

# Chronobiology of Dreaming

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## ABSTRACT

A review of the scientific literature clarifies several chronobiologic features of dreaming. The literature supports the conclusions that dreaming intensity, and to a lesser extent dreamlike quality, is modulated by a sinusoidal, 90-minute ultradian oscillation, a “switchlike” circadian oscillation, a 12-hour circasemidian rhythm, and a 28-day circatrigintan rhythm (for women). Further, access to dream memory sources appears to be modulated by a 7-day circaseptan clock. Greater clarification of these rhythmic influences on dreaming may help to explain diverse and often contradictory findings in the dream research literature, to better relate dreaming to waking-state cognitive processes, to better explain relationships between disturbed phase relationships and dream disturbances, and to shed new light on the problems of dreaming’s function and biologic markers.

In the 50 years since discovery of a link between dreaming and the endogenous biorhythmic events defining rapid eye movement (REM) sleep<sup>1</sup> there has occurred strikingly little convergence between chronobiology and the study of dreaming—despite a vast accumulation of research in both domains. While many of the findings in one of these domains have clear implications for understanding basic and applied questions in the other, there still is no comprehensive theory that links chronobiologic concepts and findings to the processes of dreaming. This chapter is intended to redress this situation by reviewing evidence that is pertinent to the chronobiologic nature of dreaming. Five sections review chronobiologic processes of different types: ultradian, circasemidian, circadian, circaseptan, and circatrigintan.

In this chapter, the term *dreaming* is used in an inclusive sense equivalent to that of *sleep mentation*, in other words, the occurrence of any subjectively experienced cognitive events during sleep.

## ULTRADIAN RHYTHMS

Transitions between REM and non-REM (NREM) sleep are widely viewed as “switchlike,” flipping abruptly from one type of sleep to the other. Some measures, such as delta electroencephalograph (EEG) power, do in fact display marked switchlike transitions at the onset and offset of REM sleep. However, studies of multiple physiologic systems indicate that REM-NREM transitions are much more sinusoidal than typically acknowledged.<sup>2</sup> For example, the polarity of neurons driving REM sleep onset demonstrates a more graduated, oscillatory fluctuation that begins well before EEG-defined REM sleep onset.<sup>3,4</sup> It could be argued that the switchlike versus oscillatory nature of REM and NREM dreaming has been under debate for several decades among authors who

contend that REM and NREM dreaming differ qualitatively (i.e., the transition is switchlike) versus those who insist the difference is quantitative (i.e., the transition is oscillatory).

In fact, research that has sampled dreaming at multiple points within and between REM and NREM sleep suggests that dreaming more closely conforms to a sinusoidal, oscillatory phenomenon than a switchlike one. This is the case for dependent measures implicating the frequency and length of recalled dreams and the quality of dream reports. These measures are discussed in separate sections later.

## Frequency and Length of Recalled Dreams

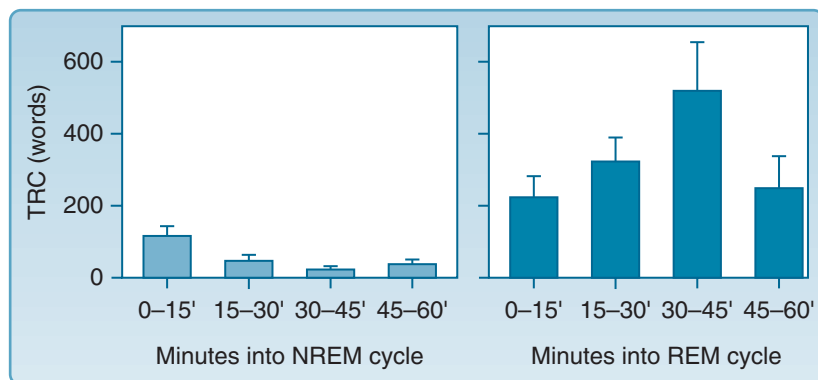
### Within-Stage Changes

The length of a dream report is typically assessed either by its total recall count (TRC)<sup>5</sup> or by the number of temporal units (TUs) composing the report.<sup>6,7</sup> TRC is typically defined as the number of nonredundant, content-bearing words in a report, excluding hesitations, speech errors, repeated words, and commentary<sup>5</sup>; TRC is log-transformed to minimize the effect of extremely long reports ( $\log[\text{TRC} + 1]$ ). TUs are identified based upon reported activities; synchronously occurring activities define a single TU. Whenever a character performs a new activity, responds to another character, or changes topics in a conversation, a new TU is scored.<sup>6,8</sup> Report length is widely thought to measure cortical activation and, thus, the overall “quantity” of output of a dream mentation generator.

