Dream Imagery: Relationship to Rapid Eye Movements of Sleep

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George Trumbull Ladd [39] suggested in 1892 that the visual elements of dreams were derivations of the "psychical synthesis" of night-time retinal sense data. This hypothesis led him to speculate that the eyeballs move during dreaming. "As we look down the street of a strange city, for example, in a dream we probably focus our eyes somewhat as we should do in making the same observation when awake. . . ."

Ladd's ingenious surmise went unverified until 1955 when Aserinsky and Kleitman [2] reported actual observations of ocular movements during sleep. They described 2 types which appear at separate times during the night in a predictable pattern: (*a*) slow eye movements (SEM's)—slow, often asynchronous, gliding excursions of the eyeballs at sleep onset and after every body movement occurring during the night's sleep; (*b*) rapid eye movements (REM's)—bursts of quick, binocularly synchronous, single and grouped ocular deviations often in clusters of unidirectional or multidirectional deflections, though single movements separated by variable periods of quiescence are seen as well. The REM's in sleep vary in velocity from waking fixational eye movements by less than 5 milliseconds per 15° arc.[13] The periods during which REM's occur appear between 3 and 6 times during an average night's sleep in all human subjects studied.[16] Their average duration is about 20 minutes, but they may last as long as an hour. Their emergence always occurs in conjunction with a low-voltage, fast, nonspindling EEG pattern (Stage 1 sleep) which lasts for the length of the period.[17] Convincing evidence has been offered in a number of studies [16,18,57] that the Stage 1 REM periods constitute the time of dreaming.

Dement and Kleitman [16] found a correspondence in several instances between the predominant direction of ocular deflections and the predominant planes of action of the dream contents. They suggested that the REM's are related to the visual imagery of the dream. Later work demonstrated an association between the frequency of eye deflections and the amount of physical action in the dream.[18]

The present study was undertaken in an attempt to achieve a more precise understanding of the relationship between dream imagery and the REM's. The operating hypothesis was that there exists a 1:1 correlation between the direction of each eye movement and the direction of each alteration in the hallucinated gaze of the dreamer. A brief

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pilot study revealed that, given good dream recall, reports of the terminal 20 to 30 seconds of visual imagery in dreams could be matched closely to the recorded sequence of REM's in terms of the latter's quantity, direction, and timing. If the dreamer fixes his gaze on a single point, there are no eye deflections; if he looks about in the dream, there is an REM for each glance. According to the hypothesis, then, the REM's are fixational movements of the visual perceptual apparatus reacting to hallucinated visual phenomena. They would be the same if the dreamer watched corresponding visual phenomena from the same vantage point when awake. Therefore, the particular configuration of REM's during sleep is a function of how the dreamer "looks" at what he "sees."

In previous studies by others, one experimenter collected and evaluated a subject's dream report and compared it directly to an eye-movement recording (EOG)[16,18] or to an electromyographic recording with which he was familiar.[56] Contrariwise, the present study depends on the ability of an experimenter, who has no knowledge of the actual REM's and only the subject's dream report as data, to construct a predictive judgment of the direction, timing, and sequence of REM's that occur just prior to an awakening. This marks the first attempt to translate the dream narrative into a form which is equatable to an REM recording (EOG). The possibility of bias was reduced because the prediction and the EOG were matched only after the prediction had been formulated from the dream report.

A congruence between eye movements and the imagery of dreams, if demonstrated, would help to clarify the nature of: (*a*) the dreamer's physiological involvement in the dream; (*b*) the dream as a discrete and continuous experience, and (*c*) Stage 1 sleep as constituting *the* dream stage and its difference from other stages during which dreaming has been said to occur.[22]

Method

Twelve subjects, 4 women and 8 men, were used in the study. Their ages ranged from 19 to 33. They were volunteers who were paid for their services. The only criterion for their selection was their claim to be good dream recallers. It is general knowledge that some individuals maintain that they do not recall dreams. Although Goodenough et al.[23] showed that all so-called "non-dreamers" manifest REM periods during sleep and remember dreams if awakened during REM periods, they also found that dream recall was poorer and less frequent in this group as compared to a group of subjects who stated that they recalled dreams frequently. Since this investigation relied on dream reports as the sole source of data for the predictive judgments, the criterion of being a *dream recaller* was felt to be necessary. The experiment was carried out in the course of 38 subject nights.

Subjects were instructed to arrive at the laboratory about one-half hour before their usual bedtime, and to have abstained from sedatives, stimulants, or alcoholic beverages. They were instructed that the purpose of the study was to investigate the relationship between the visual imagery of dreams and sleeping eye movements and that they would be awakened several times during the night—usually, but not always, during a dream. They were asked to recall, to the best of their abilities, what they saw in the last few seconds of the dream prior to awakening. It was assumed that if the subjects attempted to guess eye movement patterns when they did not recall a dream, it was more likely that they would guess incorrectly than correctly. Therefore, the subjects' knowing that there are eye movements during dreaming was not felt to be a factor favorably prejudicial to the results.

In view of the fact that the natural manner of relating a dream is to start at the beginning and tell the dream "story," the subjects were cautioned to focus their attention immediately upon awakening on the very last scenes visualized in the dream. Unless this procedure was followed it was observed that while recounting the beginning of the dream or its "plot," the subjects frequently lost irretrievably the distinct recollection of the last events, with which they awoke. Emphasis was placed on the subjects' noting the direction of their gaze and observational vantage point in relation to the objects seen in the dream. Only after the last dream images were portrayed was the dreamer asked to recount the setting and content of the total dream. The ideal "good subject" was described to the subjects as one who does not feel obliged to produce a dream at every awakening, but who describes exactly what he does remember whenever he is able to recall a dream.

Parietal, frontal, supraorbital, infraorbital, bilateral outer canthi, and bilateral ear electrodes were attached to each subject, employing a previously described rapid-eye-movement recording technique.[2,17] Each periorbital electrode was secured

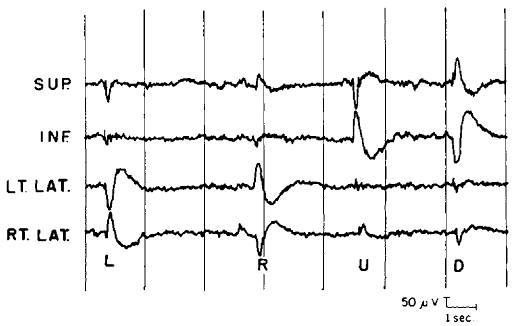

Fig. 1.—An a.c. electrooculogram showing the deflections resulting from eye movements in vertical and horizontal planes (subject is awake): REM's: *L,* left; *R,* right; *U,* up; *D,* down. The positions of the periorbital electrodes are *Sup.,* supraorbital; *Inf.,* infraorbital; *Lt. Lat.,* left lateral (outer) canthus; *Rt. Lat.,* right lateral (outer) canthus. Diagonal movement of the eyeballs would cause concurrent deflections in the tracings from both vertically and horizontally placed electrodes. Since the electrodes are in monopolar arrangement, an eye movement in one direction will cause a downward (positive) deflection in the tracing from the lead toward which the eyeball turns and an upward (negative) deflection in the tracing from the lead away from which the eyeball turns. This arrangement results in simultaneously opposite and almost equal deflections which are characteristic and are very easy to identify.

with Elastoplast tape. The lead wires were brought together into one cord and plugged into a lead box at the head of the bed, thus giving the subject ample room to move about in bed. Graphojel paste was used as the conducting medium.

The parietal and frontal leads, referred to the ears, recorded brain waves. The eye electrodes were in monopolar arrangement, giving simultaneous out-of-phase oscillographic deflections for movements of the eyeballs in each plane, as shown in Figure 1. The source of these voltage variations was the steady corneofundal potential difference [46,38] resulting from the fact that each eyeball represents an electrical dipole with a positive cornea and a negative fundus. When the eyeball moves from midposition, the cornea moves closer to one of the periorbital electrodes, while the fundus moves closer to its opposite number. This results in opposite and almost equal voltage deflections. The simultaneous recording from leads picking up vertical and horizontal eyeball deflections made it possible, from an examination of the amplitude and direction of the deflections, to arrive at a rough vector in all quandrants for each movement; (e.g., up; right; down and left; up and right; etc.). It is generally agreed that the electrooculogram is a sensitive and highly reliable way of recording eye movements.[40,38,10] The recordings were done via an 8-channel Model III Grass electroencephalograph which employs capacitance-coupled ink-writing oscillographs. Most frequently, subjects were run in pairs, but the experimenter, by switching to the appropriate leads, could devote to the subjects being awakened at least 1 channel for brain waves and 4 channels for ocular movements. Because the a.c. oscillograph returns to the baseline immediately after an eye movement, it is difficult to be certain of eyeball position relative to the midposition. For example, the eyes often will return slowly to their midposition following a movement to the periphery, but whether or not the eyes return, the oscillographic tracing returns to the baseline in either case. The direction of each fixational change is always evident, however, so long as electrical blocking of the oscillograph does not occur.

The experimental design required the presence of 2 experimenters. One watched the EEG and selected the moment of awakening. He awakened the subject abruptly by sounding a loud buzzer placed near the subject's head. A return of α-rhythm and muscular potentials to the tracings signaled awakening. Awakenings were done during Stage 1 sleep: (*a*) after single eye movements; (*b*) after short series of deflections in the same direction or in alternating directions; (*c*) after periods of ocular quiescence; (*d*) after bursts of rapid deflections, or (*e*) after still other distinctive REM sequences.

The second experimenter (the interrogator) remained in another room. He had no opportunity to observe the electrical REM tracings being recorded. His isolated position made it impossible for him to construct a predictive judgment * about the eye movements from any information other than the dreamer's description of what he saw. Upon hearing the buzzer, the interrogator immediately entered the subject's room and interrogated the subject. This experimental arrangement is portrayed in Figure 2.

