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Dreaming and Episodic Memory: A Functional Dissociation?

Magdalena J. Fosse*, Roar Fosse*, J. Allan Hobson, and Robert J. Stickgold

Abstract

■ The activity that takes place in memory systems during sleep is likely to be related to the role of sleep in memory consolidation and learning, as well as to the generation of dream hallucinations. This study addressed the often stated hypothesis that replay of whole episodic memories contributes to the multimodal hallucinations of sleep. Over a period of 14 days, 29 subjects kept a log of daytime activities, events, and concerns, wrote down any recalled dreams, and scored the dreams for incorporation of any waking experiences. While 65% of a total of 299 sleep mentation reports were judged to reflect aspects of recent waking life experiences, the episodic replay of waking events was found in no more than 1–2% of the dream reports. This finding has implications for understanding the unique memory processing that takes place during the night and is consistent with evidence that sleep has no role in episodic memory consolidation. ■

INTRODUCTION

Much evidence now indicates that sleep has a function in memory reorganization and consolidation (Maquet, 2001; Stickgold, Hobson, et al., 2001) and thus in the enhancement of waking cognitive function. In particular, both REM sleep (REM) and non-REM sleep (NREM) seem to play a role in internal neurocognitive modifications following performance on procedural tasks (Louie & Wilson, 2001; Stickgold et al., 2001; Smith, 1996). Regardless of whether mental activity during sleep plays a role in these modifications, one would expect the formal properties of dreams to reflect the quality of the underlying memory reprocessing that is taking place. Thus, the study of sleep mentation can enhance our understanding of the experience-based neural plasticity that takes place during sleep.

An often held view is that dreams incorporate episodic or narrative events from recent waking life. Surprisingly, not much controlled empirical research has investigated this issue. In the only relevant study found in the literature, Dement, Kahn, and Roffwarg (1965) analyzed 813 REM dreams for references to the sleep laboratory situation. They defined a complete incorporation of the experimental situation to be as follows: ''The experimental situation and its purpose is clearly depicted. S usually dreams he is in bed with electrodes attached. The characters are usually the same as in the real situation, but may vary in number, and other characters not in the real situation may be introduced'' (p. 120). Using this rather literal definition, external judges scored a complete incorporation in 12% of the dreams.

In contrast to the limited research on episodic memory replay during dreaming, several studies have demonstrated the incorporation of single experiential features from waking, most typically originating from the immediately preceding day (Cavallero & Cicogna, 1993; Arkin & Antrobus, 1978a, 1978b; De Koninck & Koulack, 1975; Goodenough, Witkin, et al., 1975; Foulkes, 1967; Hall, 1967; Witkin & Lewis, 1967; Karacan, Goodenough, et al., 1966; Domhoff & Kamiya 1964; Foulkes & Rechtschaffen, 1964; Whitman, Pierce, et al., 1962). This so-called day-residue (Freud, 1900) often consists of isolated procedural, semantic, or episodic elements from a waking event (Cicogna, Cavallero, et al., 1991; Cicogna, Natale, et al., 2000; Cavallero, Foulkes, et al., 1990; Cavallero & Cicogna, 1993), combined with other memory representations in a way that gives rise to the typically unrecognizable nature of dreams (Hobson, 1988). The generally isolated character of waking features that are incorporated into dreams raises questions about the role of the episodic memory system in sleep neurocognition.

Extensive dreaming takes place not only during REM but also during NREM, particularly late in the night (Fosse, Stickgold, et al., 2001a, 2001b, 2001c). NREM dreams could potentially contain a higher degree of episodic memory replay than REM dreams, because episodic memory systems might be more accessible during

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NREM than REM (Buzsáki, 1996). No studies were found in the literature that bear directly upon this question.