By either measure, REM sleep reports are consistently longer than NREM reports. These measures also suggest that dream output over consecutive REM and NREM episodes oscillates in an ultradian pattern. When relationships between report length and time elapsed in REM or NREM sleep are assessed, report length fluctuates sinusoidally over time (Fig. 43–1).<sup>9</sup> For dreams from REM sleep (dark blue bars), length estimates are lowest 0–15 and 45–60 minutes after REM onset and highest for times in between. For dreams from NREM sleep (light blue bars), an *opposite* pattern is observed. A similar sinusoidal pattern was found in a second study.<sup>10</sup> These results complement earlier work that sampled dreaming at either 5 or 15 minutes into the REM period and found longer reports in the latter condition.<sup>11</sup>

The results in Figure 43–1 are highly suggestive of a sinusoidal function and thus of an ultradian oscillation in report length that is active both within and between sleep stages. The findings are also consistent with several additional studies that assessed dream length as a function of increasing distance from prior REM sleep. In four studies,<sup>12–15</sup> NREM dream reports were either more probable or of longer length when sampled in close proximity to (all at 5 minutes) rather than more distally from (10 minutes, 30 minutes, 12 minutes, and 15 minutes, respectively) prior REM sleep. Also consistent

## REPORT LENGTHS DURING NREM AND REM CYCLES



**Figure 43-1.** Report lengths for dream reports from rapid eye movement (REM) and non-REM (NREM) periods of different durations. Mean (SEM) report length as a function of elapsed time in stage for 88 REM and 61 NREM reports. TRC, total recall count. (From Hobson JA, Pace-Schott E, Stickgold R: *Dreaming and the brain: Towards a cognitive neuroscience of conscious states*. Behav Brain Sci 2000;23:793-842.)

with the preceding, a fifth study<sup>16</sup> demonstrated that duration of NREM sleep preceding an awakening correlated negatively with report length.

The likelihood that report length reflects an ultradian oscillatory process may explain the seemingly nonconfirmatory finding<sup>17</sup> that report length differences for REM periods of 5 and 10 minutes' duration are small ( $P = .114$ ). This result may reflect random variation in measurements that are sampled too close together on an ultradian curve, thus minimizing the chances of detecting a gradual change.

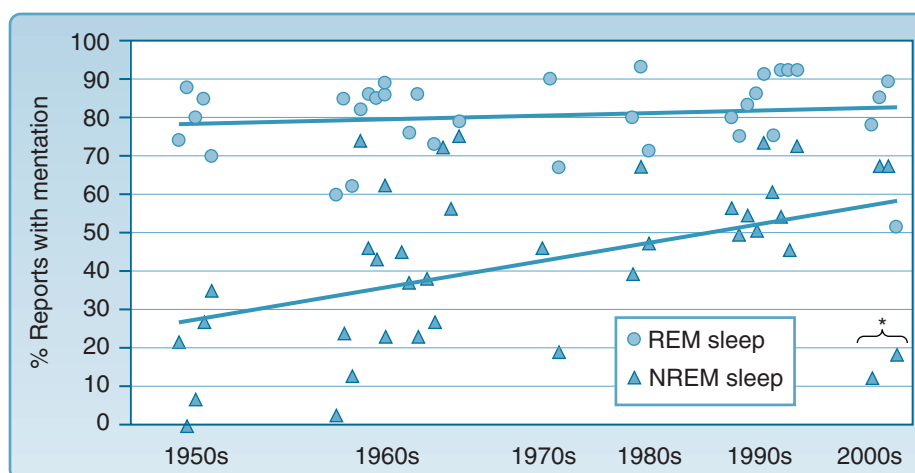
### Between-Stage Changes

REM and NREM dream reports presumably reflect activity of an imagery generator functioning at the opposite extremes of its ultradian period. Large differences in dream recall frequency and length would thus be anticipated. In fact, increased probabilities and lengths of dream reports sampled after REM as compared with after NREM awakenings are among the most highly replicated findings in the dream research literature (see reviews in Nielsen<sup>4</sup> and Hobson et al.<sup>2</sup>). Figure 43-2 illustrates the marked differences in levels of dream recall from REM and NREM sleep in 39 studies conducted between 1953 and 2004. Two recent studies<sup>18,19</sup> are noteworthy because the very low probabilities of recall from NREM sleep are possibly

due to the use of procedures that minimize the influence of prior REM sleep on NREM dream recall.

