

THE RELATION OF EYE MOVEMENTS DURING SLEEP TO DREAM ACTIVITY: AN OBJECTIVE METHOD FOR THE STUDY OF DREAMING

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The study of dream activity and its relation to physiological variables during sleep necessitates a reliable method of determining with precision when dreaming occurs. This knowledge, in the final analysis, always depends upon the subjective report of the dreamer, but becomes relatively objective if such reports can be significantly related to some physiological phenomena which in turn can be measured by physical techniques.

Such a relationship was reported by Aserinsky and Kleitman (1) who observed periods of rapid, conjugate eye movements during sleep and found a high incidence of dream recall in Ss awakened during these periods and a low incidence when awakened at other times. The occurrence of these characteristic eye movements and their relation to dreaming were confirmed in both normal Ss and schizophrenics (4), and they were shown to appear at regular intervals in relation to a cyclic change in the depth of sleep during the night as measured by the EEG (5).

This paper represents the results of a rigorous testing of the relation between eye movements and dreaming. Three approaches were used: (a) Dream recall during rapid eye movement or quiescent periods was elicited without direct contact between *E* and *S*, thus eliminating the

possibility of unintentional cuing by *E*. (b) The subjective estimate of the duration of dreams was compared with the length of eye movement periods before awakening, reasoning that there should be a positive correlation if dreaming and eye movements were concurrent. (c) The pattern of the eye movements was related to the dream content to test whether they represented a specific expression of the visual experience of dreaming or merely a random motor discharge of a more active central nervous system.

METHOD

The Ss for the experiments were seven adult males and two adult females. Five were studied intensively while the data gathered from the other four were minimal with the main intent of confirming the results on the first five.

In a typical experiment, *S* reported to the laboratory a little before his usual bedtime. He was instructed to eat normally but to abstain from alcoholic or caffeine-containing beverages on the day of the experiment. Two or more electrodes were attached near the eyes for registering changes in the corneoretinal potential fields as the eyes moved. Two or three electrodes were affixed to the scalp for recording brain waves as a criterion of depth of sleep. The *S* then went to bed in a quiet, dark room. All electrode lead wires were further attached to the top of the head and from there to the lead box at the head of the bed in a single cord to minimize the possibility of entanglement and allow *S* a free range of movement. The potentials were amplified by a Model III Grass Electroencephalograph in an adjoining room. The electroencephalograph was run continuously throughout the sleep period at a paper speed of 3 or 6 mm. per sec. which allowed easy recognition of eye-movement potentials. A faster speed (3 cm./sec.) was used for detailed examination of the brain waves although the slower speed permitted at least an approximate

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² Aided by a grant from the Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

TABLE 1
SUMMARY OF EXPERIMENTS

Ss	Nights Slept	Awakenings	Average Nightly Awakenings	Average Sleeping Time
DN	6	50	8.3	7:50
IR	12	65	5.4	4:20
KC	17	74	4.4	6:00
WD	11	77	7.0	6:30
PM	9	55	6.1	6:20
KK	2	10	5.0	6:00
SM	1	6	6.0	6:40
DM	1	4	4.0	7:00
MG	2	10	5.0	6:10
Totals	61	351	5.7	6:00

estimation of the gross pattern. The criteria of eye-movement potentials and their differentiation from brain wave artifacts have been discussed at length elsewhere (1, 4).

At various times during the night Ss were awakened to test their dream recall. The return to sleep after such an awakening invariably took less than 5 min. Table 1 is a summary of the experiments showing the number of nights each S slept and the number of awakenings. In all, 21% of the awakenings fell in the first 2 hr. of sleep, 29% in the second two, 28% in the third two, and 22% in the fourth two.

RESULTS

*The occurrence of rapid eye movements.*³—Discrete periods during which their eyes exhibited rapid movements were observed in all nine Ss every night they slept. These periods were characterized by a low-voltage, relatively fast pattern in the EEG. The interspersed periods in which rapid eye movements were absent showed EEG patterns indicative of deeper sleep, either a predominance of high-voltage, slow activity, or frequent, well-defined sleep spindles with a low-voltage background. No REM's were ever observed during the initial onset of sleep although the EEG always passed

³ In most of the remaining text the following abbreviations will be used: REM's (rapid eye movements) and NREM's (no rapid eye movements).

through a stage similar to that accompanying the rapid eye movement periods occurring later in the night. These findings concerning associated EEG patterns were identical with previous observations on uninterrupted sleep (5).

