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Dream Research

Slow Wave Sleep Dreaming

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Summary: Fifty volunteers slept two nonconsecutive nights in a sleep laboratory under electropolygraphic control. They were awakened for one report per night. Awakenings were made, in counterbalanced order, from slow wave sleep (SWS—stage 3–4 and stage 4) and rapid eye movement (REM) sleep. Following dream reporting, subjects were asked to identify memory sources of their dream imagery. Two independent judges reliably rated mentation reports for temporal units and for several content and structural dimensions. The same judges also categorized memory sources as autobiographical episodes, abstract self-references, or semantic knowledge. We found that REM reports were significantly longer than SWS reports. Minor content SWS–REM differences were also detected. Moreover, semantic knowledge was more frequently mentioned as a dream source for REM than for SWS dream reports. These findings are interpreted as supporting the hypothesis that dreaming is a continuous process that is not unique to REM sleep. Different levels of engagement of the cognitive system are responsible for the few SWS–REM differences that have been detected. **Key Words:** Slow wave sleep—REM sleep—Dreaming—Memory.

Dream researchers face a paradoxical situation: although a fairly large amount of evidence supports the idea that dreaming occurs during the whole night, irrespective of sleep stages, mental activity in nonrapid eye movement (NREM) sleep is still considered a kind of second rate product in comparison with REM dreaming. And indeed, among scientists and the general public the old-fashioned—and wrong—equation "Dreaming = REM dreaming" is still widely accepted.

As a result, several models of REM dream production have been developed: 1) the activation-synthesis model by Hobson and McCarley (1); 2) the connectionist model by Antrobus (2); and 3) the unlearning model by Crick and Mitchison (3), among others. NREM dreaming, on the other hand, has been either totally neglected as nonexistent or considered unworthy of modeling research.

Some recent studies on NREM dreaming, however, suggest new hypotheses that go beyond, or at least lead to a new interpretation of, the REM/NREM dichotomy. The most important results can be summarized as follows:

1) Content analysis has shown that REM/NREM [sleep onset (SO), stage 2 (ST2), and slow wave sleep (SWS)] differences are sometimes minor and variable across experiments (4–6).
2) The qualitative differences observed between REM and NREM (SO and ST2) dreams are by-products of differences in length, REM reports being commonly longer than NREM ones (4,7,8).
3) NREM (SO, ST2 and SWS) reports as long as, or even longer than, REM reports have been frequently found (4,6,8,9).
4) There is a difference in the quality of dream memory sources involved in the production of REM and NREM (SO and ST2) dreams. Episodic memories are more frequently identified as sources of SO than of REM dreams, whereas semantic knowledge is more involved in the production of REM dreams than ST2 dreams (8–11).
5) When controls for length of reports are observed, REM/NREM differences in the quality of memory sources tend to disappear (9,11).

Assuming that the dream is the result of the interaction

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between a diffuse mnemonic activation and a set of cognitive processes that reorganizes and interprets what is activated in memory, we can use the above results to put forward some interesting hypotheses.

First, it appears that dream processing is relatively independent of a strict correlation with a high level of cortical activation, a factor that can be considered, at best, as a condition facilitating the efficiency of the cognitive system of dream production. Second, what differs among the various sleep stages is the quantity and quality of memories available to, and the level of engagement of, the dream production system.

The above-mentioned findings do not support a dichotomic distinction between REM and NREM mentation, rather they suggest the hypothesis of the existence of a continuous dream processing characterized by a variability across and within sleep stages. Thus, it does not seem that the well-established physiological REM/NREM dichotomy is paralleled by a cognitive REM/NREM dichotomy.

A pilot study on mental activity in SWS (6), a sleep phase that, from a physiological point of view, is maximally different from REM sleep, has given results that basically agree with the above-mentioned hypotheses: SWS dreams are significantly shorter than REM ones and show only marginal differences in content and no differences regarding memory sources.

In order to give further support to the above hypothesis and to give a better definition of NREM mentation that goes beyond the traditional REM/NREM dichotomy, we decided to study SWS mentation in a larger sample, a kind of study that has been relatively neglected by dream researchers.

