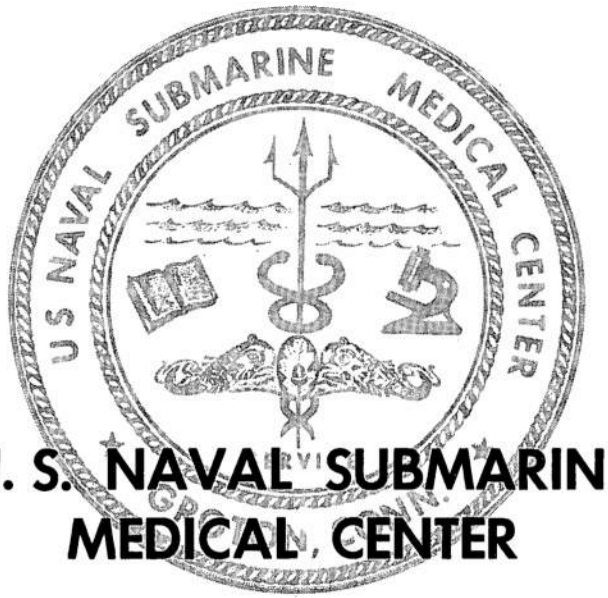

U. S. NAVAL SUBMARINE MEDICAL CENTER

Submarine Base, Groton, Conn.

REPORT NUMBER 563

EFFECT OF RAPID EYE MOVEMENT (DREAMING) SLEEP DEPRIVATION ON RETENTION OF AVOIDANCE LEARNING IN RATS

by

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Research Work Unit MR011.01-5010.01

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SUBMARINE MEDICAL RESEARCH LABORATORY
U. S. NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 563

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR011.01-5010.01

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SUMMARY PAGE

THE PROBLEM

To determine whether the rapid eye movement (REM) stage of sleep is involved in the retention of a simple learning experience in rats.

FINDINGS

Deprivation of REM sleep abolishes retention of an incompletely learned passive avoidance response in rats.

APPLICATION

The results suggest that REM sleep is necessary for adaptation to new experiences, especially those which cannot be completely understood on first exposure. Sleep disturbance may be a significant factor in the failure to adapt adequately to a crisis situation. A recent report describing a high incidence of transient sleep disturbance during Polaris submarine patrols suggests that this factor may be a more important aspect of vulnerability to the problems of submarine life than has previously been suspected.

ADMINISTRATIVE INFORMATION

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ABSTRACT

The effect of deprivation of rapid eye movement (REM) sleep upon retention of a passive avoidance response was studied in rats. An incompletely-learned avoidance response was established in one trial by shocking the animals when they stepped down from an elevated platform. Fourteen animals were then deprived of REM sleep by placing them on small inverted pots in a pool of water. Twelve control animals were placed on slightly larger pots which permitted normal sleep. None of the REM-deprived animals showed retention of the response when tested the day after training, whereas 60 percent of the control animals showed retention. The results suggested that REM sleep is essential for adequate adaptation to new experiences, especially those which cannot be completely comprehended upon first exposure.

EFFECT OF RAPID EYE MOVEMENT (DREAMING) SLEEP DEPRIVATION ON RETENTION OF AVOIDANCE LEARNING IN RATS*

INTRODUCTION

The question of whether sleep is involved in adaptation or the learning process has periodically been considered since antiquity. Until recently, psychoanalysts were the only workers with extensive access to the mental concomitants of sleep, and their clinical judgments about the function of dreaming varied (Hawkins, 1966). Freud favored the hypothesis that dreams served to discharge instinctual drive tensions which otherwise might interfere with sleep. Other analysts, like Adler and Maeder, believed that dreams were primarily concerned with search for solutions to unsolved problems. French and Fromm (1964) presented extensive evidence that dream content was related to current emotional conflicts of the dreamer and frequently showed clear attempts to resolve these conflicts. On the basis of a clinical observation that sensations which have not recently been perceived do not appear in dream material, Greenberg and Leiderman (1966) speculated that dreaming might serve to transfer recent perceptions from a short-term system for the influx of new perceptions on the following day.

Recent discussions of psychoanalytic theory (Modell, 1963) have suggested that the concept of 'drive discharge' is a clinical metaphor, and should not be seriously considered as a basic mechanism of dreaming. Furthermore, it is now known that dreaming is much more than an epiphenomenon for the protection of sleep. The D-state or REM state, as it is now commonly called because of its characteristic rapid eye movements, occurs throughout the mammalian kingdom and occupies about a fifth of the time spent asleep. The many distinctive physiological characteristics of the REM state justify its designation as a 'third state of existence' separate from non-dreaming sleep and waking (Hartmann, 1965). In particular, the brain is intensely active during REM sleep, which suggests an important biological function. Further support for this notion was provided by Dement's striking finding that subjects deprived of dreaming by being awakened whenever their EEG showed the characteristic pattern of REM sleep, show a marked increase in dreaming when allowed to sleep undisturbed (Dement, 1960).

Consideration of the apparent protective effect of sleep upon retention of recently learned material (Van Ormer, 1932) and the unexplained phenomenon of reminiscence — greater retention on the day after a learning trial than immediately following the trial (McGeoch and Irion, 1952)—suggested that the cerebral activity of the REM state might serve to consolidate memory for recently learned material analogous to the proposal of Greenberg and Leiderman (1966). Our initial research (Pearlman and Greenberg, 1965) failed to provide evidence for this hypothesis. We found that depriving subjects of dreaming had no significant deleterious effect upon retention of various types of verbal learning such as nonsense syllables, vivid stories, and long lists of paired associates.