The primary purpose of the interrogator's queries was the attempt to identify the dreamer's spatial orientation in the dream, as well as the exact timing and sequence of his gaze shifts. The interrogator then translated the dreamer's narrative of the terminal dream imagery into a series of eye movements. He would infer what the eye movements were from his previously acquired knowledge of the relationship between a particular type of visual activity and the REM's necessary to consummate it. (One of the authors, H. R., had done a preliminary investigation into the patterns of eye movements in awake subjects associated with various types of gaze shifts with and without coincidental head movement. These included quick glancing in all directions, watching close-up action, peering into the distance, following rapidly and

* The term *predictive judgment* as used in this study refers to the interrogator's attempt to give a description of an REM pattern that he has not seen. It does not pertain to a prediction of possible future events.

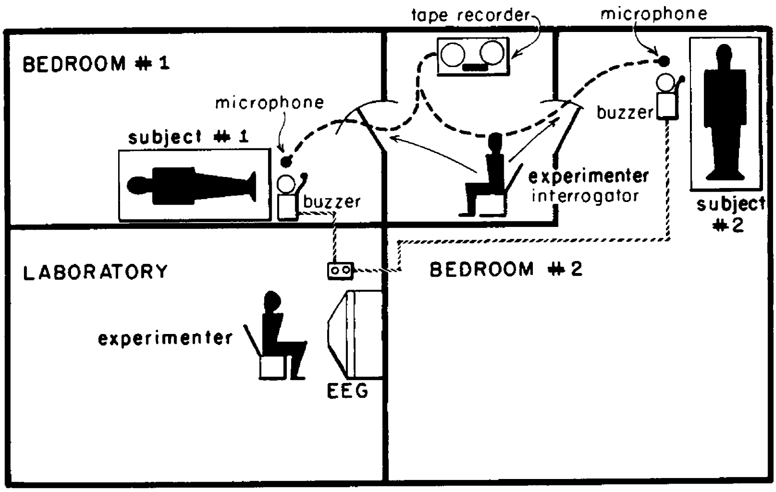

Fig. 2.—Diagram of the laboratory arrangement for the experiment. One experimenter followed the EEG and EOG tracings. He chose the time of awakening by pressing a button which rang a buzzer in one of the subjects' bedrooms. The other experimenter (interrogator) sat in another room and could not view either the EOG tracings or the subjects' eyes. When the buzzer was rung, he would enter the room of the awakened subject with the microphone to the tape recorder, and record both the subject's narrative and his subsequent interrogation of the subject.
The diagram shows 2 subjects being studied. An awakening was done on only 1 subject at a time, but 2 subjects were usually run each night to maximize the number of dream awakenings.

slowly moving subjects, reading, etc.) After each awakening, the interrogator formulated a predictive judgment of the number, direction, and timing of REM's, occurring immediately preceding (up to 20 or 25 seconds before) the awakening. Examples will be shown.

Each subject was awakened between 1 and 8 times during a night. The awakenings were done during Stage 1 periods, with the exception of sleep onset and the first REM period, because dream recall is somewhat poorer at these times than during other Stage 1 periods.[16] This poor recall is believed to be the result of subject fatigue and the short, fragmentary nature of the first REM period. The REM periods were allowed to run from 3 to 25 minutes before interruption. The duration depended upon the unpredictable time of occurrence of a unique REM pattern which the experimenter chose to select for an awakening. Transcriptions were made from taped recordings of the dream narratives and interrogations. Once a predictive judgment of the REM's was formulated, it was never altered. The transcribed dream narratives were helpful later in evaluating the interrogator's process of arriving at the REM predictions.

For each awakening, the subject submitted a "Confidence Level," a rating of the clarity of his recall, i.e., the vividness of the imagery (for movement, position, and sequence) and his certainty that it had occurred as it persisted in his memory. A rating of 3+ was given to a terminal dream segment remembered with high clarity; 2+ to a segment recalled with moderate exactitude; 1+ to vague or "fuzzy" recall of the dream episode.

After all the data were gathered, the predictions were compared to the electrical recordings. The comparison was begun by matching the last recorded REM (just prior to the awakening) to the last predicted REM. Then the preceding recorded and predicted REM's could be compared by moving backwards, the beginning of the predictive statement constituting the comparison cut-off point. If the reverse were attempted, that is, if the first predicted REM were to be matched to start the comparison, no starting point could be designated with certainty as the correct one on the EOG. Two of the authors, one of whom was unaware of the subject's Confidence Levels, served as judges and independently rated the correspondences between the predictive formulations and the electrooculographically recorded eye movements. The correspondences were scored on a scale from *Good* to *Poor*. Criteria were developed for each correspondence rating as follows:

Good: The prediction shows an exact or near exact correspondence to the directions, timing, and sequence of eye movements in the electrical record. (A subgroup rated as *Excellent* included a number of dreams in which the correspondences are perfect.)

Fair: The record and prediction match in only a general way but are consistent with each other.

Poor: The record and prediction are unmatched in direction, timing, and sequence.

Assigning a correspondence rating required each judge to evaluate the match between a descriptive prediction and an EOG record. Hence, some interpretation was required. Moreover, since 1 judge knew the clarity rating (3+, 2+ or 1+) of each dream, he may have been biased by this information in selecting a correspondence rating. For these reasons, a comparison between the 2 judges' ratings was carried out.

It will be noted that the number of nights that each subject served in the study varied. This was a function only of the fact that certain subjects proved to be poor dream recallers (contrary to their prior claims) or dreamt fewer times than other subjects. For purposes of economy they were used less often. Consequently some subjects contributed more dreams than others to the total studied.

Results

A total of 152 awakenings was done during Stage 1 periods. Of these, there was no recall in 19 awakenings. In 8 additional instances, recall of the very last dream sequences was too scanty to permit any judgments of eye-movement directions. In 4 cases the subject neglected to submit a Confidence Level. Hence, a total of 31 Stage 1 awakenings were not used. Dream recall was 87.5%, since 133 of 152 awakenings yielded cogent and extended dream narratives.

There is evidence to suggest that although the subjects were told they would be awakened from dreams, they did not fabricate narratives when recall failed them. The dream recall of 87.5% is almost identical with the 88% and 90% recall during REM periods in controlled studies reported by Dement [12] and Goodenough et al.[23] of dream recall in which awakenings were done during non-REM and REM periods. Thus, it was assumed that the subjects did not feel impelled to report dreams they did not remember. Conversely, we were led to accept with confidence the dreams they did report.

Of the 121 dream awakenings used in the study, the subjects rated their memory of the last imagery as 3+ ("high clarity") in 77 instances, as 2+ ("moderately clear") in 28, and as 1+ ("vague") in 16 instances. Three representative examples of 3+ dreams are presented below. In each case, the eye-movement record is reproduced along with the salient portion of the dreamer's narrative as well as the interrogator's predictive judgment. These illustrations exemplify how the interrogator translated the dreamer's experience into an eye-movement pattern. In each case both judges scored a *Good* correspondence rating, indicating that the interrogator predicted the REM's accurately. Of major importance is the demonstration of exactness with which the eye deflections can be correlated with the dream account and with the interrogator's prediction.

Example 1.—Transcript, Subject 7, Sept. 26, 1960 (Fig. 3):

"Right near the end of the dream I was walking up the back stairs of an old house. I was holding a cat in my arms."

"Were you looking at the cat?"

"No, I was being followed up the steps by the Spanish dancer, Escudero. I was annoyed at him and refused to look back at him or talk to him. I walked up, as a dancer would, holding my head high, and I glanced up at every step I took."

"How many steps were there?"

"Five or six."

"Then what happened?"

"I reached the head of the stairs and I walked straight over to a group of people about to begin a circle dance."

"Did you look around at the people?"

"I don't believe so. I looked straight ahead at the person across from me. Then I woke up."

"How long was it from the time you reached the top of the stairs to the end of the dream?"

"Just a few seconds."

Interrogator's Prediction.—"There should be a series of 5 vertical upward movements as she holds her head high and walks up the steps. Then there should be a few seconds with only some very small horizontal movement just before the awakening."

For the most part, in this example, the subject's description required little clarification or interpretation for the interrogator to formulate an accurate prediction. The interrogator did assume, however, that the dream-

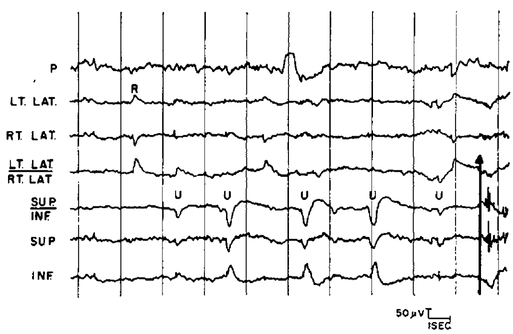

Fig. 3 (Example 1).—An a.c. electrooculogram showing the eye movements during the last 20 seconds before the awakening (arrow). Electrode positions: *P*, parietal (EEG); *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus; *Lt. Lat./rt. lat.*, same leads in bipolar arrangement; *Sup.*, supraorbital; *Inf.*, infraorbital; *Sup./Inf.*, same leads in bipolar arrangement. REM's: *R*, right; *U*, up. Note the 5 distinct upward deflections recorded in the vertical leads corresponding to the interrogator's prediction of 5 upward movements. The EEG pattern throughout the record was low-voltage, fast, and nonspindling (Stage 1 sleep).

er had to look in a horizontal plane after reaching the top step, as she commenced to walk over to the group to assume her position in the circle dance. His prediction of some small horizontal movements at the end proved correct. Note that each hallucinated physical movement and dreamed image of the dreamer-participant had the time duration that one might expect for a like event in real life. Time is not substantially condensed or speeded up for the dreamer as it may be, for instance, with subjects in hypnotic trances.[11]

Example 2.—Transcript, Subject 6, Nov. 28, 1960 (Fig. 4):

"Were you dreaming?"

