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11. Partially supported by NIMH research grant MH-13705-01, general bio-medical sciences grant SOS FR 07045-03 to D.G.S., and by NSF grant GB-7041 to D.G.S. and J.J.B.

14 May 1969; revised 9 July 1969

Rapid Eye Movement Sleep: A Sleep-Dependent Process

Othmer *et al.* (*1*) reported that cyclic patterns of brain activity, similar to those that occur during sleep (*2*), also continue during daytime wakefulness. Their conclusions, if valid, would have fundamental implications for the function and nature of rapid eye movement (REM) sleep processes. However, they are based on measurements of only a single variable, REM itself, as representative of continuing cycles of brain activity throughout the 24-hour period. I take exception to their analysis for the following reasons:

1) Rapid eye movement is only one of a large constellation of physiological manifestations of REM sleep. To conclude that the periodic cerebral activity pattern of REM sleep continues during wakefulness by day on the basis of gross similarities of eye movement patterns alone is unjustified. That REM normally occurs during daytime wakefulness is axiomatic. Indeed, one of the characteristics used to define wakefulness is the presence of REM (*3*). It is well known that REM sleep occurs during daytime naps (*4–6*), so that REM sleep in normal individuals is contingent upon the prior occurrence of nonrapid eye movement (NREM) sleep, with the proportion of NREM sleep following a diurnal rhythm corresponding closely to that of body temperature (*4*).

To support their conclusions, Othmer *et al.* would have to demonstrate either that REM sleep occurs periodically during extended periods of wakefulness, or that during wakefulness there exist periods of REM accompanied by other activated physiological patterns of brain and body activity alternating with periods of relative ocular quiescence and reduced physiological activity. Neither of these alternatives was evident in their results.

2) Othmer *et al.* attempted to show that subjects exhibited periods of wakefulness accompanied by eye movements similar to those of REM sleep. As illustrations they presented two examples (their Fig. 2, IIIA and IIIB) of the polygraphic recordings during such periods which are ambiguous for scoring. As well as can be judged, the electroencephalogram (EEG) in these two examples is not one of unambiguous wakefulness characterized by predominant alpha rhythm, as shown in section IV of the same figure. Rather, the EEG more closely resembles that of stage 1 sleep, shown in section V, with slow rolling eye movements present and in sections I and II of REM sleep. Although alpha rhythms are evident, they appear to constitute less than 50 percent of the record. Taken together with the presence of REM's and absence of muscle tone, I would classify these samples as stage REM sleep (*3*).

It would seem most important to have shown examples of wakefulness without REM, which occurred for periods exceeding 2 hours as indicated in Fig. 1. Examples of transitions from such periods into wakefulness accompanied by REM would also have been more informative than an arbitrary example of an extreme form of waking voluntary eye movement (Fig. 2, IV). Periods of wakefulness as long as 2 hours unaccompanied by rapid eye movements must represent a remarkable phenomenon.

3) Othmer *et al.* conclude "that REM occurs at intervals throughout a 24-hour period and not solely during the usual periods of sleep." Even if one grants that the reported wakeful periods accompanied by REM were indeed genuine wakefulness, subject 1 failed to display such periods under three of the four conditions, subject 3 only once on each of three of the conditions and not at all under condition II, and subject 2 on only two occasions during conditions I and IV (Fig. 1).

4) The article contains insufficient description of the experimental methods and is replete with incongruous data. No description of the electrode placements for recording the EEG, electrooculogram (EOG), and electromyogram (EMG) was given, nor was there a description of the time constants used, which are especially important in the evaluation of the EOG. The speed of the recordings shown in Fig. 2 is indicated neither by a time marking nor in the text. Othmer *et al.* give no quantitative criteria for discriminating between single REM's and bursts of REM's, but merely present two ambiguous illustrations of the distinction (Fig. 2, IIIA and IIIB).

What were the instructions given to the subjects, and what were they told regarding the purpose of the experiment? It would seem crucial that the subjects be naive about the nature of the investigation? What exactly are "eye-rollers"? Why were two of the subjects studied after nights when they themselves reported lack of sleep? Clearly, sleep deprivation disrupts the normal patterns of sleep and wakefulness (*7*). Adaptation nights prior to the experimental sessions would have been desirable.

What was the rationale for the adoption of the different conditions and especially for waking subjects after 3 minutes of stage 2 sleep under condition (iv)? Figure 1 incomprehensibly shows that all subjects had at least as much if not more stage 2 under condition (iv) as under any of the other three conditions! Moreover, immediate transitions from stage W to stages 3 and 4 under this condition, as the authors describe in the text are not evident in a single instance in the same figure; in fact, it shows subject 2 to have had small amounts of stage 3, while subjects 1 and 3 had no stage 3 or 4 sleep at all.