Study of the effects of dream deprivation upon personality patterns revealed by projective testing (Greenberg, Pearlman, Kawlische, Kantrowitz, and Fingar, 1968) and of the process of dreaming in patients with Korsakoff's psychosis (Greenberg, Pearlman, Brooks, Mayer, and Hartmann, 1968) suggested a refinement of the hypothesis. Instead of a general role of dreaming in all aspects of memory formation, it was proposed that dreaming was involved only in the integration of emotionally significant experiences with the existing personality structure. Very similar hypotheses were simultaneously and independently formulated by Dewan (1967) and Breger (1967).

*This paper was presented by the author at the annual meeting of the Association for the Psychophysiological Study of Sleep, Denver, Colo., Mar. 24, 1968.

The revised hypothesis places more emphasis upon the adaptive function of dreaming in adjusting to new experiences. It suggests that dream deprivation would seriously hamper the ability of a subject to learn to cope with stressful experiences even though his memory function might be unimpaired on conventional tests and his behavior remained grossly within normal limits. Similar clinical observations are commonplace in the literature on effects of sleep deprivation, but they have previously been ascribed to 'fatigue' or other non-specific effects of sleep loss (Murray, 1965).

An experimental analogue of this model in the rat is suggested by the findings of Kamin (1957). Kamin showed that retention of an incompletely learned avoidance response does not follow a normal forgetting curve. He trained rats in a shuttle box until they showed correct avoidance on six out of ten trials (60%) and then tested different groups for retention of the avoidance response at various intervals following the initial training. At one hour after training, the animals showed a conventional drop to 20% correct responding; at six hours, however, retention **increased** to 40%, and by 24 hours, the animals once again showed 60% correct responding. The only significant intervening process is sleep. A passive protection of the memory trace during sleep from interfering new experience could not account for the increase in retention. Thus, an active memory process is suggested, perhaps analogous to the perseverative neural activity involved in the consolidation process (Glickman, 1961), which would most probably occur during the REM state.

METHOD AND RESULTS

Subjects were 26 Holtzman rats, three to four months old. The procedure was a modification of Kamin's technique suitable for one-trial learning. Each rat was placed on an elevated platform which was then lowered to a table top. As the animal stepped from the platform to explore the table top, it received a mild shock to its feet. For details, consult Pearlman (1966). The intensity of the shock (1.4 ma.) was selected so that about 60% of the control animals would show evidence of retention of the shock experience by freezing for more than ten seconds when placed on the platform 24 hours later. Fourteen animals were REM deprived by placing them on small inverted pots in a pool of water during the 24 hours following the shock (cf. Morden, Mitchell, and Dement, 1967). Twelve control animals were placed on slightly larger pots which permitted the muscular relaxation of REM sleep without making the rat fall into the water. On the following day, **none** of the 14 REM-deprived rats showed retention of the avoidance response whereas seven of the twelve controls (58%) did.

DISCUSSION

These results tend to confirm the existence of an active memory process occurring during REM sleep. It is possible that the REM deprivation procedure is simply a traumatic interfering experience which blots out memory of immediately preceding experiences. Observations of the behavior of the animals and the relatively small differences between the REM deprivation and control situations tend to contradict this interpretation. This question can be definitely resolved only through further work. Another possible complication arises from the fact that some rats do not sleep normally on the small pots so that some of the results might be ascribed to sleep loss rather than to selective REM deprivation. Further research with more precise techniques of REM deprivation will be necessary to avoid this problem.

The striking effect of a brief period of REM deprivation upon retention contrasts markedly with the essential absence of alteration of other aspects of behavior. Since most animal learning is closely tied to interference with instinctual drive function with obvious emotional concomitants, one would expect a more prominent effect of REM deprivation in animals than in humans, that are capable of extensive learning through symbolic operations which require little instinctual or emotional involvement. Some recent research suggests, however, that emotional

or adaptive learning in humans may also be highly sensitive to REM deprivation. Greenberg, Pillard, and Pearlman (1968) found that REM deprivation prevents the conventional habituation of autonomic response and anxiety on repeated viewing of a frightening film. These results and those of Greenberg, Pearlman, Kawlische, Kantrowitz, and Fingar (1968) suggest that dreaming serves a kind of homeostatic function with regard to stressful experiences. During dreaming, the brain functions to adapt to stressful experiences of the preceding day, so that they are no longer disturbing to the individual.

REM deprivation appears to prevent the integration of the shock experience into the animal's store of knowledge of its **umwelt** with resultant obvious deficiency in coping behavior. A similar effect of dream deprivation upon the ability of humans to adapt well to stressful conditions like combat seems likely but remains to be investigated. The possible importance of this factor increases with realization that anxiety itself produces a marked reduction in amount of REM sleep even when subjects are allowed to sleep without interruption (Rechtschaffen & Verdone, 1964).

The relevance of these findings to submarine research is not immediately apparent since sleep disturbance is not commonly reported as a problem in adjustment to patrols on nuclear submarines. A recent paper by Earls (1969) suggests that transient periods of sleep disturbance are much more frequent than has previously been realized. Perhaps, this omission is due to the general tendency of people to minimize and forget the unpleasant aspects of an experience once it is over. Periodic disturbance in REM sleep (Hawkins and Mendels, 1966) appears to be a regular part of life on a nuclear submarine and thus, the factor of impaired adaptation to unexpected experiences implied by the present findings may be more significant than has previously been recognized.

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