To investigate episodic memory replay during sleep, subjects matched their own dream experiences to their daytime activities over a 14-day period, focusing on the degree of similarity in locations, actions, objects, characters, themes, and emotions. In this study, we used a spontaneous awakening protocol known to sample dreams from both NREM and REM (Stickgold, Pace-Schott, et al., 1994). Only if episodic memory replay was found to characterize at least a moderate proportion of nocturnal dreams would a subsequent series of focused studies be warranted of mental activity associated with specific sleep stages, such as NREM and REM, and with the phasic (active) and tonic (quiet) physiological epochs within each stage.

RESULTS

The analyzed data set consisted of 299 spontaneously recalled dreams collected from 29 participants (mean 10.3 reports per person, *SD* 5.1). An additional set of 31 reports, which had not been properly scored by the participants, was excluded from the analysis. The length of the remaining 299 reports (total recall count [TRC], Antrobus, 1983) ranged from 7 to 609 words (mean 144.1 words per report; *SD* 137.2; median 115 words per report).

From the total of 299 mentation reports, 194 reports (65%) contained 364 memory entries that were possible candidates for episodic memories. The other 115 reports contained no such candidates. More than half the reports with incorporation contained one memory entry, while 38 reports contained two, 23 reports contained three, and the remaining 18 reports contained three to seven memory entries each.

We performed a systematic search for episodic memories in these dreams, with the array of specific requirements based on the definition of episodic memory introduced in a stepwise manner. Table 1 summarizes the candidates for episodic memory replay that remained after each requirement was applied. Examples of the memory entries that were excluded at each step are given in Table 2.

Confidence Level

In order for a dream element to be included as a candidate for episodic memory, the participants needed to be at least moderately confident that it was, in fact, caused by the waking event that they identified. As can be seen in Table 1, 67 of the memory entries (18.5%) either lacked a score for confidence level or were given a confidence level of 1 = *not confident at all* or 2 = *very faintly confident*. These entries were excluded from the further search for episodic memories, because their association with any waking event was highly doubtful at the outset.

Included in the remaining analysis are the 297 out of 364 entries (81.5%) that were given a confidence level of 3 or above (Table 1).

Which Dream Features Most Frequency Matched the Waking Events?

Each of the 297 remaining memory entries were scored as similar to a waking event on one or more of the following experiential features: characters, objects, actions, themes, emotions, and location. The 297 memory entries included a total of 973 scored features, with the frequency of occurrence for each feature shown in Figure 1.

To be treated as a strong candidate for an episodic memory, the wake and dream events were required to have a high degree of similarity (strongly similar or identical) for at least one experiential feature. Based

Table 1. Candidates for Episodic Memory as a Function of Successive Definitional Criteria

Criteria	*Subjects*	*Reports*	*Memory Entries*
A. Dreams with content	29	299	364
B. With waking sources	27	194 (65%)	
C. Confidence level > 2	27	170 (57%)	297 (82%)
D. Similarity level > 3 for one feature	25	151 (51%)	246 (68%)
E. Similar location	20	48 (16%)	61 (17%)
F. Location + at least two other aspects	28	33 (11%)	45 (12%)
G. Conserved objects, actions, characters	14	17 (6%)	23 (6%)
I. Episodic (perceptual) waking source	9	11 (4%)	12 (3%)
J. Scored as episodic by external judges	4	5 (1.7%)	5 (1.4%)

Confidence level ranged from 1 = *not confident at all* to 5 = *absolutely certain* and similarity level ranged from 1 = *no similarity* to 5 = *identical*.