METHODS

Sixty university students (29 males and 31 females), aged 19–26, who were good sleepers and dream recallers, took part in the experiment as subjects. After an adaption night, each subject was studied for two nonconsecutive nights with standard electropolygraphic controls [three electroencephalogram (EEG), two electrooculogram (EOG) and one electromyogram (EMG)]. Only one awakening was scheduled per night in one of two different conditions:

Slow wave sleep (SWS). Subjects were awakened after 10 minutes of continuous delta sleep, stage 3–4 and stage 4 [according to the criteria of Rechtschaffen and Kales (12)], provided that at least 30 minutes from the initial sleep onset had elapsed.

Rapid eye movements (REM). Subjects were awakened during the second REM period, 10 minutes after the appearance of the first clear burst of rapid eye movements.

The order of the awakenings was counterbalanced across subjects.

Upon each awakening (carried out by means of an acoustic signal) mental experience reporting was solicited via intercom with the standard questions: "Please tell me everything you can remember of what was going on through your mind immediately before I woke you up" and, 30 seconds after the end of the subject's spontaneous report, "Can you remember anything else?"

Whenever an awakening in any condition failed to produce a content report, additional nights were scheduled until a report was obtained.

Immediately after each dream interview, the recording of the report was replayed to the subject. The interviewer segmented the report on-line into short thematic units expressing an action or a complete concept. A new thematic unit was considered to occur whenever there was a change in characters, in the prevailing activity or in the setting. After each segment, the subject was asked to identify the immediate memory sources of the segment just heard with the standard question: "What memory sources can you identify for this part of your dream?" Subjects had been previously oriented to this task and they had also listened to a tape in which an experimenter demonstrated the technique.

Dream report scoring

Dream reports were submitted to two independent judges who had no prior knowledge of the hypotheses formulated.

Judges scored the reports along three dimensions. The first, length, was measured in temporal units.[1] The second dimension used for scoring was continuity. Reports that contained more than one temporal unit were scored "continuous" whenever they showed a narrative structure. Plausibility was the third scoring dimension. Reports were scored "plausible" or "implausible" according to waking standards.

For each report they scored, judges were instructed to perform a content analysis noting: (a) the presence of the dreamer (i.e. the Self); (b) double representations of the Self; (c) the presence of a setting; (d) elements referring to the experiment (lab references); (e) the number of nonself characters physically present; (f) the presence of undefined characters (e.g. groups of people, crowd, etc.); (g) any dimensional distortion of char-

[1] A temporal unit was defined as "consisting of whatever activities could have occurred synchronously and were not described by the subject as having occurred successively. Judges were told to assign a new temporal unit whenever (a) a character performed an activity that could not, in waking life, be synchronous with her/his previous activity; (b) a character responded to another character or event; or (c) there was a topical change in vaguely recalled conversation". (4, p. 268)

TABLE 1. *Comparisons between rapid eye movement (REM) and slow wave sleep (SWS) reports for all the dimensions considered*

	REM	SWS
Self	96.00%	84.00%
Double self	4.00%	2.00%
Setting	90.00%	80.00%
Laboratory references	20.00%	18.00%
Number of nonself characters[a]	2.82	1.54
Undefined characters[a]	48.00%	30.00%
Dimensional distortions	12.00%	14.00%
Space–time distortions	24.00%	12.00%
Body feelings	22.00%	22.00%
Plausibility	34.00%	50.00%
Emotions[b]	62.00%	34.00%
Temporal units[c]	5.10	1.88
Continuity	65.12%[d]	78.95%[e]

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.0001$.
[d] $n = 43$.
[e] $n = 19$.

acters and/or objects (shape, color and size); (h) any spatiotemporal distortion; (i) any body feeling and (j) any emotions that were clearly expressed by the dreamer.

Interrater reliability was >82% for all the dimensions considered. Judges then resolved their scoring discrepancies, and the reconciled versions were used in data analysis.

