Latent learning impaired by REM sleep deprivation*

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Stage REM sleep may be involved in some forms of learning. This hypothesis was examined by studying the effects of Stage REM deprivation in Blodgett's latent-learning situation. Stage REM deprivation blocked the appearance of the latent-learning effect, suggesting that adaptive coping of this sort is dependent upon Stage REM sleep.

The function of Stage REM sleep has remained enigmatic despite extensive research (Snyder, 1969). Indirect evidence has suggested that Stage REM (dreaming) involves the integration of past and present experience leading to effective coping (Breger, 1967; Greenberg, 1970; Pearlman, 1970). The simplest forms of coping, such as avoidance of a dangerous situation (Joy & Prinz, 1969), could not be dependent upon Stage REM because this would be inconsistent with survival. The utilization of more complex bits of previous experience which have recently become important to the organism might involve Stage REM. As formulated by Dewan (1970) and Bryson & Schacher (1969), reprogramming of this sort would interfere with the performance of existing programs if both were to occur simultaneously during waking. Thus, reprogramming could be accomplished efficiently during Stage REM. Retention of some types of learning is impaired by Stage REM deprivation (Fishbein, 1970; Leconte & Bloch, 1970), consistent with this hypothesis.

Another experimental approach to this problem is provided by the latent-learning situation. Blodgett's (1929) classic study showed that rats given daily trials in a maze with no reward showed little reduction in blind alley (cul) entries and running speed, compared with animals which were rewarded following each completion of the maze. If the unrewarded animals were then given a reward on the fourth day, their performance on the following day improved markedly and was indistinguishable from that of the regularly rewarded animals. Blodgett concluded that the animals had acquired a latent knowledge of the maze during the unrewarded trials and that the great improvement resulted from integration of the reinforcement with this knowledge.

The present study consisted of two parts. First, Blodgett's procedure was replicated with interpolation of Stage REM deprivation between the rewarded trial and the trial on the following day. Then, an attempt was made to localize the effect of REM deprivation more precisely by confining the learning situation to a goalbox with no maze. The procedure of Tenen (1965) and Pinel (1969) was used, with interpolation of REM deprivation between the rewarded trial and the retention trial on the following day.

METHOD

Forty male albino rats, 3-4 months old, were placed on a 1-h/day feeding schedule and reduced to 90% of their original weights. After a week on the schedule, 32 were given one trial per day in a six-unit multiple-T-maze, identical to Blodgett's except for the absence of doors at choice points. Trials were run under 23 h of food deprivation, and supplemental feeding was given an hour later. The number of cul entries and the time to traverse the maze were recorded. If an animal had not completed the maze in 15 min, it was removed. Thus, habituation to the maze was kept relatively equal for all animals. Twenty Ss had one or two incomplete trials. They were equally divided between experimental and control groups. On the fourth day of training, the animals found food in the goalbox for the first time. Following their supplemental feeding, 16 animals were deprived of REM sleep by being placed on islands (about 7 cm in diam) in a pool of water (Morden, Mitchell, & Dement, 1967) until 3 h before the trial on the following day. EEG recordings of two other animals indicated that the deprivation of REM sleep by this technique was selective. Each animal had several REM periods of a few seconds' duration, which were abruptly interrupted by awakening or return to slow-wave sleep (total less than 1% of time asleep). The amount of non-REM sleep (53% and 38% of the 24-h period) was similar to that observed under normal conditions (Duncan et al, 1968; Mouret, Pujol, & Kiyona, 1969), suggesting that little loss of non-REM sleep had occurred. Sixteen animals formed a control group for the stressful aspects of the REM-deprivation procedure. They were immersed in cool water for 20 min to 1 h at varying intervals prior to the trial on the fifth day. This experience seemed more stressful than the REM-deprivation procedure. The controls always became exhausted and frequently had to be removed from the water to avoid drowning. They required more than 3 h to recover sufficiently to be able to run the maze. REM-deprived animals showed only the characteristic transient irritability and hyperactivity following removal from the island. When the 3-h period before the maze trial had elapsed, measurements of spontaneous activity of the REM-deprived animals did not differ from baseline values. On the fifth day, both groups ran the maze to

Table 1
Mean Values (Ranges in Parentheses) for Rewarded Trial and Test Trial (16 Animals in Each Group)