"Yes. Just as you were awakening me. I can't remember—oh yes, I was on a subway train, a Broadway subway train, riding down to—I can tell you exactly what I was looking at . . . I think I was using a pay phone on one wall of the train, you know in those little compartments at the end. The train was moving between stations, and I was talking, and I remember saying something about soundproofing. But my eyes at that moment were moving very quickly I think."

"Were you facing the wall of the train?"

"Yes. . . ."

"What was the direction that the train was moving?"

"I believe it was going toward my right."

"Were you looking at the phone or away from the phone?"

"I was looking through the door window on the opposite wall at the wiggly lights in the tunnel whizzing by toward my left."

"How long before you awakened did this happen?"

"About 30 seconds, maybe a little more. I didn't look out that window continuously. I looked back at the phone on the wall."

"What happened just before you awakened?"

"I think I looked from the phone to the window and back to the phone quickly, then I woke up . . . ."

Interrogator's Prediction.—"About a half minute before the awakening there should be a period of jerky nystagmoid movements with the quick component to the left. Then just before the buzzer there should be a large horizontal movement to the left followed by one to the right."

In this case the dreaming observer watched passing tunnel lights, providing a set of circumstances that resulted in optokinetic nystagmus. This is the only instance in our study in which the phenomenon of nystagmus was expected from the dreamer's narrative. A short burst of nystagmoid REM's appears clearly on the EOG in Figure 5. This ex-

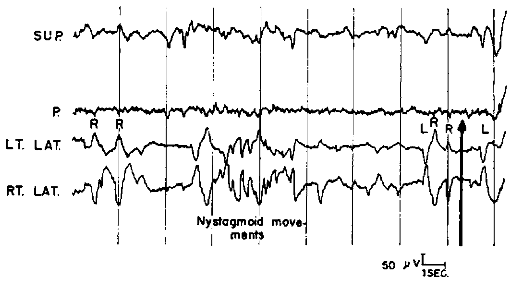

Fig. 4 (Example 2).—An a.c. electrooculogram of the last 17 seconds before an awakening (arrow). Electrode positions: *Sup.*, supraorbital; *P*, parietal (EEG); *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. REM's: *R*, right; *L*, left. This tracing is of special significance because of the presence of a period of rapid, saccadic eye movements with the quick component to the left (nystagmoid movements). The subject had described watching tunnel lights go quickly by as he rode in a subway car. The *P* lead shows a Stage 1 sleep record.

ample amply demonstrates the value of the interrogator as intermediary. Only a trained observer would be prepared to analyze the report of a visual experience in such a way as to be able to predict the experience's correlative eye movements. A research design, however, which employs prediction introduces its own difficulties (see Example 5 below).

Example 3.—Transcript, Subject 5, Dec. 13, 1960 (Fig. 5):

". . . the last thing I remember is looking down at a small piece of paper, held at about chest level, trying, slowly and haltingly, dwelling on each word, to translate something that looked like 3 lines of French poetry. It took about 20 or 30 seconds to do it, probably. I don't remember if I looked up at any time from the paper. As I remember, essentially, I kept my eyes on the paper."

Interrogator's Prediction.—"There should be relative REM quiescence with the exception of a few spaced *leftward* glances—as if the subject has finished a line of reading and returns to the next line."

In this example the experimenter utilized his knowledge not only of the dreamer's "situation," but of the characteristics of the recording equipment. The interrogator concluded that the only quick eye movements with an appreciable arc were the return movements to the *left* at the end of each line of poetry. In this case he concluded that the movements of the eyes to the *right* that occur in word to word reading (tiny saccadic de-

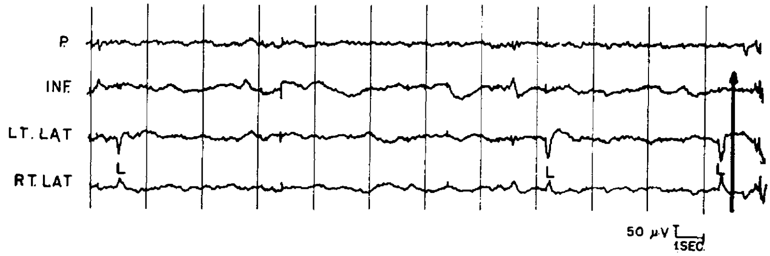

Fig. 5 (Example 3).—An a.c. electrooculogram of the last 23 seconds prior to an awakening (arrow). Electrode positions: *P*, parietal (EEG); *Inf.*, infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. REM's: *L*, left. There are 3 discrete eye deflections to the left corresponding to the eyes moving from the end of 1 line of printing to the beginning of the next line. If this were rapid reading, deflections to the right would have been recorded as well. However, in this case, the reader stopped at every word, and the EOG could not perceptibly record the resulting small deflections. Hence, the intervening record appears as if there had been eye movement quiescence. The lead shows a Stage 1 sleep record.

flections) were probably of insufficient amplitude to be picked up by the a.c. amplifiers. Consequently, the prediction was made of ocular quiescence between the leftward glances. EOG's employing d.c. amplification would make possible a prediction not only

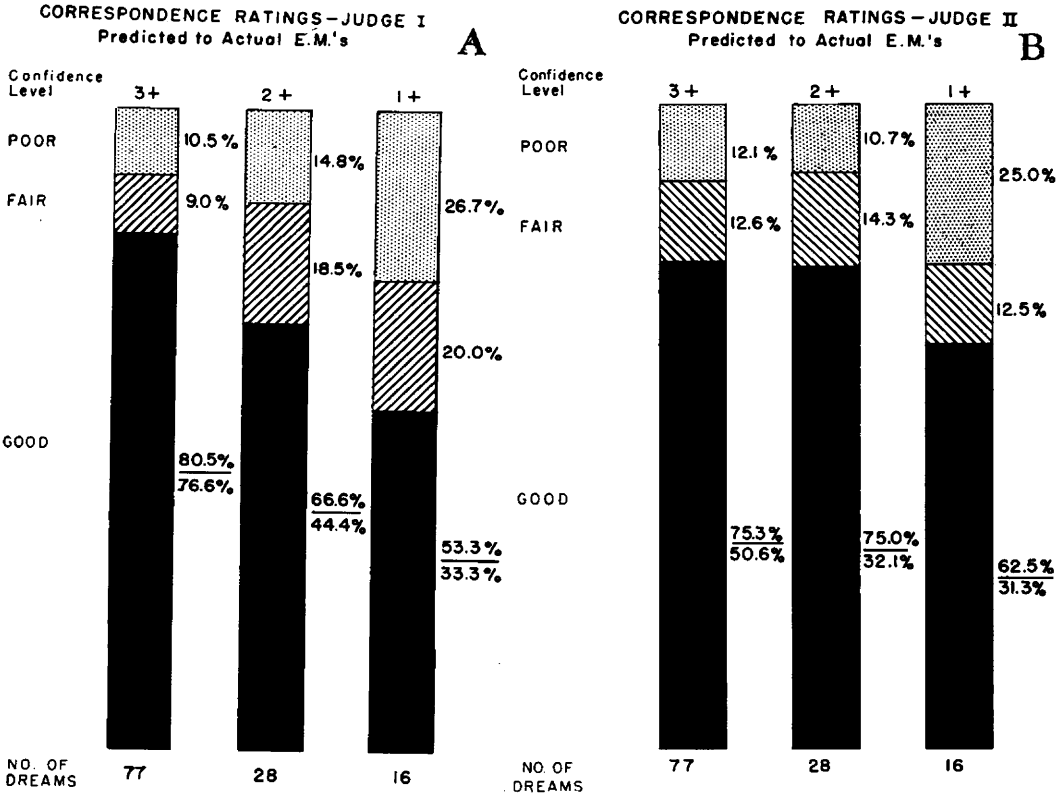

Fig. 6, *a* and *b*.—Graphs showing 2 judges' ratings of the correspondence between EOG recordings of the REM's and an experimenter's predictive judgement of the REM's. The dreams were sorted into groups according to their clarity for the dreamer (Confidence Level): 3+, high clarity dream endings; 2+, moderate clarity dream endings; 1+, vague or fuzzy dream endings. The correspondence ratings are: *Good,* exact or near exact correspondence; *Fair,* general but consistent correspondence; *Poor,* little or no matching of the EOG and the prediction. The per cent value of the *Excellent* subgroup (perfect or exact correspondences) is shown below the percentage of *Good* correspondences (e.g., 80.5%/76.6%) as a percentage of the total number of dreams in the clarity group as a whole.

Both judges found that the interrogater's predictions corresponded most closely to the EOG when the subject had been able to give the interrogater a vivid account of the dream; conversely the highest per cent of poor correspondences fell in the vaguely recalled group of dreams.

of the leftward returns but of the small, saccadic deflections to the right as well.[10]

As may be expected from the above examples, the correspondence ratings for the whole series, broken down into groups by clarity (Confidence Level), show that when dream recall was vivid, there was a high (75%-80%) probability that an accurate prediction of the eye movements could be made. Figure 6, *A* and *B*, shows this relationship. As the clarity of the dream diminished for the subject, so did the ability of the interrogator to predict accurately. It is interesting that among the 1+ group, while the interrogator's ability to construct a correct formulation was diminished, the dream memory still proved sufficient to result in a 53.3% *Good* correspondence for Judge 1 and 62.5% for Judge 2. A characteristic of a few of the subjects operated as an influencing factor here. During their first few experimental nights, these individuals were chary of rating their dreams 3+. They tended to reduce their ratings to 2+ or 1+, thus reflecting an initial unwillingness to treat a dream memory as something about which they could be certain. Some of the more exacting and self-critical subjects persisted in this tendency even when their verbal accounts evinced a highly detailed recall of the dream. As a result, the 2+ and 1+ groups were inflated by a significant number of what were actually "high clarity" dreams. Accordingly, the correspondence levels are not as low as might have been expected in these groups.