An accurate appraisal of the mean duration of the REM periods was impossible since most were terminated artificially by an awakening. However, those that were not so terminated varied between 3 and 50 min. in duration with a mean of about 20 min., and they tended to be longer the later in the night they occurred. The eyes were not constantly in motion during such periods; rather, the activity occurred in bursts of one or two, up to fifty or a hundred movements. A single movement was generally accomplished in .1-.2 sec. and was followed by a fixational pause of varying duration. The amount, pattern, and size of the movements varied irregularly from period to period.

The REM periods occurred at fairly regular intervals throughout the night. The frequency of occurrence seemed to be relatively constant and characteristic for the individual. DM and WD averaged one eye-movement period every 70 min. and every 75 min. respectively. KC averaged one eye-movement period every 104 min. The other Ss fell between these two extremes. The average for the whole group was one REM period every 92 min.

Despite the considerable disturbance of being awakened a number of times, the frequency and regularity with which REM periods occurred was almost exactly comparable to that seen previously in a study of uninterrupted sleep (5). If the awakening occurred during a NREM period, the return to sleep was never

associated with REM's, nor was the time of onset of the next REM period markedly changed from that which would have been expected in the absence of an awakening. An awakening during an REM period generally terminated the REM's until the next period, and the sequence of EEG changes, excluding the brief period of wakefulness, was the same as that following an REM period that ended spontaneously. Exceptions occurred when S was awakened during an REM period in the final hours of sleep when the period was likely to be quite long if uninterrupted. On these occasions, the REM's sometimes started up again when S fell asleep. It seemed as though a period of heightened CNS activity had not run its normal course and, although S was able to fall asleep, he continued to dream.

Eye movement periods and dream recall.—For all awakenings to elicit dream recall, the arousing stimulus was the ringing of an ordinary doorbell placed near the bed and sufficiently loud to ensure immediate awakening in all levels of sleep. The Ss then spoke into a recording device near the bed. They were instructed to first state whether or not they had been dreaming and then, if they could, to relate the content of the dream. When S had finished speaking E, who could hear their voices, occasionally entered the room to further question them on some particular point of the dream. There was no communication between S and E in any instance, it must be emphasized, until S had definitely committed himself. The Ss were considered to have been dreaming only if they could relate a coherent, fairly detailed description of dream content. Assertions that they had dreamed without recall of content, or vague, frag-

TABLE 2
INSTANCES OF DREAM RECALL AFTER AWAKENINGS DURING PERIODS OF RAPID EYE MOVEMENTS OR PERIODS OF NO RAPID EYE MOVEMENTS

S	Rapid Eye Movements		No Rapid Eye Movements	
	Dream Recall	No Recall	Dream Recall	No Recall
DN	17	9	3	21
IR	26	8	2	29
KC	36	4	3	31
WD	37	5	1	34
PM	24	6	2	23
KK	4	1	0	5
SM	2	2	0	2
DM	2	1	0	1
MG	4	3	0	3
Totals	152	39	11	149

mentary impressions of content, were considered negative.

The awakenings were done either during REM periods or at varying increments of time after the cessation of eye movements during the interspersed periods of NREM's. The Ss, of course, were never informed when awakened whether or not their eyes had been moving.

Table 2 shows the results of the attempts to recall dreams after the various awakenings. The REM or NREM awakenings for PM and KC were chosen according to a table of random numbers to eliminate any possibility of an unintentional pattern. For DN, a pattern was followed: first three REM awakenings, then three NREM awakenings, and so on. WD was told he would be awakened *only* when the recording indicated that he was dreaming, but REM and NREM awakenings were then interspersed randomly. The type of awakenings for IR was chosen according to the whim of E.