	REM Deprived		Stress Control	
	Cul Entries	Time (Sec)	Cul Entries	Time (Sec)
Group mean on fourth trial	7.2 (1-37)	115 (42-517)	10.1 (1-39)	206 (27-637)
Group mean on fifth trial	7.8 (2-17)	137 (25-383)	6.1 (1-26)	119 (21-612)
Mean percentage improvement for each S between fourth and fifth trials	−178%* (65 to −1100)	−76%* (49 to −463)	11% (95 to −200)	18% (96 to −193)

**Differs from stress control group ($p < .01$)*

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Table 2
Mean Number of Explorations (Ranges in Parentheses) During Third Trial and Test Trial (Four Animals in Each Group)

	REM Deprived	Stress Control
Group mean of third trial	4.0 (2-7)	1.8 (1-3)
Group mean of test trial	7.2 (4-10)	3.2 (2-5)
Mean percentage increase for each S between test trial and third trial	98% (43-166)	110% (0-200)

an empty goalbox with wet food outside its walls.

In the second experiment, the eight remaining animals were given daily 5-min trials in an apparatus like that of Pinel. It consisted of a box with a small niche in one wall. The number of times each animal explored the niche was recorded by a photoelectrically activated counter. The feeding schedule was similar to that of the first experiment. On the fourth day of training, the animals found food in the niche. Four animals were then REM-deprived, and four were given the stress control treatment. On the following day, the animals had another trial with an empty niche.

RESULTS

Most of the stress control animals showed the expected striking reduction in cul entries and running time on the fifth day. The performance of REM-deprived animals ranged from somewhat worse to slightly better than on the preceding day. For statistical evaluation, each animal was used as its own control. A measure of percentage improvement for each rat was calculated from the difference between performance on the fourth day and the fifth day divided by that on the fourth day. The Mann-Whitney U test showed the REM-deprived and stress-control groups to differ significantly in degree of reduction of cul entries ($p < .01$) and of running time ($p < .01$). Mean values for the two groups are shown in Table 1.

In the Pinel box, however, REM-deprived and control groups showed an equal increase in number of niche explorations, compared to the day prior to the rewarded trial. Percentage increases, calculated as in the Blodgett experiment, showed no significant difference between the groups. Mean values appear in Table 2.

DISCUSSION

The results suggest that REM deprivation prevented integration of the unrewarded maze exploration with the reinforcement experience. The concept of integration is important because the results with the one-trial appetitive procedure indicate that REM deprivation produced no deficit in retention of information about the reinforcement.

An alternative interpretation of the effect of REM deprivation has been proposed by Albert, Cicala, & Siegel (1970). They suggested that REM deprivation produces a drive state analogous to hunger, sensitizing the animal to environmental stimuli, with resultant increase in exploratory behavior. The one-trial appetitive procedure, however, showed no difference in exploratory behavior between REM-deprived and control animals. Some of my unpublished work has shown that 1 day of REM deprivation does not produce a significant increase in rate of barpressing for continuous food reward. Joy & Prinz (1969) also failed to find an effect of REM deprivation upon simple conditioned avoidance learning. The increased rate of hypothalamic self-stimulation following REM deprivation found by Ellman & Steiner (1969) might suggest some alternation in motivational state, but it seems likely that learned activities closely related to the rat's instinctive behavior are unaffected by REM deprivation. Thus, the REM state appears to operate at the more complex level involved in latent learning and two-way avoidance (Leconte & Bloch, 1970).

Previous work with this REM-deprivation procedure has raised questions about whether the crucial variable is really REM deprivation or some nonspecific factor such as stress, fatigue due to total sleep loss, or hyperactivity following confinement upon the small pot (Leconte & Bloch, 1970; Mark et al, 1969). An attempt was made to control each of these factors. A short period of REM deprivation was used. The control group underwent a stressful experience at least equal to that of the REM-deprived group. Non-REM sleep loss seemed minimal, and the hyperactivity of the REM-deprived animals had subsided before testing. The issue could be settled by studying animals following recovery from REM deprivation. This work is now in progress, and preliminary results confirm the findings of the present study.

REM sleep is associated with phenomena ranging from the fleeting, but fascinating, dream to the periodic peremptory activation of the sleeping brain appearing throughout the mammalian kingdom. The enigmatic quality of REM sleep has arisen, in part, from the difficulty of devising a theory to connect these differing phenomena. The idea of effective coping is such a psychophysiological bridge. The present data should be added to the evidence implicating REM sleep in the reorganizing and synthesizing activity of the brain (Oswald, 1969).

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