The 2 judges selected the same correspondence rating (*Good, Fair,* or *Poor*) in 98 of 121 dream awakenings (81%). They differed by more than 1 rating level in only 2 out of 23 instances of rating discrepancies. Taking the 3+ group alone, the judges rated alike 87% of the time. The close agreement of the judges' ratings in the high clarity group is a probable consequence of the many examples of high correspondence in that group between predictions and the EOG. The failure of the judges to agree in every instance seemed to relate, in the main, to differences of exactitude in interpreting the criteria for the selection of the correspondence ratings.

*Combined Judges' Ratings of the 3+ (High) Clarity Dream Endings by Subject **

Subjects	Good	Fair	Poor	Totals
1	3	0	0	3
2	3	0	1	4
3	3	0	0	3
4	2	0	0	2
5	17	1	1	19
6	5	2	1	8
7	12	1	1	14
8	6	0	1	7
9	0	1	0	1
10	3	0	1	4
11	6	3	2	11
12	1	0	0	1
Totals	61	8	8	77

* To obtain this rating concensus the 2 judges went over each 3+ dream on which their ratings differed (10) and equalized their ratings. (Graphs in Figure 6,*A* and *B* are comprised of the independent, uncompared judges' ratings.)

Although some subjects were used more than others, there is no evidence that this weighted the correspondence ratings in the direction of supporting the hypothesis. The 6 highest contributors offered sixty-three 3+ dreams of which 78% were rated *Good;* the 6 lowest contributors offered fourteen 3+ dreams of which 86% were rated *Good.* The Table shows a breakdown of performance by individual subject among the 3+ dreams. It is clear that all the subjects were able to score a reasonably high per cent of good correspondence when reporting dreams that were recalled clearly, although some subjects scored higher than others. The REM patterns of 2 of the subjects (5 and 7) showed virtually exact correspondence (*Good*) to the predictions in 29 of 33 dreams (88%), lending weight to a hypothesis of unvarying correspondence between dream imagery and REM activity rather than an association present only some of the time.

Some of the factors responsible for less-than-perfect correspondence became evident in the course of the investigation, and they serve to explain why a 100% *Good* correspondence was not realized with this method even in the 3+ group. The examples which follow illustrate some of these factors. In addition, they demonstrate a number of fascinating aspects of the dreaming process.

(*a*) The dreamer is an observer of (and frequently a participant in) certain hallucinated events which are primarily visual in nature.[47] In testing the ability of awake subjects to describe visual observations in terms of a sequence of gaze shifts, it was not always possible to find errorless correlations between their remembered glances and the recorded eye movements. Sometimes they made glances they were unaware of; sometimes they described their glances in incorrect sequence. It is evident that inaccuracies in the *memory* of dreamed events would represent an even greater potential source of these types of error.

(*b*) Given perfect recollection, the subject may still introduce distortion in *communicating* and *reporting* the dream events. Some subjects characteristically recounted their dreams clearly and carefully (Subjects 1 and 5); others were desultory and inexact (Subjects 6 and 11), making the formulation of a predictive judgment very speculative. It was probably not accidental that the judges rated the lowest correspondences among the dreams reported by the subjects who divulged the latter type of account, for the interrogator depended upon the subject's ability to recount his dream memory clearly. The degree to which a narrative truly depicted the dream scene is the degree to which the experimenter's prediction could aspire to accuracy. Sleepy subjects, some with poor descriptive powers, who were eager to return to sleep quickly, delivered dream reports to the interrogator from which he formulated predictive judgments that might be consistent with the narratives but essentially at variance with the subject's actual memory of the events.

(*c*) The dream description notwithstanding, error could be introduced by the *experimenter* (interrogator) who was formulating predictions about visual scenes that he had not directly experienced. The vantage point of the dreamer in relation to what he observed—his spatial orientation—was often difficult to establish even when dream memory and dream reporting were good. This was the case because the vantage point of the dream observer might change kaleidoscopically. For instance, one subject reported that at one instant in a dream she watched herself walk to a door and open it. But immediately her vantage point switched. She now saw through the door opener's eyes (herself), and the image she experienced was of the people who had rung the door bell. Another subject reported watching herself on a screen, but the very next sensation was of feeling herself walking out of the screen. These examples illustrate that the accurate reconstruction of a sequence of eye movements by the interrogator occasionally suffered, owing to the subject's confusion as to whether he observed action or acted it out. However, even in cases when the dreamer was certain that he was an observer rather than a participator, his visual orientation might be fluid, as in the following example of a dreamer watching a football game:

Example 4.—Transcript, Subject 2, Sept. 19, 1960:

". . . Where were you watching the game from?"

"It was a film of the game."

"How far from the action were you?"

"I saw the plays as they happened. I saw each individual man."

"That means you were right with them or right near them?"

"Yes."

"Were you as close to them as the side lines or closer?"

"I don't know. You see, the reason why I say it seemed like a movie, was because there were a couple of crazy players who kept switching back and forth. *And no matter how they were switching, I was always there. . . .*"

The dreamer was perplexed because wherever the action moved he always seemed to move with it. He had no single vantage point from which to gauge the directions of his gaze. In this respect the experience was like watching a movie or a TV screen. But once this fact was established, the interrogator could predict the REM's with some certainty (see *e* below: discussion of active "viewing").

(*d*) The interrogator occasionally *misinterpreted* the subject's accurate report. The prediction was accordingly distorted and did not tally well with the recorded eye movements. Hence, the correspondence rating suffered. The following example illustrates this difficulty:

EXAMPLE 5.—Transcript, Subject 5, Nov. 14, 1960 (Fig. 7):

(The dreamer is sitting among a group of people watching a violinist. Then someone sits down directly in front of her and blocks her view.)

". . . There was a girl sitting to my right but I don't think she's the one who blocked my view."

"From which direction did the girl walk before she sat down in front of you?"

"I don't know. It was not like real life where you would watch a person walk over. She just suddenly was there in front of me."

"Did you keep your eyes on the violinist until your view was blocked?"

"Yes."

The experimenter assumed that if a person appeared to block the dreamer's view she had to come in from the side.

Prediction.—"Quiescence while listening to the music, then a quick *right-left* eye movement."

Figure 7 shows that the last eye movements were purely vertical as a careful interpretation of the report suggested. This exemplifies what was found about 10 times: that the predictor, in basing his inference less directly on the dreamer's narratives and more on his own interpretive assumptions, would formulate incorrect judgments. One judge rated this dream as a *Poor* correspondence while the other rated it *Fair*. Although this example was rated as *Fair-Poor* (on the basis of directional inaccuracies), it is supportive

Fig. 7.—An a.c. electrooculogram showing the last 17 seconds before an awakening (arrow). Electrode positions: *P*, parietal (EEG); *Sup.*, supraorbital; *Inf.*, infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. REM's: *D*, down; *U*, up.

Note the extended period of eye-movement quiescence preceding the burst of vertical deflections. This corresponds to the dream report of the subject watching an individual playing a violin on a stage. The deflections occurred at the point in the dream when the subject watched someone sit down just in front of her. The *P* lead shows a Stage 1 sleep record.

Fig. 8 (Example 6).—An a.c. electrooculogram of the last 15 seconds prior to an abrupt awakening (arrow). The electrode positions: *F*, frontal (EEG); *P*, parietal (EEG); *Sup./Inf.*, supraorbital/infraorbital (bipolar); *Lt. Lat./Rt. Lat.*, left lateral canthus/right lateral canthus (bipolar). (Vertical REM's are shown on the *Sup./Inf.* line; horizontal REM's appear on the *Lt. Lat./Rt. Lat.* line.) REM's: *D*, down; *L*, left; *R*, right.

In this example, the subject alleged that he watched a car pass him traveling to his right. But the interrogator's questioning elicited that the subject picked up the car in his "vision" by looking to the left and down a hill (see, Example 6). The last REM is to the right, and the subject stated that the car was just passing in front of him (moving to his right) when he was awakened.

The a.c. oscillographic tracings return to the baseline after the initial deflection. Therefore it is difficult to know whether the series of leftward eye deflections was saccadic but progressively more lateral, or whether after each leftward movement the eyes slowly returned to the midposition.

The *F* and *P* leads show a Stage 1 sleep record. There is an artifact in the *P* and *Sup./Inf.* tracings 12 seconds before the awakening.

of the study's hypothesis because there exists a global correspondence between the imagery and the REM's. One expects, and finds, a long period of ocular quiescence followed by a short burst of movement.

On the other hand, the experimenter's assumptions and attempts to clarify the dream report repeatedly proved crucial to the establishment of correct predictions. The subject's report in the following example would have rendered the interpretation incorrect if not qualified:

EXAMPLE 6.—Transcript, Subject 8, Sept. 21, 1960 (Fig. 8):

". . . . Then I was walking along and I caught sight of a car moving toward my *right*. Just then I woke up."

"You say it was moving towards your right?"

"Yes, from left to right."

"But when you first saw it, in what direction did you look?"

"Well, it was coming up a hill on my *left*. I guess I glanced to my *left* quickly to see it."

"How long did you follow it?"

"A few seconds. Just as the car moved past me I woke up."

"So you first looked up to the left and then following the car to your right."

"That's right."

Prediction.—"There should be some *leftward* glances with a *downward* component. The last movement should be to the right."

This case, like Example 2, demonstrates the value of careful interrogation. Unquestioned acceptance of the subject's account would have led to the expectation of a series of movements to the right, whereas the opposite was the case. In general, a subject usually gave an account of where he looked, but not of his total field of vision, his vantage point, or the REM's necessary to look at what he saw. Accordingly, the subject's account, by itself, was inadequate for purposes of comparison to the EOG. Several subjects, however, did describe their accounts in terms of directional gaze deflections. After a few tries, they proved as adept as the interrogator.