Table 2. Examples of Excluded Memory Entries

Exclusion Criteria	*Dream Element*	*Waking Element*
Not confident	I walk by the front door of my apartment and I see that it has been left open all night, just a crack, and very cold air is blowing in. I am afraid that Lucy, my cat, has escaped during the night.	In my e-mail to Ted I wrote to him about leaving the door open, even if we are not ready to walk through it.
Not similar features	Now I'm in a hallway at some co-ed college or university (it may be Harvard, but it looks a lot like Wellesley). I'm arranging things on this shelf that is supposed to be my temporary locker space, someone else has put their stuff there and that annoys me, so I move it over and continue to arrange my stuff.	Being at Harvard for class and thinking how strange it is to be in a co-ed environment again (I went to Wellesley for undergraduate study).
Not similar location	My Dad and I leave to go shopping. We go from room to room, store to store. One of the stores is filled with muffins, muffins from floor to ceiling, all different kinds, I can't decide which one I want, but I do want one; what an opportunity.	When I left Starbucks, we had so many leftover pastries and muffins to throw away or take home. I couldn't decide which muffins to take and which to toss, I feel guilty letting food go to waste.
Not two additional aspects	. . . I notice that the guy's roommate has opened the door to my apartment and is throwing things inside the hallway, trash or something. The guy's roommate looks like the actual neighbor who lives in that apartment in real life.	Last Sunday I was talking briefly with my neighbor.
Not episodic waking source	I'm at my house outside with my Mom and sister. I'm throwing the apples that have fallen on the ground from our apple tree into the woods to get rid of them.	While showing pictures of my hometown, house and family to coworkers, I was simultaneously reminiscing about life in high school years. One picture was of our apple tree in full bloom in spring. In the fall we have to pick up the apples on the ground.

on this criterion, 14% of the memory entries and 6% of the dream reports were eliminated, indicating that most dreams with reported incorporations had a relatively high similarity score for one or more experiential features (Table 1; Figure 1).

To test the relative frequency of occurrence of the six experiential features, the percentage of the matched memory entries that included each feature was first calculated for each subject. In this analysis, four subjects were temporarily excluded who had only one or two matched memory entries. A repeated-measures ANOVA based on subject percentages revealed that the experiential features were not equally likely to be scored as similar in waking and sleep [$F(5,20) = 3.8$, $p = .0037$]. For the matched memory entries of the included 21 subjects, the most frequent features were theme (average subject percentage of 53%), emotion (52%), and character (50%), followed by action (41%) and object (39%), with location having the lowest subject average (29%). Pairwise contrasts showed that theme, emotion, and characters all were significantly more frequent than location ($p < .004$). In addition, location tended to be less frequent than action ($p = .064$), and action was less frequent than each of theme ($p = .01$) and emotion ($p = .033$). Thus, the prevalence of experiential features can tentatively be described as follows: themes $\approx$ emotions $\approx$ characters $>$ actions $\approx$ objects $>$ location.

Memory Entries with Similarities in Location and Two Additional Features

In line with our working definition of an episodic memory, we required location to be similar in the dream element and the waking element. This single requirement resulted in the most pronounced decrease in candidate elements, because location was similar in the wake and dream elements in only 17% (61) of the entries.

For these 61 entries, location almost always cooccurred with at least one additional feature (Figure 2). Location occurred alone only in six instances and was

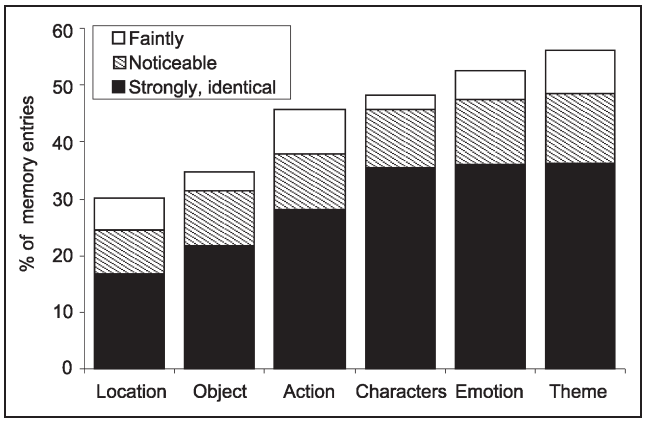

Figure 1. Frequency of occurrence for each experiential aspect. Each column indicates the percentage of the 364 memory entries scored by the subjects as similar to a waking experience on the noted experiential feature. Levels of similarity for these wake–sleep matches varied, with 1 = *no similarity at all* (not in the figure), 2 = *very faint similarity*, 3 = *noticeable similarity*, 4 = *strong similarity*, 5 = *identical*. Included in the figure are only entries with a confidence level of at least 3.

most frequently found in conjunction with four or five other features (28 entries or 45%). There were no significant differences in the frequencies with which location cooccurred with the other experiential features.

