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Differential effects of REM and non-REM awakenings on the spiral aftereffect

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Fourteen Ss were awakened 2 min after the beginning of a REM period and 5 min after the end of a REM period, and were tested on a spiral aftereffect. The duration of a spiral aftereffect was found to be longer for the tests made following REM periods than for the tests made following non-REM periods. The results were interpreted to indicate penetration of a cortical arousal during the REM period into wakefulness. The "carry-over" effect from the sleep stages into the waking state lends support to the theory that the REM state may be superimposed as an ultradian cycle on the 24 h.

Until recently, the three stages of consciousness-wakefulness, REM sleep (rapid eye movement sleep), and non-REM sleep were thought to be different phases of a 24-h cycle, each controlled by different neural mechanisms. The concept of three separate states of consciousness has been questioned in the last few years by research suggesting that the REM state might be superimposed as an ultradian cycle throughout the 24 h, including both wakefulness and sleep (Webb, Agnew, & Sternthal, 1966; Globus, 1971; Kripke, 1968; Othmer, Hayden, & Segelton, 1969; and others).

A possible method of demonstrating the penetration of the REM state into wakefulness is by showing that the periods of wakefulness following REM states are different qualitatively from periods following non-REM sleep. Surprisingly enough, little research has been done in order to observe possible differences between these two wakefulness periods. Fiss et al (1966) found indirect evidence that the REM state, or part of it, penetrates into wakefulness when he found that responses to the Thematic Apperception Test following awakening from REM sleep were more "bizarre" and more "dream like" than responses following awakening from non-REM sleep.

A different method, using the spiral aftereffect (SAE) as an index for cortical excitation level, was suggested by Lavie and Giora (1973). The duration of the SAE tested following awakening from REM sleep was longer than the duration of the SAE tested after awakening from non-REM sleep. The differential SAE was explained as a result of the penetration of the highly activated REM state into wakefulness. However, since Ss were tested for only a short time (4-5 min) following the awakening, the differential durations could be only a short by-product of the previous phase of sleep, which decays after some minutes.

The purpose of this experiment was to show that Ss awakened from REM and from non-REM states continue to resemble different cortical arousal levels for a period of at least 15 min.

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METHOD

Fourteen naive Ss, men and women whose ages were from 17 to 27 years, were tested. Ss were asked to avoid alcohol, drugs, etc., during the day preceding the night the data were accumulated. Ss reported to the laboratory on the experimental night 1 h before their usual bedtimes. Upon their arrival, they were fitted with electrodes to record their EEG and EOG. Two channels of information were recorded from each S: bipolar electroculogram (EOG) from the outer canthus of the left eye, the outer canthus of the right eye, and an ear reference point; and a bipolar electroencephalogram (EEG), prefrontal-postfrontal. Polygraphic recordings were plotted on a six-channel Grass Model 5D polygraph. Then the Ss were taken to the bedroom, a soundproof chamber connected to the control room by an intercom system.

The SAE apparatus used was a white 7-cm disk with a black Archimedes spiral rotated in a counterclockwise direction at 80 rpm for 30 sec each time. The apparatus, which was operated from the control room, was located near the bed on a small table, with the center of the spiral about 1.5 ft from the ground. Ss observed the spiral while lying on the bed, from approximately 4 ft. Ss were instructed to look steadily at the spiral as it spun, to continue to look at the spiral after it stopped, and to report verbally with the word "stop" when they stopped seeing any kind of motion. The duration of the illusion was timed by a stopwatch.

After being connected to the polygraph, Ss were given an experience with SAE to familiarize them with the phenomenon. Ss were then tested three times on the SAE. Each test included four trials, and the average score of the four trials was the score of the test. The intertrial interval was 10 sec within each block of four trials. Between blocks of trials, Ss were given 2 min of rest. The approximate time for the three test blocks was 15-17 min. After the test, Ss went to sleep. During the night, Ss were awakened twice: first, 2 min after the beginning of the REM period (REM No. 1 or 2), and then 5 min after the end of the next REM period from Stage 2. The order of awakenings was balanced across the nights in a systematic fashion; that is, if the first S had the order of REM No. 1, non-REM No. 2, the second S had the order of non-REM No. 1, REM No. 2. Assignment of Ss to these orders was made randomly.