(*e*) The interrogator's task was complicated by the failure of the buzzer to awaken the subject instantaneously in some instances. As a result, on these occasions, the buzzer was incorporated into the dream, and a few more eye movements occurred after the buzzer sounded. After a few instances, the interrogator learned to decide when this had happened and when to include the postbuzzer eye movements in the prediction. The following example, in which the incorporation is clear and undisguised, will illustrate this circumstance. The subject dreamed that he was lying in bed:

Example 7.—Transcript, Subject 2, Dec. 16, 1960 (Fig. 9):

"This was an unusual dream. I was listening to conversation and was fascinated by it. I was lying on my back and for quite some time I just lay there looking at the wall and listening to their conversation out in the hall. . . . He was telling about some friend who had deserted his wife. It was almost as if he were hinting he might do the same thing and she was objecting. Then the buzzer sounded and she was coming back into the room. I looked from the wall down to the doorway. Then I awakened."

Prediction.—"There should be a long interval of ocular quiescence as the dreamer stares at the wall listening to the people in the hall. Just at the awakening there should be some *downward* movement with a *leftward* component."

The preceding example illustrates, too, that active "viewing" may be going on even though there is eye-movement quiescence. Apparently, dreams do not stop in between eye-movement bursts. In other words, the dream continues uninterrupted through Stage 1. In all of the examples in this study involving periods of ocular quiescence, the narratives gave evidence of uninterrupted dreams in which the dreamers watched stationary objects or persons. Frequently a conversation was in progress between the dreamer as participant and another person at whom he was looking. Considerable dream action and change of imagery can be taking place, however, in the absence of REM's, if the dreamer is observing a narrow field of vision from far off. Under such circumstances, little shift of gaze is required because the range of view comprises a very small arc. In another study Dement [14] received a report of a highly active dream from a subject who

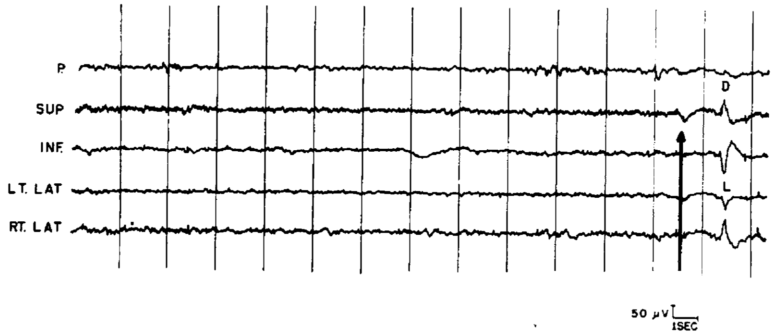

Fig. 9 (Example 7).—An a.c. electrooculogram showing 25 seconds of a recording before the awakening buzzer was sounded and 4 seconds after it was sounded. Electrode positions: *P*, parietal (EEG); *Sup.*, supraorbital; *Inf.*, Infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. REM's: *D*, down; *L*, left. Note that the buzzer did not abruptly awaken the subject. The *P* lead shows a continuation of Stage 1 after the buzzer. REM's may take place after the buzzer while the subject remains asleep. In these instances, the buzzer is often incorporated into the dream as in this example (see transcript).

The subject awakened during the next 1-2 seconds.

Fig. 10.—An a.c. electrooculogram of the last 40 seconds prior to an awakening. Electrode positions: *F*, frontal (EEG); *P*, parietal (EEG); *Sup.*, supraorbital; *Inf.*, infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. The buzzer was actually sounded several seconds earlier than shown by the arrow in the record. The *P* lead shows a Stage 1 sleep record.

This example illustrates the finding of long stretches of REM quiescence during Stage 1 sleep. When quiescence occurs after gross body movements, subjects frequently do not recall dreaming.[57] In most other cases the subject reports visual imagery appropriate to REM quiescence. In this case the dreamer intently watched 2 men holding a conversation.

was showing long periods of REM quiescence. This was puzzling until the subject pointed out that in the dream she saw all the action on a television screen.

Figure 10 is another instance of ocular quiescence during Stage 1. In this dream the subject reported that for a few minutes up to awakening, he watched 2 men seated in 1 place holding a conversation. He remembered and could recount the conversation. Note the absence of any REM's of large amplitude for more than 40 seconds.

(*f*) On occasion, subjects reported a series of visual images which correlated perfectly with the recorded eye movements, but they added that they had a "feeling" that something *else* had happened between the end of the imagery and the awakening which did not have the quality of a clearly recalled sensory experience. Such sensations were not accorded a time dimension about which the subjects could be certain. The postimagery addendum, unlike most dream events, was merely "known" or "felt," and referred to only in quasi-experiential terms. Nevertheless, it was usually included by the subject into the dream proper. In most cases, there was a close correspondence between the preceding REM sequence and the dream narrative which extended to the moment of awakening. There were no eye movement concomitants of the extra "feeling." Thus the sensation of further events is thought of by the authors as a "waking-up phenomenon." It is apparent how this phenomenon, when it occurs, can contaminate an eye-movement prediction if it is included by the interrogator in his formulation. Moreover, the possibility that this phenomenon plays a role in the reports of dreaming from non-REM periods should be seriously considered.[22]

(*g*) It is a characteristic of the a.c. EOG equipment that the absolute position of the eyeball cannot be established from the record.[38,10] The only data provided are the occurrence of an REM, its direction, and a close approximation of velocity and arc. Hence, the same EOG deflection would be found in Figure 1 (first REM, left) whether the eyeball moved from midposition to the left periphery, or from the right periphery to the center midposition. This difficulty presented some problems for the interrogator when he tried to predict the directional deflections of the eyes from the account of the visual imagery. The interrogator, however, made it a practice to familiarize himself with the dreamer's hallucinated head and eye position preceding the dreamed deflection of gaze described by the subject.

The portion of transcript following illustrates this point:

Example 8.—Transcript, Subject 4, Sept. 27, 1960:

". . . .The last thing I saw were my parents on my left."

"Where were you looking before you looked at them?"

"I was looking at the sky through a window on my left."

"Further to your left than your parents in relation to you?"

"I think so, yes."

"Then you looked at your parents?"

"Yes."

"Then you must have look *down* and to the *right* to see them?"

"I guess so."

The interrogator, in predicting the final deflection as *down* and *right,* proved correct. By questioning the subjects in this fashion, the REM direction necessary to reach a certain fixation point could usually be inferred.

(*h*) Another source of error in judging the REM's recorded by the EOG is the failure of the a.c. amplifiers to pick up very slow movements [38,10] ("pursuit" movements [31]). Relatively few of the reports contained accounts of watching slowly moving objects. When the narratives seemed to suggest slow eye movement, the interrogator could usually account for it in his prediction, but this factor undoubtedly contributed to the possibility of error when the interrogator attempted to construct a statement of the exact REM sequence.

The above 8 considerations suggest that the failure to realize 100% correspondence can be explained by implicating the influence of factors of equipment, method, and communication without necessarily finding the basic eye movement—dream image hypothesis wanting. It is somewhat surprising, all factors considered, that as high a correspondence as 75%-80% was realizable even among the 3+ dreams. The assumption seems justified, then, that if the dreamer's recall were faultless, his reporting accurate, the interrogator's interpretive judgment valid, and technical hindrances removed—that is, if the error-laden middle ground between dream imagery and its translation into REM sequences could be avoided—our accuracy of prediction would undoubtedly approach 100%.

Mention should be made of the problem of statistical analysis of the data in this study. Questions might be raised regarding the likelihood of correctly predicting a series of eye movements on the basis of chance, or whether our figures represent results which are significantly greater than chance. For a single eye movement, if one were attempting to choose 1 direction from a possible 4 (up, down, right, left), one could gauge the results against the statistical yardstick of 25% expected by chance alone if there were equal likelihood of deflections in each direction. (Actually, there exists a slight preponderance of horizontal movements in comparison to vertical.) But calculating chance would be prohibitively difficult, if not impossible, when each awakening shows a varying pattern of eye movements, frequently multidirectional and separated by different intervals of time (Fig. 11). Rough estimates are available, however, for certain types of patterns. The experimenter who observed the recording and awakened the subject, selected different se-

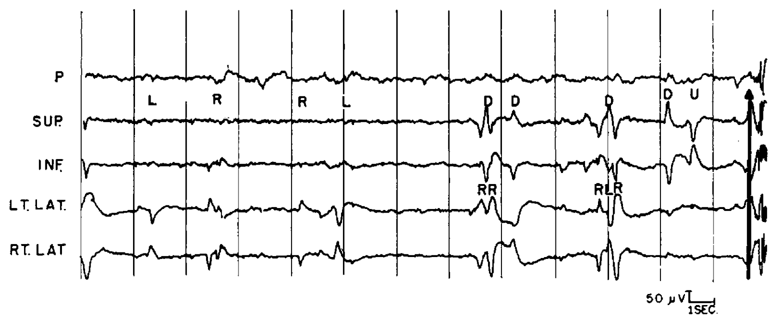

Fig. 11.—An a.c. electrooculogram of the last 25 seconds prior to an awakening (arrow). Electrode positions: *P,* parietal (EEG); *Sup.,* supraorbital; *Inf.,* infraorbital; *Lt. Lat.,* left lateral canthus; *Rt. Lat.,* right lateral canthus. REM's: *L,* left; *R,* right; *D,* down; *U,* up.

Note the variations in sequence, direction, and timing of the REM's. A diagonal deflection of the eyeballs results in a recording of concurrent vertical and horizontal deflections.

The first 10 seconds of the record showing to-and-fro horizontal deflections was correlated with the subject's account of being a spectator at a football game, looking at the opposite stands from one end to the other and back. He then looked down to his right to watch a cheerleader climb up into the stands in which he sat.