One fundamental requirement for an episodic memory is that not just one but several features of the original waking episode be recalled in an integrated fashion. This requirement was dealt with in two ways. First, at least two other features were required to occur together with location in the memory entries. Second, if particular objects, actions, or characters were present in the waking event, these needed to be a part of the dream element as well.

The requirement that any entry should include at least two features in addition to location reduced the number of candidates to 45. When further requiring that actions, objects, and characters present in the waking event also be present in the dream, only 23 entries remained.

Domain of Waking Reference (Memory Source)

The 23 entries still remaining had been identified without taking into account the actual type of waking experience, that is, the memory source. We assumed that participants could have scored a dream element as identical to a waking ''event'' even when the waking experience was not an actual perceived event, but instead a thought that the subject had during waking. We therefore asked subjects to indicate whether each waking memory source was a thought, a perception (episode), or a combination of thoughts and perceptions.

Of the 23 remaining memory candidates, nine (39%) were related to waking thoughts alone. By definition, these did not represent episodic memories and hence were excluded from further analysis.

Inspection of Candidates for Episodic Memory

For the 14 remaining strong candidates for episodic memories, two were excluded due to incorrect scoring by the subjects; one entry was a recognition of a familiar object in the dream (a boyfriend's house) that did not refer to any specific waking episode preceding that dream; and a second entry was a duplicate of another entry.

The final 12 memory entries all met the following criteria: Subjects were confident (confidence >2) that the dream event reflected the waking event; the waking source was perceived as a percept rather than a thought; and location and at least two other experiential features were sufficiently similar (>3) in the dream event and the waking event. These 12 entries constituted only 3.3% of all the memory entries and were found in 11 of the 299 dream reports (4.0%).

Third Person Ratings of Episodic Memories

Due to the inherent problems of using first person ratings of mental activity, and the participants' lack of awareness of what constituted an episodic memory and thus also of the degree of similarity required between a wake and dream event, the validity of the participants' ratings was confirmed by five external judges who rated the reports for episodic memories.

The judges were provided with a set of 36 dream–wake pairs that included all 12 memory entries identified above and two sets of 12 additional dream–wake pairs,

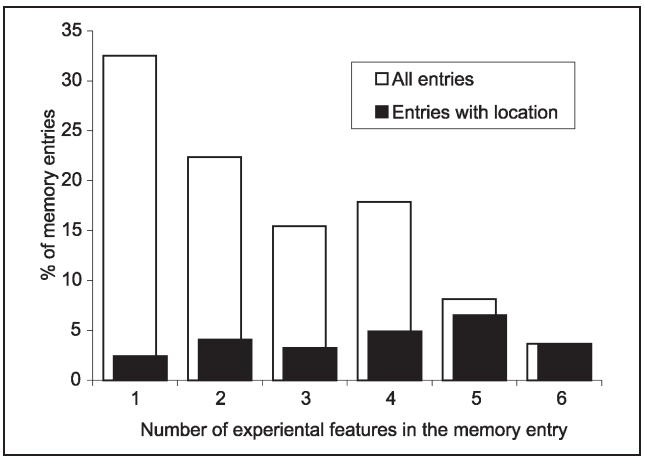

Figure 2. Number of experiental features in the memory entries. The number of different experiental features in, first, the 246 remaining memory entries (shadowy bars), and, second, the subset among these entries with matched location (black bars). Included are only memory entries with a confidence level of 3 or above and a similarity level of 4 or above for at least one experiential feature.