Paralleling the differences in Figure 43-2 are similarly large REM-NREM differences in dream report length; REM-to-NREM ratios in TRC vary from 2:1 to as high as 5:1.<sup>10</sup> Much of the variability observed for both measures of recall and length may occur because experimental protocols have not consistently controlled for phase relationships between REM and NREM sampling points.

The use of a constant time-in-stage preawakening delay for both REM and NREM sleep (e.g., 10 minutes for each) guarantees neither similar phase relationships to the ultradian acrophase (for REM) and nadir (for NREM) nor constant phase relationships between the REM and NREM samples for several reasons. First, REM and NREM sleep occupy different proportions of the sleep cycle (e.g., 20% REM, 80% NREM); second, the proportions of REM and NREM sleep change across the night; and third, the periodicity of the 90-minute REM-NREM cycle is highly variable.<sup>20</sup> Further, the common procedure of sampling mentation with progressive temporal delay into stage (PTDIS) protocols—for example, 5 minutes into the first REM, 10 minutes into the second REM, 15 minutes into the third REM, and so on—further confounds ultradian phase with time-of-night (see also later).



**Figure 43-2.** Percent recall of dreaming from rapid eye movement (REM) and non-REM (NREM) sleep awakenings in 39 studies from 1953 to 2004. Variation in recall from NREM sleep is attributable in part to changing definitions of dreaming, in part to nonstandardized choice of awakening times for dream sampling, and in part to uncontrolled sleep stage interactions. Flagged values (see *asterisk*) for very low NREM recall in 2001 and 2004 studies reflect use of the sleep interruption technique<sup>19</sup> and an ultrashort sleep-wake schedule,<sup>18</sup> both of which minimize possible influences on dreaming of prior sleep other than from the target stage.

## Quality of Dream Reports

### *Within-Stage Qualitative Changes*

As is the case for measures of dream recall frequency and length, much evidence indicates that the vividness, intensity, dreamlikeness, and other qualities of dream imagery increase progressively within REM sleep periods, whereas other evidence suggests that these qualities may decrease within NREM episodes. Unlike the findings for recall and length, however, clear sinusoidal variation of these measures has not yet been established.

For REM sleep, subject ratings indicate that dream reports from long REM sleep episodes (9 minutes or more) are more dreamlike in several respects than those from short episodes (1 minute or less).<sup>21</sup> Long REM sleep reports are more active, distorted, dramatic, emotional, anxious, unpleasant, and clear or vivid, and they contain more different scenes, more scenes with clear visualization, and more socially unacceptable content (violence or hostility) than short REM sleep reports. Consistent results were obtained when dreams were sampled from REM periods of several different lengths.<sup>22-24</sup> In the latter study, four male college students were each awakened twice from both REM 2 and REM 4 periods for each of six conditions—0.5, 2.5, 5, 10, 20, and 30 minutes after REM onset—and asked to rate 12 qualities of their dreams. *Recall, emotion, anxiety, pleasantness, and clarity* showed linear increases over time. Three of these measures (emotion, anxiety, pleasantness) had additional trend components, suggesting possible ultradian modulation, with two major peaks at 10 and 30 minutes.<sup>23</sup> Others<sup>25,26</sup> report that plausibility and sensibleness of dreams in relation to daily life do not change as a function of REM length. The possibility that some qualities of dreaming are subject to ultradian modulation while others are not is consistent with Kramer's<sup>24</sup> claim that an "affective surge" arises during REM sleep and is "contained" or processed by other dream content. The hypothesized surge function may be chronobiologically modulated, whereas the dream container may not.

For NREM sleep, evidence again points to relationships that are *opposite* in direction to those observed for REM sleep and thus suggests that measures reflect activity on the descending slope of an ultradian oscillation. In one study,<sup>27</sup> dreamlike fantasy (Df) scale\* scores were lower ( $P < .10$ ) for reports from 20-minute NREM (stage 4) episodes than for 5-minute NREM episodes, even though the reports were matched within subjects and for time of night. In a second study,<sup>14</sup> NREM (stage 2) reports obtained 12 minutes after the end of REM sleep episodes were rated less dreamlike ( $M$  rating = 4.17) than were NREM reports obtained 5 minutes after REM sleep episodes ( $M = 4.73$ ,  $P < .001$ ).