The Ss uniformly showed a high incidence of dream recall following

REM awakenings and a very low incidence of recall following awakenings during periods of NREM's regardless of how the awakenings were chosen. In particular, DN was not more accurate than the others although there was a pattern he might have learned, and WD was not less accurate although he was deliberately misled to expect to have been dreaming every time he was awakened. Over a narrow range, some Ss appeared better able to recall dreams than others.

Table 3 compares the results of the first half of the series of REM awakenings with the last half. Practice was certainly not a significant factor as only one S showed any degree of improvement of recall on later nights as compared with the early ones.

The incidence of dream recall dropped precipitously almost immediately upon cessation of REM's. In 17 NREM awakenings that were done within 8 min. after the end of a REM period, 5 dreams were recalled. Although small, this was a much higher incidence of dream recall than occurred when the NREM awakenings followed the end of REM periods by *more* than 8 min. In the latter category only 6 dreams were recalled in 132 awakenings.

TABLE 3
COMPARISON OF FIRST HALF OF SERIES OF RAPID
EYE MOVEMENT AWAKENINGS WITH
SECOND HALF

S	First Half		Second Half	
	Dream Recall	No Recall	Dream Recall	No Recall
DN	12	1	5	8
IR	12	5	14	3
KC	18	2	18	2
WD	19	2	18	3
PM	12	3	12	3
Total	73	13	67	19

In general, Ss were best able to make an emphatic statement that they had not been dreaming when the NREM awakenings were done during an intermediate stage of sleep as indicated by a brain-wave pattern of spindling with a low-voltage background. When aroused during a deep stage of sleep characterized by high-voltage, slow waves in the EEG, Ss often awoke somewhat bewildered. In this state they frequently felt that they must have been dreaming although they could not remember the dream or, on the other hand, that they had not been asleep at all. They sometimes had a great variety of feelings to describe—such as pleasantness, anxiety, detachment, etc., but these could not be related to any specific dream content.

Most of the instances of inability to recall dreaming after awakenings during REM periods occurred in the early part of the night. Of 39 negative reports in the entire study, 19 occurred after awakenings during REM periods falling in the first 2 hr. of sleep, 11 after REM awakenings during the second 2 hr., 5 in the third 2 hr., and 4 in the last 2 hr. There was no such variation relating to awakenings during the interspersed periods of ocular quiescence, the incidence of dream recall being uniformly low, regardless of whether the early or late part of the night was being considered.

Length of rapid eye movement periods and subjective dream-duration estimates.—If the length of the REM periods were proportional to the subjectively estimated duration of the dreams, it would further help to establish the relatedness of the two and would give some information about the rate at which dreaming progresses.

At first, Ss were awakened at

TABLE 4
RESULTS OF DREAM-DURATION ESTIMATES
AFTER 5 OR 15 MIN. OF RAPID
EYE MOVEMENTS

S	5 Minutes		15 Minutes	
	Right	Wrong	Right	Wrong
DN	8	2	5	5
IR	11	1	7	3
KC	7	0	12	1
WD	13	1	15	1
PM	6	2	8	3
Total	45	6	47	13

various increments of time after the REM's had begun and were requested to estimate to the nearest minute the amount of time they had been dreaming. This proved to be too difficult, although the estimates were always of the same order of magnitude as the lengths of the REM periods, and were occasionally exactly right.

A series was then done in which Ss were awakened either 5 or 15 min. after the onset of REM's and were required on the basis of their recall of the dream to decide which was the correct duration. The 5- or 15-min. periods were chosen on the basis of a random series. Table 4 shows the results of these awakenings. All Ss were able to choose the correct dream duration with high accuracy except DN. This S, however, made most of his incorrect choices by estimating 15 min. to be 5 min. This is consistent with the interpretation that the dream was longer, but he was only able to recall the latter fraction and thus thought it was shorter than it actually was.

In addition to depending on the amount of actual dreaming, the lengths of the dream narratives were undoubtedly influenced by many other factors as, for example, the loquacity or taciturnity of S. How-

ever, the lengths of the dream narratives still showed a significant relationship to the duration of REM periods before awakening. Table 5 shows the correlations between minutes of REM's and lengths of dream narratives for each S. The number of words in the narrative was the measurement of length. Of the 152 dreams recalled, 26 were not included because poor recording did not allow complete transcription. Dream narratives recalled after 30 or as much as 50 min. of REM's were not a great deal longer than those after 15 min. although Ss had the impression that they had been dreaming for an unusually long time. This was perhaps due to inability to remember all the details of very long dreams.