Ss were awakened by being called by their first names. They were given 1½ min to adapt to the light, which was standard fluorescent light, and then they were tested on the SAE in the same way as they had been tested before sleep. During the 2 min between the blocks, Ss were kept awake by controlled conversation.

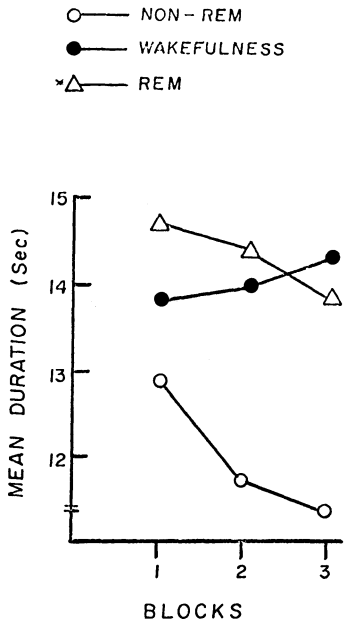

Fig. 1. Average durations made on 14 Ss for REM and non-REM awakenings and wakefulness for the three blocks of trials.

RESULTS

The means of the three blocks of trials in the three conditions are presented in Fig. 1. Twelve Ss had higher durations of SAE for REM than for Non-REM. Two Ss showed the same durations.

Analysis of variance, repeated measures design, was performed on the mean durations. The duration of the SAE after awakening from REM sleep, after awakening from non-REM sleep, and before sleep differ significantly ($F = 5.26$, $df = 2/26$, $p < .025$). The statistic q (suggested by Tukey, 1951) was used in order to test for differences among the three durations. The duration of the SAE following awakening from REM sleep was longer than the duration of the SAE following awakening from non-REM sleep, and the wakefulness durations were significantly longer than the non-REM durations. No difference was found between the REM durations and the wakefulness durations.

Each block of trials following REM awakening was compared to each corresponding block of trials following non-REM periods. All the comparisons were significant in the expected direction: Block 1, $t = 1.92$, $0.1 > p > .05$; Block 2, $t = 2.91$, $p < .01$; Block 3, $t = 2.67$, $p < .02$. The critical t (one-tailed test) suggested by Cochran and Cox (1957) was used for the above comparisons. The order of awakening and the blocks of trials had no effect on the durations of the SAE.

DISCUSSION

These results agree with the results reported by Lavie and Giora (1973). The significant difference in the SAE durations strongly suggests that the cortical excitation levels associated with the two phases of sleep continued into wakefulness when the Ss were awakened. The reported data agree with the observations made by Broughton (1968) on a difference in visual evoked responses upon awakening from REM sleep and non-REM sleep. While the REM awakenings resulted in evoked responses similar to evoked responses obtained during the waking state, awakening from non-REM sleep resulted in evoked responses that resembled the EEG characteristics of non-REM sleep. These results lend support to the suggestion made by Jouvet (1962) and Hubel and Nauta (1960) that EEG activation and behavioral arousal after awakening from non-REM sleep are not initiated by the same mechanisms that are responsible for the cortical arousal during REM phases.

The decrease in the duration of the SAE following awakening from non-REM sleep is similar to the decrease in the duration of the illusion found under the influence of CNS depressants (Costello, 1963). This decrease is consistent with the assumption that cortical activities are inhibited during non-REM sleep, as suggested by many researchers (cf. Jouvet, 1967). The existence of differential perception of the spiral aftereffect following awakening from REM sleep and non-REM sleep agrees with the recent accumulation of data which question the existence of REM sleep, non-REM sleep, and waking as three separate states of consciousness.

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