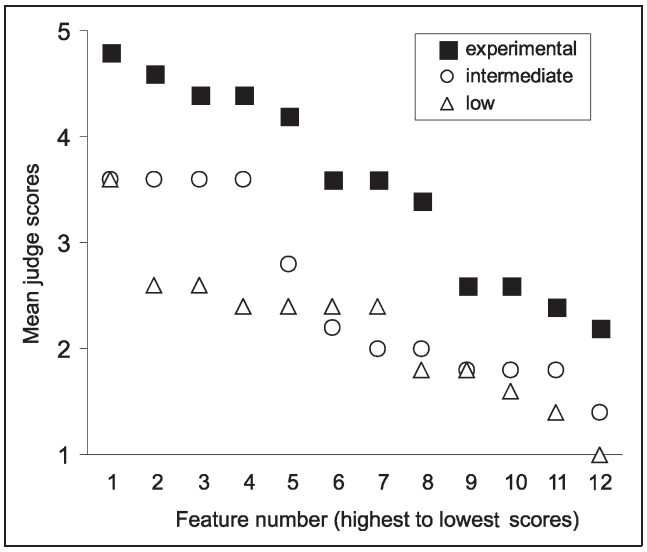

Figure 3. Evaluations by the external judges. Mean judge scores for the 12 wake–dream memory pairs in the experimental category based on the subjects' ratings and in each of the two control categories. The features in each category were assigned numbers from 1 to 12 in decreasing order based on average judge score.

randomly sampled from two subgroups of memory entries that had not qualified as episodic memories based upon subjects' ratings. One set was chosen from entries with low scores on both confidence and similarity level and which contained only a few dream features. A second set was derived from dreams with intermediate scores on these factors. The memory source for these 24 additional entries was either percepts, percept/thoughts, or thoughts, and these were evenly distributed in the control set. The 36 dream–wake pairs were presented in a random order, and each wake–dream pair could be given a score from 1 = *no similarity between dream and waking event* to 5 = *dream and waking event are identical*.

The interrater reliability was defined as the average of the correlation between the scores for all the pairs of judges. This correlation varied between .70 and .82, with an average of .77. For each dream, we calculated the mean of the scores given by the five judges.

Only a subset of the 12 dream entries that qualified as episodic memories based upon the participants' own ratings were given high scores by the external judges. The 12 target dreams could be sorted into three categories based on their average scores: (1) a low score category (n = 4), with means between 2.0 and 2.5, which was similar to most of the control pairs; (2) an intermediate category (n = 3) with a mean of about 3.5; and (3) a high score category (n = 5) with means above 4.3 (Figure 3). The four dreams in the ''low score'' category barely qualified as episodic memories, indicating a liberal use of the scoring criteria on the part of the subjects. Only the five wake–dream pairs in the high score category were found to be strong candidates for episodic memory replay as based on both the subjects and the judges ratings, with three additional pairs serving as moderately strong candidates. The five strong candidates were found in 1.7% of the original 299 mentation reports and represented only 1.4% of all the memory entries.

DISCUSSION

The hypothesis that a replay of episodic memories contributes to dreaming was tested using 299 dream reports from 29 participants. Of all the dreams, 194 (65%) included 364 specific memory entries noted by the subjects to be connected to antecedent waking experiences. Only 12 entries met the following operational definition for an episodic memory—moderate to high similarity and confidence levels for at least three experiential features, including location and any characters, objects, or actions present in the waking event. When rated by independent judges, 5 of these 12 entries qualified as strong candidates for episodic memory. Thus, only 1.4% of the matched dream elements appeared to be direct, complete, and transparent replicas of waking episodes.

The very low percentage of dreams with matched episodic content needs to be considered in light of our reliance on subjective reports of mental experience. Many areas of cognitive neuroscience share the problem of interpreting subjective reports, for example, those that study perception, mental imagery, and declarative memory.