Specific eye-movement patterns and visual imagery of the dream.—The quality and quantity of the REM's themselves showed endless variation. There was much or little movement, big or small movements, and so on. As has been stated, the movements occurred in bursts of activity separated by periods of relative inactivity. However, the brain-wave stage during the whole period remained the same whether there was much or little movement at any given moment of the period.

It was hypothesized that the movements represented the visual imagery of the dream, that is, that they

TABLE 5
CORRELATION BETWEEN DURATION OF REM
PERIODS IN MINUTES AND NUMBER OF
WORDS IN DREAM NARRATIVES

Subjects	Number of Dreams	r	P
DN	15	.60	< .02
IR	25	.68	< .001
KC	31	.40	< .05
WD	35	.71	< .001
PM	20	.53	< .02

corresponded to where and at what the dreamer was looking. An attempt to account for every movement by having *S* state chronologically in what directions he had gazed in the dream proved futile. The *Ss* could not recall the dream with such a high order of detail and precision.

In a slightly different approach, *Ss* were awakened as soon as one of four predominant patterns of movement had persisted for at least 1 min. and were asked to describe in detail the dream content just before awakening. The four patterns were: (*a*) mainly vertical eye movements, (*b*) mainly horizontal movements, (*c*) both vertical and horizontal movements, and (*d*) very little or no movement. The prevalence of the horizontal or vertical components was determined by placing leads both vertically and horizontally around the eyes.

A total of 35 awakenings was accumulated from the nine *Ss*. Periods of either pure vertical or horizontal movements were extremely rare. Three such periods of vertical movements were seen. After each of these the dream content involved a predominance of action in the vertical plane. One *S* dreamed of standing at the bottom of a tall cliff operating some sort of hoist and looking up at climbers at various levels and down at the hoist machinery. Another *S* dreamed of climbing up a series of ladders looking up and down as he climbed. In the third instance the dreamer was throwing basketballs at a net, first shooting and looking up at the net, and then looking down to pick another ball off the floor. Only one instance of pure horizontal movement was seen. In the associated dream *S* was watching two people throwing tomatoes at each other. On 10 occasions *Ss* were awakened after 1 min. of little or no

eye movement. In these, the dreams all had the common property that the dreamer was watching something at a distance or just staring fixedly at some object. In two of these awakenings in different *Ss* the patterns were the same, as follows: about a minute of ocular inactivity followed by several large movements to the left just a second or two before the awakening. Both instances, interestingly enough, were virtually identical as regards dream content. In one case *S* was driving a car and staring at the road ahead. He approached an intersection and was startled by the sudden appearance of a car speeding at him from the left as the bell rang. In the other, the dreamer was also driving a car and staring at the road ahead. Just before the awakening he saw a man standing on the left side of the road and hailed him as he drove past.

In the 21 awakenings after a mixture of movements *Ss* were always looking at things close to them, objects or people. Typical reports were of talking to a group of people, looking for something, fighting with someone, and so forth. There was no recall of distant or vertical activity.

In order to confirm the meaningfulness of these relationships, 20 naive *Ss* as well as 5 of the experimental *Ss* were asked to observe distant and close-up activity while awake. Horizontal and vertical electrodes were attached. The eye-movement potentials in all cases were comparable in both amplitude and pattern to those occurring during dreaming. Furthermore, there was virtually no movement, as indicated by the eye potentials, when viewing distant activity, and much movement while viewing close-up activity. Vertical eye-movement potentials were

always at a minimum except for the upward movements accompanying blinking, and in a few cases when *E* tossed a ball in the air for them to watch.

