM sleep, which exceeded 100 µv and which were accompanied by low voltage, mixed frequency EEG.

Data from each of these variables were subjected to analysis of variance using planned comparisons (Grant, 1956). Three different comparisons were tested for each measure. The first comparison tested differences between the baseline period and the six experimental nights. As anticipated, there was a significant decrease in percent REM from the baseline to the experimental nights, $F(1, 3) = 10.82$, $p < .05$. An expected increase in percent deprivation from the baseline period to the experimental nights was also significant, $F(1, 3) = 17.96$, $p < .05$. Similarly, an anticipated increase in spikes/minute REM from baseline to experimental nights was significant, $F(1, 3) = 14.69$, $p < .05$, although no significant change was found in absolute spikes, from baseline to the six experimental nights.

The second comparison analyzed each dependent variable for evidence of a linear trend across the six experimental nights only. None of the measures displayed a significant linear trend. The third analysis tested for the possibility of significant differences between subjects' overall means. Percent REM was significant, $F(3, 18) = 7.51$, $p < .005$, as was percent deprivation, $F(3, 18) = 3.43$, $p < .05$. Similarly, spikes per minute REM was significant, $F(3, 18) = 5.35$, $p < .01$, as well as absolute spikes, $F(3, 18) = 4.69$, $p < .05$. Grant (1956) states that "this will usually be found in the case of reliable measures of performance" (p. 153).

Discussion

The results indicate that a method of REM sleep deprivation using operant conditioning is quite feasible and may, with refinements to the apparatus, prove to be a clean and efficient means of decreasing the time spent in the REM stage while making the task less wearisome for those involved. The findings of the present study also appear to lend support to the multitude of evidence for information processing in the absence of conscious alertness. That all of the subjects were able to arrest the appropriate physiological activity in response to an auditory stimulus below the awakening threshold, seems to indicate the presence of relatively complex mental activity below the level of conscious thought.

Although the mean deprivation for the four subjects was considerably below that achieved by Dement's method of multiple awakenings, the results become more significant when it is realized that the operating efficiency of the REM alarm was, at best, no greater than 75%. That is, on no more than 75% of eye movement potentials reaching or exceeding 100 mv was the auditory signal activated. Since the REM alarm used in this experiment was a prototype, it unfortunately had some characteristics which proved to be quite detrimental to the primary objectives of the study. Besides its erratic nature in responding to the appropriate cues, the alarm was also prone to activation at inappropriate times. Due to budget and time restrictions, the mechanism was designed to react to eye movements of a set amplitude, regardless of EEG readings. As a result, the tone was frequently activated by eye movements accompanying brief awakenings and gross body movements which occurred throughout the night.

Now, one of the principal reasons for developing this process of REM sleep deprivation was to make the research task less arduous for both subjects and experimenters. However, with the aforementioned flaw in the apparatus, the experimenter was required to manually terminate the inappropriate signals. This, of course, made it imperative that the experimenter remain awake all night, each experimental night. This difficulty could have been remedied by simply making the auditory signal's onset contingent on low voltage, mixed frequency EEG potentials, as well as on eye movements of a specified amplitude. But, by the time the problem was realized, the experiment was already underway, and the functioning of the REM alarm could not be easily altered.

The wearisome nature of the subjects' task, on the other hand, was substantially reduced since their sleep was virtually uninterrupted. All subjects reported sound and restful sleep, and three of the subjects (#1, #3, and #4) reported that nights in the laboratory were typically more restful than an average night in their own beds. A frequent complaint of all subjects, however, involved the discomfort of the reference electrodes. The use of these ear-clip electrodes for extensive periods resulted in skin irritation, itching, peeling, and on one occasion bleeding from the ear lobes, and are therefore strongly discouraged for use in sleep studies.

REM rebound, as measured by increased dream attempts across nights or decreased latency to the onset of the first REM period, was not apparent, although increases in the frequency of eye movements per minute of REM sleep were. A typical strategy for reducing REM time was followed by all of the subjects. On the more successful nights, subjects omitted the greater portion of their first REM stage, and decreased the length of subsequent REM episodes. Records from less successful nights usually showed the same number of dream attempts, but with each REM period persisting longer.

The results of the second comparison, testing for evidence of a linear trend across the six experimental nights, were not anticipated. It was expected that a significant trend downward for percent REM, and consequently an upward trend for percent deprivation would be found. That is, it was thought that learning would occur gradually over the experimental nights. However, since there is evidence of one-session conditioning of the alpha rhythm to subliminal stimulation (Barratt & Herd, 1964), and in light of Basmajian's (1963) success in half-day sessions (see Introduction), the results are not surprising.

Although the female subjects were more successful in arresting REM sleep than were the males, it is impossible to attribute these results to differences in sex. Since sex differences have not been extensively reported in REM sleep deprivation studies or in research concerned with information processing during sleep, and since the sample size in the present experiment is so small, any speculation regarding sex differences would be inappropriate.

The ease with which the subjects adapted to the experimental situation was, however, a factor which did seem to contribute to the degree of success of a subject to decrease REM sleep time. Subjects #1 and #4 were, without question, more relaxed upon entering the lab each night and the most consistent in pre-sleep regimen, as well as latency to sleep onset. Rather than "trying" to go to sleep immediately, as was the case for Subjects #2 and #3, Subjects #1 and #4 read until they became sleepy and then asked for lights out. As a result, sleep onset was invaribly quicker and more consistent, and restlessness during the night was greatly reduced. While relaxation is obviously an asset in many task-related experimental situations, sleep studies may be especially influenced by the comfort of the subject.

The deprivation process seemed to become less effective toward the morning hours. Frequently, the large majority of total REM time was accumulated during the last REM episode of the night. It might be hypothesized then, that REM rebound occurred nightly, rather than amassing night upon night. The literature suggests that auditory thresholds decrease with accumulated sleep (Rechtschaffen, Hauri, & Zeitlin, 1966; Shapiro, Goodenough, & Gryler, 1963; Goodenough, Lewis, Shapiro, Jaret, & Sleser, 1965). Thus, it must be assumed that the REM alarm was discerned by the subjects at least as well during the last REM period as it was during the previous REM stages, and consequently, should have resulted in a proportionate amount of deprivation. A nightly rebound effect would seem to account for the contrary findings. Regardless of the reason for this loss of effectiveness with accumulated sleep, the process <u>is</u> most efficient during the first 5-5½ hours of sleep. Perhaps the use of the present method combined with a less radical version of Sampson's (1965) process of partial sleep deprivation would produce the maximum deprivation of REM sleep.

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