The characteristics of the nighttime sleep bear little resemblance to those which have been almost universally reported by others. During the initial

8 hours of nighttime sleep, the amounts of time spent in stage 2 by each subject under each condition are abnormally low, well below the typical value of 50 percent of the total sleep time (*8*), while values of stages 3 and 4 are abnormally high (Fig. 1). Stages 3 and 4 are also unusual in occurring throughout the entire night, rather than only during the first few hours of sleep. One must conclude either that the authors did not score the records according to the conventional procedures (*3*) as they claimed or that all the subjects were suffering from severe sleep deprivation (*7*). Figure 1 also shows several periods marked by solid areas, extending higher than the stage 4 level on the ordinate, which are left unexplained.

The authors reported retrieval of mental activity during different periods of wakefulness. Presumably this means that subjects were being interviewed at times during the experiment in addition to those described under condition (iv). These interventions should have been described and accounted for, since they might well have influenced the results.

The times at which meals were taken were not controlled. Food intake might have a profound effect on activity cycles, and this should have been held to fixed times in all subjects and under all conditions for purposes of comparability.

5) Although the data of Othmer *et al.* do not support their conclusions regarding the independence of REM sleep processes from sleep itself, studies by Globus (*6*) do support this conclusion. Globus observed that the occurrences of REM sleep periods during afternoon naps were determined by real time and not by the time of prior stage 2 sleep onset, which was systematically varied.

Finally, Othmer *et al.* identify REM sleep as the time at which dreaming occurs with no reference to the considerable data which indicate that dreams also occur during NREM sleep (*9*).

Present knowledge indicates that, in the adult, the REM sleep process is unique to the sleep state itself and that REM sleep may serve cerebral-activating functions normally contingent upon the prior occurrence of NREM sleep (*10*). Data presented by Othmer *et al.* would not seem to contradict this statement.

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14 May 1969; revised 7 July 1969

Lunar Thermal Anomalies: Magnetic Phase Transitions on the Lunar Surface?

Allen and Ney (*1*) recently discussed the anomalous behavior of temperature-time cooling data for surface material of the lunar craters Tycho, Copernicus, and Aristarchus as determined by infrared measurements. The conspicuous feature of these anomalies is an initially rapid decrease in the brightness temperature to 170 ± 30°K, with the temperature then remaining nearly constant through the rest of the lunar night, whereas the temperature normally falls to about 90°K in most other areas of the lunar surface. Allen and Ney suggest that the thermal anomalies are evidence that the craters contain hot and cold regions—with the hot portions (rock fragments 1 m or larger in size, constituting 2 to 10 percent of the areas) having a color temperature of 220°K. These fragments are thought to be "thermally connected to a subsurface temperature of about 200°K."

Another possible explanation for these unusual temperature-time curves can be found in the thermal properties of those minerals believed to be crystalline phases in lunar surface materials. It is known that some of these phases undergo magnetic phase transitions at temperatures ranging from 56°K in titanomagnetite and 65°K in fayalite, to 1033°K in metallic iron (Table 1). In the process of cooling a paramagnetic mineral through its spin-ordering transition, a thermal arrest may be encountered due to a large increase in heat capacity in the vicinity of the transition (*2*). Considering the postulated abundance and distribution of ferromagnesian phases in lunar material (*3*), the thermal arrests indicated by the infrared data may be related, at least in part, to magnetic phase transitions.

The prolonged thermal arrests in Tycho, Copernicus, and Aristarchus and in other areas outside the craters (*4*) may indicate the presence of a mineral unusually enriched in a transition element or simply a larger proportion of such a phase in the surface material. If the arrests are due only to magnetic ordering, the fact that the brightness temperature remains nearly constant through the night suggests that complete ordering is not achieved before dawn.

The fine structure of the cooling data for some lunar material (*5*) also suggests that magnetic ordering in one or more of the minerals may go to completion within a few hours after sunset (or shortly after the start of an

Table 1. Temperatures of heat capacity "maxima" associated with magnetic transitions (*10*). Hematite (Fe_2O_3) has a magnetic transition at 250°K, but no heat capacity anomaly at this temperature (*11*).

Mineral	Formula	Heat capacity "maximum" (°K)
Titanomagnetite	Fe_2TiO_4	56
Ilmenite	$FeTiO_3$	57
Fayalite	Fe_2SiO_4	65
Chromite	$FeCr_2O_4$	75
Titanomagnetite	Fe_2TiO_4	99
Magnetite	$FeFe_2O_4$	114
Chromite	$FeCr_2O_4$	135
Alabandite	MnS	139
Wustite	$Fe_{0.947}O$	189
Troilite	FeS	598
Magnetite	$FeFe_2O_4$	880
Maghemite(?)	Fe_2O_3	950
Iron (alpha)	Fe	1033
Maghemite(?)	Fe_2O_3	1050