The *P* lead shows a Stage 1 sleep record.

quences and directions of movements at random to use for awakenings. Fifteen of the 3+ dream awakenings were done after single unidirectional deflections. In these instances, chance of a correct guess can be at most 1 out of 4 (because the predictor may select 1 of 4 single directions but may also select no direction, or any combination or series of deflections), but 13 of the 15 were correct (*Good* correspondences). Moreover, 23 of the dreams consisted of a sequence of eye movements in the same direction (Fig. 3). The chance of accurately predicting a series of movements must be a much smaller ratio than for a single movement. Yet, 21 of the 23 such examples were correct (*Good* correspondences). All the other types of eye-movement patterns show predictive accuracy of the same order of magnitude. Accordingly, the over-all figures clearly represent a very high order of statistical significance.

Two more examples of awakenings have been selected to demonstrate points of interest. Figure 12 contains sleep spindles in an otherwise low-voltage record indicating a Stage 2 pattern.[17] The buzzer was sounded, after which ensued a brief burst of vertical eye movements before the subject awakened. The subject could recall only a momentary image, just prior to awakening, of a man waving a hammer up and down in front of

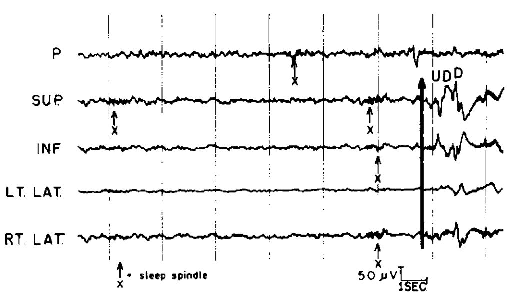

Fig. 12.—An a.c. electrooculogram of the last 13 seconds before the awakening buzzer was sounded and the subsequent 4 seconds. Electrode positions: *P*, parietal (EEG); *Sup.*, supraorbital; *Inf.*, infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus. REM's: *U*, up; *D*, down.

Note the burst of predominantly vertical REM's occurring just after the buzzer. These corresponded well with the dreamer's narrative for a very short dream. The EEG shows spindling and is clearly a Stage 2 sleep record *before* the buzzer. See the text for an explanation of the close approximation of Stage 2 sleep with REM's.

her. She recalled nothing before that. The dream account and the recorded eye movements in Figure 12 show an excellent correspondence.

If we accept this incident as one of a short dream emerging from a Stage 2 record, its occurrence would appear to argue against the unvarying association of dreaming with Stage 1 sleep. When the EEG record was examined *in toto*, however, it was found that the awakening was carried out about 1 hour and 35 minutes after the first Stage 1 period. This is about the interval that usually separates the first Stage 1 period from the second. It is likely that the second Stage 1 period was just about to emerge. One might wonder, however, whether the buzzer played a role in inducing the emergence of Stage 1. Dement and Wolpert [18] have shown that noise, light flashes, and water spray, applied during nondream periods, often caused restless sleep and lightening of sleep depth but proved unable to initiate Stage 1 with REM's. The latter appears to be the physiological representation of a complex, cyclicly appearing brain activation which is largely independent of environmental change. Attempts to "lighten" sleep with external stimuli or pharmacological agents like *d*-amphetamine only disturb sleep and diminish the Stage 1 periods.[42,13] It is probable, therefore, that the Stage 1 sleep level was in the process of reestablishment in the brain and was at the point of being evinced in the cortical EEG when the buzzer sounded. Only under these circumstances could the buzzer be said to have "induced" the dream.

Figure 13 is an illustration of a "wrong" (*Poor*) prediction. The subject reported climbing the steps to board an airplane. The interrogator predicted a series of vertical movements, but the only movements on the record were a series of rapid horizontal deflections about 10 seconds before the subject awakened. It is of interest that after the prediction was formulated, the subject later reported rummaging through merchandise on a counter (probably responsible for the horizontal movements) just before walking up the gangway. She also pointed out that when

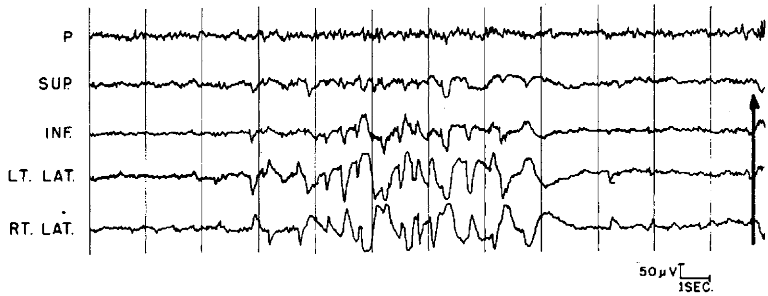

Fig. 13.—An a.c. electrooculogram of the last 24 seconds before an awakening (buzzer). Electrode positions: *P*, parietal (EEG); *Sup.*, supraorbital; *Inf.*, infraorbital; *Lt. Lat.*, left lateral canthus; *Rt. Lat.*, right lateral canthus.

Note the burst of rapid, predominantly horizontal REM's beginning 18 seconds prior to awakening. This is an example of a *Poor* Correspondence in that the subject's account of the dream ending could not be matched to the EOG record (see text). The *P* lead shows a Stage 1 sleep record.

walking up the steps, she kept her eyes on the stewardess standing at the doorway of the plane (probably responsible for the eye-movement quiescence just before awakening). This example also illustrates that *post hoc* examination was successful, in many cases, in finding the source of judgemental errors. In only 4 of 18 *Poor* correspondences did the narratives seem wholly unrelated to the EOG on *post hoc* examination.

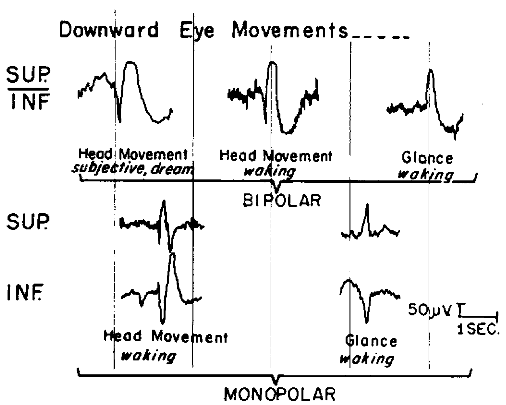

Fig. 14.—An a.c. electrooculogram of REM's in the *downward* direction with and without associated movement of the head. Electrode positions: *Sup.*, supraorbital; *Inf.*, infraorbital; *Sup./Inf.*, supraorbital/infraorbital (bipolar). (The supraorbital (monopolar) and the bipolar leads indicate an upward deflection of the eyes when the pen moves downward, and downward eye movement when the pen moves upward.) Note that in both monopolar and bipolar tracings a downward motion of the eyes, when accompanied by downward movement of the head, is characterized by a brief initial upward eyeball deflection. This is not so with a downward glance. The top left figure shows this initial upward deflection in an REM during Stage 1 sleep. In this instance the subject dreamed he looked down sharply, although his head did not actually move. This is referred to as a "head movement" type of REM because it appears so similar to the tracing resulting when the head does actually move (top middle figure).

In the course of the present study, an observation was made which is under further investigation; it will be reported on more fully in a future paper, but we wish to mention it briefly. Just prior to a number of dream awakenings in our study the presence of multiphasic REM tracings were observed on the EOG (Fig. 14, bottom *left* triphasic pattern vs. bottom *right* monophasic pattern). These are not infrequently seen throughout REM periods. The diphasic and triphasic tracings are recordings of single eye movements during which the eyeball reverses direction once or twice in relation to the head. EOG patterns of this nature are usually seen when the eyes and the head are both in motion.

In conjunction with the multiphasic REM's occurring just prior to awakening, the subjects, when interrogated, frequently reported attempts to look about quickly at something in the dream. They usually replied in the affirmative when asked whether they felt that they had turned to look, i.e., that they had moved their heads as well as their eyes. But the sleeping subjects were observed not to have moved their heads, and the absence of muscle potential on the EOG record confirms that the heads were stationary.

Preliminary findings, in our laboratory, of eye movement associated with head movements in awake subjects are consistent with the observations of Fenn and Hursh [20] and Hodgson and Lord [25] that the head and eyes do not begin their movement together. If the head starts from a position of rest and turns, as the eyes move to the *side* or in an *upward* direction, the eyes precede the head.

As the head catches up, there is an eye movement in the opposite direction relative to the head. This results in a diphasic tracing on the EOG in which the initial deflection is in the direction of gaze. In *downward* movements of the eyes and head a triphasic EOG pattern may be seen. Starting from a fixed position, the head appears to precede the eyes, causing a short upward deflection of the eyes relative to the down-moving head. This results in an initial deflection on the EOG opposite to the direction of gaze (first phase). Then the eyes start down (second phase) reaching their destination before the head does. Then the head catches up (third phase) resulting in a final upward deflection of the eyes relative to the head. This total sequence causes a triphasic EOG tracing contrasting with the monophasic tracing of single downward glance (Fig. 14, contrast top *middle* with top *right* figures). The multiphasic "head-movement" type REM may be distinguished from a rapid to-and-fro glance without head movement. The latter also has a diphasic EOG pattern, but usually has a more sharply sloped second phase tracing though these distinctions are not always easy to make with a.c. recording.

The fascinating aspect of the finding of the "head movement" type of REM's among the REM's of Stage 1 was that the sleeper was not actually moving his head. As described, some of the subjects occasionally reported turning their heads *in the dream* to peer at something. We suggest that the *feeling* of head turning was part of the hallucinated phenomena of the dream—a motor and proprioceptive hallucination in this case, not an actual alteration of the head position. Accordingly, while the sleeper's head remains at rest, the dreamer's hallucinated head turns about, and a "head movement" type of REM occurs. The eyes seem to behave in accordance with the movement the dreamer perceives his head to be making in the dream.