One problem reflects uncertainty about the ability of subjects to accurately report prior mental activity. This problem is only exacerbated when subjects have brain lesions or psychiatric conditions or are trying to recall prior sleep mentation. The sleep research community has addressed this problem in detail (Hobson, Pace-Schott, et al., 2000; Nielsen, 2000; Foulkes, 1996; Rechtschaffen & Buchignani, 1992; Arkin & Antrobus, 1978a, 1978b). One way to minimize the problem is to target those specific aspects of mental activity that are of greatest interest and using affirmative probes and objective rating techniques to quantify this mental activity. This type of measures have been used to study such features as emotion (Fosse, Stickgold, et al., 2001a, 2001b, 2001c; Merritt, Stickgold, et al., 1994), hallucinations (Antrobus, Kondo, et al., 1995; Rechtschaffen & Buchignani, 1992), and reflective awareness (Fosse, 2000) during sleep, and are used in the current study as well.

A second problem is the risk of demand characteristics that might bias subjects' reporting. Thus, in the current study, the number of identified episodic memory replays in dreams might be exaggerated due to the instructions given to the subjects clearly implying that we are looking for dream elements sharing features with waking events. However, such biases

would only mean that our conclusions could be stronger than we have measured.

Nevertheless, the final resolution of this problem will have to wait for a clearer understanding of the brain basis of mental activity that can provide converging evidence for the conclusions of phenomenological studies. Such converging evidence has begun to accumulate (e.g., see Fosse, 2000; Fosse, Stickgold, et al., 2001a, 2001b, 2001c).

Comparison of Present Results to Previous Findings

Compared to the 1.7% of dream reports that we found to contain plausible episodic memories, the 12% reported by Dement et al. (1965, see Introduction) is surprisingly high. This difference may well reflect their more liberal matching criteria, allowing, for example, character substitution which—to us—indicates synthetic rather than episodic construct.

Studies of the waking memory sources for sleep mentation suggest that the more prone a sleep stage is to support extensive hallucinatory dreaming, the less prone it is to be associated with ''any'' feature of episodic memory activity. The memory sources for dreams have often been investigated by having subjects associate to recalled sleep mentation upon awakening. In a recent meta-analysis, Baylor and Cavallero (2001) found that episodic memory sources were identified for only 29% of ''thematic units'' in REM dreams, but for as much as 55% of the thematic units in sleep onset mentation, with NREM occupying an intermediary position (recalculated from Baylor & Cavallero, 2001). In contrast, hallucinatory mentation during sleep shows the opposite variation, being the least extensive at sleep onset and reaching the highest values during REM (Fosse, Stickgold, et al., 2001a, 2001b, 2001c). Thus, the more hallucinatory or dream-like the mental activity during sleep is, the less prone individual thematic units are to be in any way associated with a waking episodic event.

Direct evidence has recently been provided that even at sleep onset where episodic memory sources are most frequent, episodic memories do not typically contribute to the hallucinated activity (Stickgold et al., 2001). After having played the computer game Tetris, subjects were awakened for mentation reports during the first few minutes after sleep onset. Subjects reported dream imagery of isolated elements of the computer game, consisting of game pieces that were falling down, sometimes rotating and fitting into patterns at the bottom of the screen, all in a manner congruent with the actual game. In contrast, the subjects reported no images of the computer or keyboard, of the room they were in, or of themselves playing the game, all of which would be present in an episodic memory.

Amnesic patients with extensive bilateral temporal lobe damage that included the hippocampal formation reported seeing the same type of isolated Tetris images, but without recalling their origin in wake. Thus, the medial temporal lobe episodic memory system clearly played no role in producing these sleep onset images.

It can be hypothesized that the sleep onset images in both the amnesic patients and the normal healthy subjects reflected memories of neocortical origin that were activated without contributions from the episodic memory system (Stickgold et al., 2001). Stickgold et al.'s conclusion is likely to be valid for NREM and REM mentation later into the night as well, because the evidence reviewed above indicates that NREM and REM appear to be even less associated with episodic memory function than sleep onset.