Memory source report scoring

Transcripts of memory source reports were then submitted to the two judges who had previously scored dream reports. Memory sources were classified by judges into the three following memory categories:

1) Strict episodes—discrete episodes in the life of the dreamer with precise spatiotemporal coordinates (e.g. "It reminds me of last Sunday when I went to the theatre with some friends of mine").
2) Abstract self-references—memories not connected to any particular spatiotemporal context, referring to the dreamer's general knowledge of himself and/or his own habits (e.g. "It reminds me of my fondness for candies" or "This is related to the fact that usually I go out in the evening").
3) Semantic knowledge—elements of general knowledge of the world, including episodes from the biographies of others (e.g. "It reminds me that America was discovered in 1492" or "That particular red color is associated with Ferrari cars").

Interrater reliability was 87% for the initial classification of memory source units into strict episodes, abstract self-references and semantic knowledge. As it was the case for dream report analysis, judges resolved

TABLE 2. *Mean percentages of episodic, abstract self-referred, and semantic dream sources for rapid eye movement (REM) and slow wave sleep (SWS) dream reports*

	Episodic	Abstract self-referred	Semantic[a]
REM			
Mean	33.86	24.20	41.94
SD	23.50	17.08	20.95
SWS			
Mean	38.05	30.37	31.58
SD	31.63	27.47	22.76

[a] $p < 0.01$.

their scoring discrepancies, and the reconciled versions were used in data analysis.

RESULTS

Ten subjects (four males and six females), had to be excluded from the study because they failed, over repeated attempts, to produce a content report in the SWS condition. Of the remaining 50 subjects, 27 subjects (20 for SWS and seven for REM) required some additional nights to remember a dream. The median number of additional nights required for each stage was: REM—1 night (range = 1–2); SWS—1 night (range = 1–5).

Altogether, 100 valid dream reports (50 SWS, 50 REM) and 100 valid memory source reports were obtained from 50 subjects (25 males and 25 females).

Average dream recall rates computed on the original sample of 60 subjects were 89.16% (median = 100.00; range= 0–100) for REM and 64.53% (median = 75.00; range = 0–100) for SWS. When we considered only the subjects (50) who could remember a dream in both conditions, the recall rate was 93.00% (median = 100.00; range = 50–100) for REM and 77.44% (median = 100.00; range = 20–100) for SWS.

For dream report analysis we found that:

1) REM reports were reliably longer (in terms of mean number of temporal units) than SWS reports (REM = 5.10 ± 4.14, SWS = 1.88 ± 1.68; $F_{1,49} = 28.56$, $p = 0.0001$);
2) the mean number of nonself characters was significantly higher in REM than in SWS dreams (REM = 2.82 ± 3.43, SWS = 1.54 ± 3.83; $F_{1,49} = 5.04$, $p = 0.028$);
3) the percentage of REM dreams that contained undefined characters was significantly higher than that of SWS dreams (REM = 48%, SWS = 30%; $p < 0.05$); and
4) the percentage of REM dreams that contained some kind of emotion was significantly higher than that

of SWS dreams (REM = 62.00%, SWS = 34.00%; $p < 0.01$).

No other REM/SWS comparison gave significant results (Table 1).

For memory source report analysis we found that the mean percentage of semantic memory sources identified in REM was significantly higher than that in the SWS condition (REM = 41.94 ± 20.95, SWS = 31.58 ± 22.76; $F_{1,49} = 6.79$, $p = 0.01$). Neither episodic nor abstract self-referred memory sources gave significant REM/SWS differences (Table 2).

DISCUSSION

Before discussing in detail the results we have obtained, some considerations about the validity of SWS dream reports are in order. Hobson (13) states that "following many arousals from stage IV, subjects often seem to be actively confabulating. . . . This experimental sleep talking, with its completely disorganized brain activity, puts in grave doubt the validity of any reports obtained from stage IV awakenings; and subtracting such confabulatory reports may further reduce the amount of dreaming that is actually occurring in the NREM phase of sleep".

In our experiment, we encountered only two episodes that could be defined "confabulatory". In both cases the subject, during the first few seconds following the awakening, produced some kind of "word salad" and then began to report the dream. During the replay of the report, however, both subjects neither recognized that first confabulatory portion as belonging to their dream experience nor recalled having spoken those words.

Moreover, the SWS dream reports we have obtained, besides being recognized by our subjects as a faithful description of their dream experience, present a narrative structure and organization that is highly unlikely to be found in a confabultory product.