We would like to advance the following hypothesis as the mechanism of this phenomenon: In waking life, when the head and eyes are turned to the side to look at an object, the eyes precede the head in moving toward the periphery. When the eyes reach their fixation position they remain there as the head catches up. As a result of the movment of the head relative to the fixed eye position, the second swing of the diphasic EOG deflection occurs. In order to stabilize the eyes, lest the turning head cause them to slip past their fixation point, the rectus muscle group, which initiated the deflection of the eyes to the periphery, relaxes while the opposing rectus group contracts. We propose that in sleep, when the dreamer feels that he turns to look, even though no head movement actually takes place, opposing groups of recti muscles are stimulated to contract in sequence as if to effect movement and then stabilization. Hence, for horizontal movements, a quick initial deflection of the eyes is observed, followed by a slower reverse movement in the direction of the midposition. This would result in the appearance of a diphasic "head movement" type of REM. Hence, if our hypothesis is correct, we may infer that the dreamer is hallucinating head movements when this type of multiphasic REM is encountered. Direct-current recordings will make more extensive analyses of these relationships easier to study and interpret.

Comment

The results of this investigation bear out the premise that REM's which occur while people dream have a definite and intimate relationship to the visual events being experienced by the dreamer. It has proved possible to construct highly accurate predictions of the direction, quantity, and sequence of REM's from descriptions of the vividly recalled terminal images of dream scenes. It appears that each eyeball deflection of the REM's is coincident with a subjective shift of gaze of the dreamer "viewing" his hallucinated field of vision.

Functionally, the REM's should be considered as fixational eye movements. On purely descriptive grounds they qualify as well in that their velocity is virtually that of waking fixational movements,[13] and like waking deflections, each one is followed by a short fixational pause.[40]

Physiological Correlates of Dreaming

The present study has demonstrated that the REM's of sleep are somatic correlates of dream hallucinatory phenomena, mediated by the neuronal pathways of the motor visual system. This finding furnishes the best evidence that the dream is both a mental and a physical event. In this respect it is complemented by the developing literature on the nature of the dream process.

It has been shown that the body participates in the dream hallucinations in several ways in addition to eye movements. These physiological parameters do not seem to react to the dreamed events with the precision that the REM's exhibit, but they show definite differences, depending on whether sleep is dreaming or nondreaming. Increments and variability in the cardiorespiratory cycle have been reported. Aserinsky and Kleitman[2] found a 20% higher mean respiratory rate during REM periods in human subjects. Moreover, the peak frequencies of respiratory rate occurred during REM periods. Pulse rate was 10% higher during REM periods than just before or just after. Kamiya[37] has found a 5% increase in heart rate during REM periods. He found also that superior dream recall was associated with higher frequencies of pulse and respiratory rate. Snyder[51] demonstrated, however, that in any one dream period, there may be either an increase or decrease (less frequently) in the respiratory rate. Other investigators[36] confirmed this findings in the cat. In Snyder's study, the variability of the respiratory cycle during Stage 1 was found to be so marked that it served as a precise indicator of dreaming. A correlation existed also between high respiratory intercycle variability and vividness of dream recall. Dement[13] has also observed increased respiratory and pulse frequency in Stage 1. In individual cases, he has found that a single isolated eye movement may be associated with a short period of apnea. In general, respiratory rate was observed by him to be more irregular in conjunction with Stage 1 eye movements than during Stage 1 intervals of ocular quiescence.

There are other physiological measurements which seem to reflect differences between dreaming and nondreaming sleep. For example, a fascinating relationship between skin temperature and dreaming has been demonstrated by Snyder.[50] In the waking state, the skin temperature of the forehead exceeds that of the finger. As soon as the individual falls asleep, this relationship is reversed, finger temperature then exceeding forehead temperature. During Stage 1, the 2 move closer together. Successive Stage 1 periods in the same night find the range of differences progressively narrowing, but the temperature at the 2 sites returns towards the sleep baseline at the end of each dream. This sequence continues until the waking pattern is reestablished in the last dream of the night as the forehead temperature again exceeds that of the finger. Work is currently in progress on such physiological measures as blood pressure, sympathetic nervous system reactivity, O_2 saturation, and CO_2 tension of expired air to distinguish dreaming sleep.[50]

Kamiya[37] and Hawkins et al.,[24] in separate studies, have shown that basal skin resistance is higher in sleep than in the waking state and rises to its peak levels during dreaming sleep. It is noteworthy that the basal skin resistance is at its maximum in awake individuals during intervals of heightened mental activity.

By certain criteria, dreaming sleep has been shown to be "deep" sleep. Although the Stage 1 sleep EEG pattern is similar in appearance to a waking tracing and has been called light sleep, a growing body of evidence suggests that the dreamer may be "deeper" asleep during Stage 1 than during spindling and higher voltage stages. Various experiments in humans and animals of arousal and response thresholds to external stimuli generally demonstrate significantly higher thresholds during Stage 1 sleep.[17,29,30,36,50,55] Animal investigations of awakening thresholds have been carried out employing direct electrical stimulation of the reticular formation.[5,36] These studies also demonstrate that much greater stimulation is required for arousal during Stage 1 sleep than during the so-called "deeper" stages.

Huttenlocher[28] showed that although the gross responsiveness of the mesencephalic reticular formation (nonspecific afferent system) to auditory stimuli was much less during Stage 1 sleep than during higher voltage wave sleep, the gross responsiveness of the cochlear nuclei and primary auditory cortex remained undiminished except for a reduction in the spread of impulses from the auditory cortex to association and motor areas. The primary afferent pathways thus showed no depression of responsiveness, but in spread of response to other areas. This study and the experiments using direct brain-stem stimulation suggest that the higher thresholds of excitation required for arousal during Stage 1 sleep, while perhaps in part a consequence of inattentiveness to external stimuli, are probably more significantly the result of reduced neurophysiological responsiveness to external stimuli during dreaming sleep. This contrast of a seeming "light" EEG pattern and a "deep" functional sleep level in the cat inspired Jouvet to call Stage 1 sleep the "paradoxical phase."[36]

There is, then, considerable evidence that although one is deeply asleep when dreaming, a quasi-waking level of physiological reactivity to the endogenous experiences is manifested. A study by Wolpert[56] seems to fit with these findings. He was able to show muscle action potentials (though actual movement is negligible) in isolated limbs employed subjectively by his subjects in their dreams. Although gross bodily movement is more reduced in Stage 1 than in nondream periods,[17,18] the incidence of isolated peripheral muscle activity is significantly higher. Recent work in this laboratory, carried out by Antrobus,[1] has shown a nightly incidence of small muscle movements of the extremities and face during Stage 1 dream periods. In a number of instances, pelvic movements were observed, evidently of a sexual nature. These small body movements which occur during dreaming are very characteristic. It is possible that the small muscle movements are related to the dream content in the same way as are eye movements. Movements of the facial musculature are probably associated with affective expression.

These findings coincide with Dement and Kleitman's[17] observation of fine digital movements during dreams (absent in nondream periods) and Max's[43] findings of action currents in the arms and finger musculature of dreaming deaf mutes. Over-all tonic muscle activity is sharply reduced in cats[36] and in man[13,6] during low-voltage, fast sleep. But cats (and other mammals), as well as human beings, show small peripheral phasic muscle contractions during the low-voltage phase. In these animals, they are manifested by twitching of the vibrissae, tail, and jaw.[15,36,27,49,54]

To summarize, it appears that the dreamer is almost totally immersed in his dreaming consciousness. But he participates in the dream with both emotional and physiological responses as if it were a waking experience. In placid dreams, his pulse and breathing are fairly regular, and he lies motionless. When he is under emotional stress or is physically active in the manifest dream, his pulse appears to quicken, his respirations become irregular in rate and depth, he exhibits attenuated motion of those muscles being called into action in the dream, and he gazes sharply about at the dreamed visual imagery that he clearly "sees." It is as Lewis Carroll[8] fancied that, "We often dream without the least suspicion of unreality. 'Sleep hath its own world', and it is often as lifelike as the other."

Dream Continuity and Time Dimension

The question of a dream's visual continuity has often been raised. In the past, there was no evidence that the dream did not represent fragments of dreamed material rather than a single and continuous event. Is a dream constituted by an uninterrupted sequence of visual material or by a broken succession of images? It has been conjectured that during the duration of the Stage 1 pattern, visual imagery may appear in "packets." In other words, imagery may be present only at the moment that eye deflections are occurring, but during the quiescent periods in between the bursts of eye movements, nothing is seen by the dreamer. In other words, if the dream can be compared to a movie sequence, it would be as if a fade-out occurred every few seconds. Some of our data bear on this point. A number of subjects had dreams in which long stretches of eye-movement quiescence occurred just prior to the awakening (Figs. 7, 9, and 10). In each case the subject reported that he had focused on one point and watched it while thinking or while listening to conversation. Furthermore, in most of the dreams gathered in this study, the narratives accounted for imagery coincident with and appropriate to the Stage 1 quiescent periods as well as to the REM's. The accuracy of predictive judgements often rested on whether or not the presence of fixational periods was anticipated by the interrogator. Hence, except for the quiescent periods appearing just after bodily movements and towards the end of Stage 1 periods, there is considerable evidence that the visual imagery of dreams is continuous, irrespective of ocular activity.

There is ample evidence, however, of *telescoping* in dreams; that is, an element in a sequence of action is abbreviated or left out. This is to be distinguished from changes of scene within the same dream period in which a new episode replaces one which is ending or in progress. The latter phenomenon has been shown to occur in conjunction with gross body movements.[18] As an illustration of telescoping, one subject in our study dreamt that he was standing at the foot of a flight of stairs. He walked up the flight of stairs. The next thing he remembered was putting on his jacket in a cloakroom down the hall and around the corner from the stairs. He could not recall walking down this hallway, but he was sure he would have had to in order to reach the cloakroom. The eye movements of this dream corresponded closely to the type of activity at the foot of the stairs followed immediately by vertical REM's coincident with walking up the stairs. The next REM's corresponded to those expected in the cloakroom. No horizontal REM's, found in dreams of walking and turning corners, were evident. Both the subject's memory of the dream and the REM pattern support the inference that the dream telescoped at that point, i.e., that a portion of it dropped out of sequence. The telescoping does not create a gap in the continuity of the dream proper but merely in the expected sequence of events in the dream. Many examples of the same type were found in our study.