Neurocognitive Interpretations

The notion of a lack of episodic memory replay during dreaming, however counterintuitive, is quite consistent with evidence about brain function during sleep, particularly during REM. When an integrated episodic memory is recalled during waking, information is thought to flow from the hippocampus to various sites in the cortex (McClelland, McNaughton, et al., 1995). However, single-cell recording studies in rats have suggested that hippocampal outflow to the cortex is blocked during REM, with neural information instead flowing from the cortex to the hippocampus (Buzsáki, 1996; McClelland et al., 1995; Chrobak & Buzsáki, 1994). In the wake state, controlled access to episodic memories also seems to depend upon engagement of the hippocampus by frontal cortical control systems that include the dorsolateral prefrontal cortex (DLPFC) (Eichenbaum, Cahill, et al., 1999). Human PET studies have indicated that the DLPFC is deactivated during not only REM but all of sleep (Braun, Balkin, et al., 1997, 1998; Maquet, Peters, et al., 1996; Maquet, Degueldre, et al., 1997). These alterations in brain function should significantly constrain the incidence of episodic memories in the scenarios of REM dreams.

The cognitive results and the brain activity evidence from animal REM together could be taken to predict that the hippocampus is not particularly active during this sleep stage. This prediction is consistent with the only study of human hippocampal neuronal activity during sleep that was found in the literature. This study used implanted wire electrodes to measure the firing rate of hippocampal neurons in waking, slow-wave sleep, and REM sleep in 17 patients with epilepsy (Ravagnati, Halgren, et al., 1979). The firing rates of neurons in the hippocampus proper were found to generally increase during slow-wave sleep, but then to fall to very low levels during REM. In contrast, activity in hippocampal gyrus neurons decreased during slow-wave sleep, but returned to waking levels during REM (Ravagnati et al., 1979). These findings are consistent with the animal literature showing a flow of information

into the hippocampus during REM, without any output from the hippocampus back to the cortex. However, they appear at odds with PET studies that have found increased hippocampal blood flow during REM compared to both waking and NREM (Braun, Balkin, et al., 1997).

Animal studies have revealed various forms of activity within the hippocampus during REM. For example, theta waves thought to be involved in memory consolidation are seen in large regions of the hippocampus in this sleep stage (Karashima, Nakamura, et al., 2001). Moreover, ensembles of place cells in CA1, activated during food-seeking track running, appear to be reactivated in highly similar temporal sequences during subsequent REM (Louie & Wilson, 2001).

The effects of such hippocampal activation on dreaming is unclear. For example, hippocampal activation during REM might contribute to the consolidation or modification of the hippocampal aspect of episodic memories without reactivating those memories via the entorhinal cortex. Instead, any hippocampal contributions to dreaming during REM might be through more diffuse subcortical pathways.

The last decade has produced a large body of research suggesting that sleep plays an important role in the off-line consolidation and reprocessing of memories (Stickgold et al., 2001). This memory reprocessing has characteristic properties, reflecting sleep-specific engagement and disengagement of basic neurocognitive processes. The mental activity (dreaming) that takes place during sleep is shaped and constrained by these underlying functional processes. As such, the study of the formal properties of dreaming, and of changes in these properties following experimental manipulation, can provide insights into the basic functioning of the brain during sleep. The results presented here provide strong evidence that, while elements of memories from recent waking events reactivate during sleep, this does not occur in the form of intact episodic memories. Instead, reactivation of episodic memories appears to be actively blocked during sleep.

METHODS

Procedures

A total of 15 female and 14 male students who provided informed consent participated in the study. In order to investigate the relation between waking experiences and sleep mentation, participants recorded the following three types of data for 14 consecutive days and nights:

1. main daytime experiences (daily activity log [DAL]),
2. sleep mentation reports (dream log), and
3. analyses of the relationship between waking experiences and sleep mentation (analysis of the dream).