DISCUSSION

The results of these experiments indicate that dreaming accompanied by REM's and a low-voltage electroencephalogram occurred periodically in discrete episodes during the course of a night's sleep. It cannot be stated with complete certainty that some sort of dream activity did not occur at other times. However, the lack of recall and also the fact that the brain waves were at the lightest level of sleep only during REM periods and at deeper levels at all other times, makes this unlikely. The few instances of dream recall during NREM periods are best accounted for by assuming that the memory of the preceding dream persisted for an unusually long time. This is borne out by the fact that most of these instances occurred very close, within 8 min., after the end of REM periods.

Other workers have attempted to relate dreaming to physiological phenomena during sleep. Wada (12) felt that dreaming and gastric contractions occurred simultaneously. However, this conclusion was based on only seven awakenings in two *Ss*. One was unable to recall dream content although he felt he had been dreaming and the other remembered dream content in 3 of 4 awakenings. Scantlebury, Frick, and Patterson (11) also studied gastric activity and dreaming. They felt, on the basis of three instances of dream recall out of seven awakenings, that the two were probably related, but judiciously stated that "the exact time during which a dream occurs is elusive of record." The occurrence of dreaming during a series of foot twitches occurring immediately after the onset of sleep was postulated by McGlade (9). However, he based this conclusion mainly on dreams recalled on the morning after the experiments which is highly unreliable,

and only 3 out of the 25 *Ss* studied exhibited foot twitches.

Incidental observations have been made on the occurrence of dreaming by investigators studying brain waves during sleep (2, 3, 6, 7, 8). All stages of brain waves were related to dreaming in these five papers, but no mention was made of whether or not actual dream content was recalled, and the number of reports by sleepers was generally very small.

In other studies of dreaming, excellently reviewed by Ramsey (10), attempts were made to localize dream activity by simply awakening *Ss* at various times during the night. In general it was found that dreams might be recalled at any time during the night, but that most were recalled in the later hours of sleep. This would correspond to the statistical incidence of REM's as previously reported (1, 4), and is also consistent with the finding in this study that, even when the awakenings occurred during REM periods, recall was still more difficult earlier in the night.

It was stated herein that all *Ss* showed periods of REM's every night they slept. This was also the case in another briefly reported series of experiments involving 16 *Ss* who were observed a total of 43 nights (5). It is felt on the basis of these and other studies which are unreported that periods of REM's and dreaming and the regularity with which they occur are an intrinsic part of normal sleep. In view of this, the failure to observe REM's in occasional *Ss* reported in earlier work (1, 4) deserves some consideration. One explanation is that the recording was done by sampling rather than continuously. If the REM periods were shorter than usual, they may have occurred in the intervals between the samples, thus escaping observation. Another explanation is that a lower amplification of the REM potentials was employed which, although usually adequate, did not clearly record very small movements. A third possibility is that the dreams of these *Ss* happened to be the sort, such as watching

distant activity, in which eye movement was at a minimum. Since the association of the characteristic low-voltage, non-spindling EEG was not realized at the time and thus could not aid in identifying this sort of period, they very likely would have been overlooked.

There was nothing in the experiments reported in this paper to indicate that the dreams occurred instantaneously, or with great rapidity, as some have supposed. Rather, they seemed to progress at a rate comparable to a real experience of the same sort. An increment in the length of REM periods was almost invariably associated with a proportional increase in the length of the dream. This could not have occurred if dreaming were instantaneous, since any length of REM periods would then easily accommodate a virtually infinite amount of dream activity.

It seems reasonable to conclude that an objective measurement of dreaming may be accomplished by recording REM's during sleep. This stands in marked contrast to the forgetting, distortion, and other factors that are involved in the reliance on the subjective recall of dreams. It thus becomes possible to objectively study the effect on dreaming of environmental changes, psychological stress, drug administration, and a variety of other factors and influences.

SUMMARY

Regularly occurring periods of REM's were observed during every night of experimental sleep in nine adult Ss. A high incidence of dream recall was obtained from Ss when awakened during REM periods and a very low incidence when they were awakened at other times. A series of awakenings was done either 5 or 15 min. after the REM's (dreaming) had begun and Ss judged the correct dream duration with high accuracy. The pattern of the REM's was related to the visual imagery of the dream, and the eye movements recorded in analogous situations while awake corresponded closely in

amplitude and pattern to those observed during dreaming.

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(Received May 9, 1956)