For these reasons we think that the reports we obtained following SWS awakenings can be considered valid samples of dream activity, as is the case with reports from any other stages of sleep.

The first result we want to discuss is that, not surprisingly, REM sleep is characterized by an average dream recall rate higher than that of SWS. Is this relatively higher dream recall failure in SWS due to a real absence of preawakening mental activity or can it be attributed to some form of malfunctioning of memory processes (storage and/or retrieval of the original dream experience) in NREM? Our evidence does not allow us to make a clear-cut decision between these two alternatives. We are inclined, however, to favor the second. In fact, if we hypothesized that the absence of dream recall mirrors a true absence of preawakening mental activity, this would lead us to the unwarranted—and possibly absurd—conclusion that cortical activation of any level would not be a sufficient condition for the functioning of the cognitive system of dream production. In that case, dreaming would then be radically independent of cortical activation.

We think that mental activity is continuously present during sleep and that cortical activation (even if synchronized as in SWS) is a sufficient condition for dream production. This view is corroborated by two facts. First, some of the NREM reports of our subjects are practically indistinguishable from typical REM dreams. Second, even when subjects had no dream recall upon awakening, they frequently made such comments as "definitely there was something going on, but now it is gone". In our view, it is the level of engagement of the dream processing system that is correlated with the level of cortical activation of each particular sleep stage. This correlation, however, is neither strict nor rigid, as evidenced by the existence of SWS dreams that are strikingly similar to REM dreams. We propose that certain physiological conditions form a particularly facilitating background for a certain type of cognitive processing. In addition, storage in and/or retrieval from memory could play an important role in determining the lower recall rate of SWS dreams. In fact, we hypothesize that both sleep inertia, which is higher following awakenings from SWS, and malfunctioning of storage/retrieval processes are responsible for the observed phenomenon of less frequent recall.

The second result we want to discuss is the minor length of SWS reports in comparison with REM reports. SWS dreams show similarities to those of other NREM stages (SO and ST2) (4,8,9). Also, the percentage of SWS dreams characterized by a multiunit narrative structure is clearly lower than that of REM dreams and it is similar to those of other NREM phases. Only about 38% of SWS reports are multiunit, compared to 87% of REM reports. We believe this can be explained by the lower diffusion of memory activation present in SWS at the time of dream production. This phenomenon can also explain both the lower number of nonself characters present in the dream scenes and the lower proportion of SWS dream reports characterized by the presence of unidentified groups of people or crowds, and so forth.

The lower percentage of SWS reports that contain at least one emotion can be explained within the framework of those theories of emotions that hypothesize an interaction between physiological and cognitive factors (14–18). The reduced level of arousal in SWS (a phase in which the functioning of the autonomic nervous system guarantees the maximum level of homeostasis) would account for the low level of cognitive elaboration and evaluation of emotions in that condition. This would be the case whether one considers arousal to be a necessary input to emotional experiences (cognition-arousal theory) or one thinks of it simply as a correlate. On the other hand, the higher level of arousal that characterizes REM sleep (in which the functioning of the regulation mechanisms of ANS is dramatically altered) would explain the high percentage of dreams with emotional experiences. Moreover, it should be noted that in both REM and in SWS sleep, the appropriateness of dream feelings to the dream scene is nearly complete (REM—90.62%; SWS—94.44%).

The last point to be discussed is the lower percentage of semantic memory sources involved in the production of SWS dreams than in REM dreams. This finding is similar to that of Cavallero et al. (9) for NREM-stage 2 dreams. In our view, the higher the level of activation of the dream production system (REM condition), the higher the likelihood that semantic memory elements will be activated and recruited as connective elements to ensure dream plot coherence. We hypothesize, in fact, that there is some sort of positive feedback between the two components involved in the dream-generation process: a widespread memory activation causes a higher level of engagement of the processing system, which, in turn, activates other memory elements.

Within this frame of reference our results support the conclusion that in SWS, in comparison to REM sleep, there is, in most cases, a less diffuse activation of memories (i.e. shorter dream reports, lower number of nonself characters). In addition, SWS involves a lower level of engagement of the processing component (i.e. lower percentage of semantic dream sources and worse functioning of storage/retrieval processes).

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