Daily Activity Log

Each evening, the participants were asked to report their ''major'' activities, events, and concerns from the preceding day in a DAL. The DAL reported information on three categories of waking experiences:

1. Major daily activities: These entries indicated how the participants spent their day and indicated the activities that took up most of their time (e.g., meals, commuting, work, evening activities).
2. Personally significant events: These were specified as events that the individual participated in or observed and that might not have taken much time, but were personally important (e.g., decisive actions taken and emotion-evoking events).
3. Major concerns: These were specified as thoughts that the participants had during the day and that were important to them (e.g., an upcoming exam and a romantic involvement). These concerns might or might not have taken up much of the individual's time but were nonetheless considered important.

The participants were instructed to list a maximum of five items in each category; there was no minimum number, although, logically, at least one major activity of the day was expected to be listed. Furthermore, the DAL form provided space for any additional activities, events, or concerns of the participants. Items could be listed in more than one category: For example, a subject who ran the Boston marathon would enter it as a major activity for that day and presumably a personally significant one that also occupied the participant's mind as a major concern.

Dream Log and Dream Report

A dream log entry was made whenever the participant woke up spontaneously during the night and in the morning and was used to describe in detail each dream that was remembered. For each report, the participant was instructed to exclude any interpretation or elaboration not actually experienced in the dream.

Analyzing the Dream Reports for Waking Connections

Immediately after each dream was recorded, the participants identified any element in the dream—characters, objects, actions, locations, emotion, and themes—that seemed likely to have been caused by specific waking events or thoughts from the preceding 2 weeks. For each dream element matched with a waking event, the subject provided the following information on an Analysis of Dream Report form:

- The participant's confidence that the dream element was caused by the waking event, ranging from 1 = *not confident at all* to 5 = *absolutely certain*.

- A description of the waking event in sufficient detail to allow a reviewer to determine how the waking event and the dream element were similar and how they were different.
- Whether the ''domain of similarity'' with dream event was waking percept, thought, or a combination of both.
- A scoring of the degree of similarity between the dream element and the waking event for each of the following features: location, character(s), object(s), action(s), emotion(s), and theme. ''Characters'' excluded the dreamer, while ''actions'' included those of both the participant and other characters, and even of objects (e.g., a plane flying by). The degree of similarity between the waking and dream events was indicated by using the following scale: 1 = *no similarity*; 2 = *very faint similarity*; 3 = *noticeable similarity*; 4 = *strong similarity*; and 5 = *identical*.

Rating of Episodic Memories by External Judges

In the final step, dream elements considered strong candidates for episodic memory incorporation based on the participants' own ratings were rescored by five external judges. The judges, all experienced dream and sleep researchers, were provided with the dream–wake report pairs that represented the possible episodic memories and with a definition of episodic memories as ''memory for personally experienced events that are recalled consciously and in detail, with the focus on time and place aspects.'' The set of wake–dream pairs also included a randomly chosen control set consisting of twice as many wake–dream reports as in the target set. The judges were instructed to rate the degree to which the dreams contained an episodic memory replay of the corresponding waking event, using a five-point Likert scale ranging from 1 = *no similarity between dream and waking event* to 5 = *dream and waking event are identical*. Further details about this scoring procedure are provided in the Results.

Working Definition of Episodic Memories

The progression of the quantitative analysis was guided by the following working definition of episodic memories.

1. The subject needed to be fairly confident that the dream event was a representation of the waking event.

2. An episodic replay would usually be seen to require an identical match to the waking event. However, we also included matched experiential features described as ''strongly similar.''

3. Location needed to be matched, that is, scored as at least strongly similar or identical to its waking counterpart. Following established definitions, place and time specificity are usually required for a memory of personal events and experiences to qualify as episodic (i.e., Tulving, 1991, 1993, 2000). No time specificity was required.

4. In addition to location, at least two of the remaining five features had to be matched, in particular action, characters, and object (if present). There were no such requirements for theme and emotion.

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1. Antrobus (1983) was cited in the Results but was not included in the reference list.
2. Please supply publisher location in the following references: Arkin and Antrobus (1978b); Cavallero and Cicogna (1993); Eichenbaum et al. (1999) [plus publisher name and page range here]; Hobson (1988); and Rechtschaffen and Buchignani (1992).
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