These data suggest that the dream is, for the most part, an ongoing and continuous sensory experience. Using electrooculographic tracings as a window into the dream activity, we may conclude that the dream has a dimension in actual time as well as in the dreamer's subjective appreciation of passing time. Accordingly, Maury's [41] belief that long dreams are instantaneous is not supported by brain-wave and eye-movement studies of dream duration. The hallucinated sensations seem to persist in time, having a realistic progression and flow, within the limits imposed by telescoping and kaleidoscopic action changes. Though one type of sensory stimulation may cease, as in a dream in which the dreamer went blind, other sensory experiences (auditory, kinesthetic, proprioceptive, etc.) continue without interruption.

Neither the cardiorespiratory irregularities, the muscular and eye-movement changes, the high-voltage rhythmical hippocampal waves and pontine spindles recorded in studies in cats,[36] nor the specific basal skin resistance and skin temperature alterations occur in sleep stages other than Stage 1, the "paradoxical phase." The dream events as reported from awakenings during Stage 1 are described in vivid, sequential, and continuous terms, and have concomitant parameters of objective activity in muscle, skin, cardiorespiratory and eye-movement changes. Thus, it is probable that whatever cognitive and physiological process is in progress during the remainder of sleep [22] or during hypnotic dreams,[48] it is qualitatively different from the psychophysiological status of the individual during Stage 1 sleep.

Mechanism of Rapid Eye Movements and Role of the Cortex

Other workers have recently described rapid eye movements in monkeys,[54] rabbits,[52] and dogs,[49] as well as in cats [15,36] during the low-voltage, fast stages of sleep. Hence, it is probable that the alternation of high voltage—slow with low voltage—fast brain waves occurs in lower mammalian forms and perhaps in other classes of animals. A discussion of whether or not animals dream will not be attempted here. There is, however, no evidence which militates against the belief that higher animals can hallucinate in sleep the images, sounds, touch, and emotions that they can appreciate in waking life. Certainly in purely descriptive terms, they look as if they are reacting to sensory perceptions in sleep in ways similar to the behavior of humans who, when they are awakened, report that they have been dreaming.

The mechanisms and pathways for fixational eye movements have not been fully elucidated. Hyde and Eliasson,[32] and Hyde and Eason [31] reported success at evoking conjugate ocular deviations in cat "encephale isole" preparations by stimulating widespread brain-stem areas. They feel that a complex system of dispersed neuronal elements, lying mainly in the reticular formation, coordinates directional eye movements. Wagman, Krieger, and Bender [53] demonstrated conjugate bilateral eye movements when stimulating electrically the occipital cortex of monkeys. The deflections they evoked were contralateral and were usually obliquely upward or downward resulting in a deviation toward the field of vision that would normally be appreciated by the area of the cortex that was stimulated. One might assume that when stimulated the monkeys may "see" something and turn their eyes toward the hallucinated object. However, on the basis of other data, these authors hypothesize that the eye movements are not the result of the monkeys having experienced visual images. There is evidence that the occipital cortex may influence oculomotor functioning without visual sensation via occipital corticofugal motor neurons.[7,4]

Faulkner and Hyde,[19] working with decerebrated cat preparations, showed that the neuronal pattern capable of producing coordinated eye movements is fully present in the brain stem and is more reactive in decerebrate preparations The experiments of Wagman and his co-workers, referred to above, call attention to at least the neuroanatomical possibility that the REM's associated with dreaming may have their origin in the cortex. But an observation of Jouvet et al.[35] makes this possibility unlikely. They reported the presence of REM's, cardiorespiratory alterations, and muscular twitching during sleep in decorticated cats and in a human who was functionally decorticate for 3 years. (It remains to be seen whether the character of these REM's is truly similar to those in the intact animal. For instance, are they as variable in frequency, direction, and sequence?) Nevertheless, on the basis of this finding it would appear that the cortex is unnecessary to the orgination of the impulses resulting in the REM's of sleep.

It is not yet known where the neuronal impulses which initiate the visual imagery of dreams arise. But Mikitan et al.[45] have reported evidence to suggest that the site of origin of these impulses is subcortical rather than cortical. These workers believe they have recorded increased spiking activity in the lateral geniculate body of sleeping cats during REM periods when the cortex showed a characteristic low-voltage, fast pattern.

The work of Mikitan et al. and Jouvet et al., thus, strengthens the possibility that cortical stimuli are not responsible for the initiation of dreamed imagery nor of the REM's associated with dreaming. Both the REM's and the visual sensations of dreams may have their source in a common center. Jouvet [35] has found such a site situated in the anterior pons which he feels to be responsible for the phenomena occurring during the "paradoxical phase." This arrangement would account for the association found in this study between the imagery of dreams and the rapid ocular deflections.

The cortex is usually involved in the intact individual in mediating the association between eye movements and imagery. In normal "seeing" the eye movements occur prior to the associated imagery, for the eye movements are necessary in order to bring into view objects that one wishes to see. The cortex may, however, integrate eye movements with imagery even when the individual is not aware of wishing to move his eyes. Hence, if a normal subject is asked to close his eyes and image a distinct visual experience (i.e., a tennis match), he will develop eye movements appropriate to the imagery (in this case horizontal to-and-fro movements [33]). These observations have recently been confirmed in this laboratory.[21] Schiff et al.[48] have recently observed REM's with hypnotic dreams; anyone who cares to note it, may observe hallucinators "looking," with REM's, at their visual imagery. One would infer that this type of imagery precedes the REM's, and there now seems to be evidence to suggest that in dreaming this may be so as well.

After a change in visual pattern, certain waves appear in the occipital EEG called "λ-waves." They are supposedly an evoked cortical response to stimulation caused when the suddenly changing visual pattern falls on the retina consequent to an eye movement. Thus, the λ-waves tend to follow eye movements in the waking state.[9] Dement [13] has observed certain frontoparietal sharp waves presenting during Stage 1 sleep just *before* or concurrent with the beginning of a burst of REM's. The characteristics of these sharp waves are similar to those of λ-waves except for the localization. If these sharp waves are indeed analogous to λ-waves, their appearance preceding REM bursts may indicate that the visual images in dreams just *precede* their associated eye movements. That is to say, in the waking state objects are seen just after the eye movements are made requisite to localize the objects in view. However, the imagery may occur prior to the REM's in dreaming sleep and in waking "imaging."

If we then assume that the cortex is responsible for the "plot" and contents of dreams, it is still consistent with the Mikitan, Jouvet, and Dement observations to conceive of the cortex as the center which coordinates and mediates the character of the dream with the type and directions of REM's. Hence, though the point of initiation of the changes occurring during the "paradoxical phase" may reside in the brain stem, it is the cortex which probably integrates the changes into what is known as a "dreamed experience."

Jouvet's finding of REM's in decorticates fits with the observation that human neonates have long periods of REM's before they can see.[14] They also show active moving and sucking, whereas adults show little body movement during Stage 1.[3] At some point in their maturation, the body musculature relaxes, and the only muscles which retain their tone as in the waking state, are the extrinsic eye muscles and the obicularis oculi.[2] Probably as the infant gains vision, the cortical imagery and the REM's become associated. This maturational development needs to be studied carefully.

The predominantly recalled or described types of sensory elements in dreams appear to depend on the previous use of the appropriate sense organs.[47,34,44] Individuals with congenital or early life loss of visual and auditory faculties manifest little or no sensory imagery in those modalities in their dreams. Interestingly, the congenitally deaf report very vivid visual imagery.[44] If blindness ensues after vision has been gained, however, some visual imagery may persist in dreams throughout life and be directly associated with the REM's of these individuals.

Summary

A study was performed to further investigate the significance of the rapid eye movements (REM's) occurring during Stage 1 EEG sleep periods ("dream" periods) that are observed in humans and other mammals.

The operating hypothesis of this investigation was that a one-to-one correlation exists between the direction and timing of each

REM and the direction and timing of each alteration in the hallucinated gaze of the dreamer. In other words, it was felt that the REM's constitute the physical representation of the dreamer's "watching" of the visual imagery of the dream.

Twelve adult volunteer subjects slept 38 subject nights and reported 121 dreams that were used in the study. They were requested to describe in detail the visual imagery during the final 10-20 seconds before being awakened, with special emphasis placed on the directions of their gaze and their vantage point in relation to the objects "seen" in the dream. They were awakened during dreams by one investigator watching an electrooculographic record of their REM's. Another investigator, unaware of the actual REM's, interrogated the subject immediately after the awakening. On the basis of the dream narrative, the interrogator formulated a prediction of the number, direction, and timing of the REM's during the terminal REM sequence of the dream. The predictions were compared to the EOG record by 2 judges independently.

Predictions reached a high order of accuracy when the subject's narrative was based on vivid recall of the dream. The data show clearly that accurate formulations of REM patterns can be predicted solely from the dreamer's account of his visual imagery. This evidence strongly supports the operating hypothesis.

Factors of communication, method, and apparatus were appraised in the attempt to elucidate the failure to achieve perfect correspondence between the predictive judgments and the REM record in every instance.

It is evident from this study of REM's during sleep that the dream is both a physiological and a mental process. The correspondence of on-going dream imagery with the REM's and with the ocular quiescent gaps between REM bursts furnishes evidence that the dream is a continuous phenomenon, not merely a series of interrupted "packets" of imagery. The dreamer is deeply involved as a participant observer in the experience almost as if he were awake. The work of investigators studying other physiological parameters is used to support this conclusion.

Although periods of REM's have been observed in humans and cats having no brain functioning above the brain stem, the REM's are probably modified and integrated with the contents and imagery of dreams in intact individuals by the cortex.

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