### *Between-Stage Qualitative Changes*

A large body of research<sup>2,4</sup> demonstrates that REM sleep reports are consistently more perceptual, hallucinatory, emotional,

dramatic, physically involving, and rich with characters and visual scenes than are NREM reports, whereas the latter are more conceptual, thoughtlike, and mundane.<sup>21</sup> However, these highly replicable findings are not easily interpreted as caused by ultradian processes because of their possible confounding by differences in report length described earlier. Because REM reports are consistently longer than NREM reports, it has been argued that the two may be compared only if this difference is removed or statistically controlled, for example, by comparing reports of equal length, by calculating proportions with a common metric (e.g., TU), or by removing report length as a covariate. The use of such procedures has caused significant qualitative differences between REM and NREM dream reports to disappear in some studies.

Most length control procedures have been criticized on methodologic grounds,<sup>2,4,30</sup> and there is evidence that the qualitative nature of sleep mentation changes as a function of the REM-NREM cycle, even with report length controlled.<sup>4</sup> In brief, even with length controls, REM dream reports surpass NREM dream reports on measures of self-reflectiveness,<sup>31</sup> bizarreness,<sup>32,33</sup> visual and verbal imagery,<sup>5,32,34</sup> movement imagery,<sup>35</sup> characters and self-involvement,<sup>6,36</sup> self-representation,<sup>6</sup> psycholinguistic structure,<sup>37</sup> and narrative linkage.<sup>38</sup>

### MEMORY SOURCES OF DREAMING

Memory sources that subjects are requested to furnish in association to their dreams are another form of evidence that REM and NREM dream reports differ, although it remains unknown whether these differences are attributable to an ultradian oscillator. Results from several studies indicate that NREM dream sources are primarily biographic episodes (episodic memories), whereas REM sources are a mixture of episodic and semantic memories.<sup>39-41</sup> The predominance of episodic sources for NREM dreams is maintained regardless of time of night and independent of correction for report length.<sup>8,39,41-43</sup> It is thus possible that ultradian oscillations in memory access (e.g., episodic versus semantic) partially determine the content of REM and NREM dreams. Within-stage oscillations in memory sources have not yet been demonstrated, however.

In sum, most results from quantitative and qualitative assessments can be explained as due to oscillatory ultradian modulation of dreaming processes. REM and NREM dream reports reflect the output of a generator that is sampled at varying points along its rising and descending slopes. It remains unknown whether different components of dreaming, such as memory access, quality of content, or intensity of emotion, are modulated by the same or different ultradian processes. It is also not yet known what effects the desynchronization of such processes might have on the presence or form of dreaming. Further study that controls and avoids confounding time-in-stage and time-of-night sources of variation is clearly needed.

### Basic Rest-Activity Cycle Hypothesis

Kleitman's ultradian basic rest-activity cycle (BRAC) hypothesis<sup>44</sup> has been a stimulating heuristic that conceptually links the 90-minute REM-NREM rhythm with circadian oscillations. One study of BRAC and dreaming suggested a continuation of the REM-NREM cycle and dreaming during the daytime in the form of fantasy fluctuations. Results for a series of individual

\*The dreamlike fantasy scale is an eight-item scale: 0 = no recall (mind was blank); 1 = no recall (mind not blank, but forgets); 2 = content is conceptual (no sensory imagery), everydayish; 3 = content is conceptual, bizarre; 4 = content is perceptual (sensory imagery), nonhallucinatory (did not believe it was real), everydayish; 5 = content is perceptual, nonhallucinatory, bizarre; 6 = content is perceptual, hallucinatory (believed it was real), everydayish; 7 = content is perceptual, hallucinatory, bizarre.<sup>28,29</sup>

## 538 Psychobiology and Dreaming

subjects and a separate group of normal subjects indicated that the intensity of daytime fantasy fluctuates with a 90-minute periodicity.<sup>45</sup> When these results were pooled with results from three additional experiments and assessed with superior statistical procedures, the effect was not clearly replicated; only a 200-minute ultradian rhythm was demonstrated.<sup>46</sup> On the other hand, there is ample support for the existence of daytime ultradian fluctuations in cognitive performance.<sup>46-48</sup> Correlations between daytime imagery abilities and dream recall frequency have also been reported.<sup>49</sup> Existing procedures could be adapted to assess whether rhythmicities in dreaming possess waking-state counterparts in a manner predicted by the BRAC hypothesis.

### CIRCASEMIDIAN RHYTHMS

Broughton<sup>20</sup> has argued convincingly for the existence of 12-hour, or circasemidian, rhythms that are either distinct from 24-hour circadian rhythms or are subcomponents of their expression. Accumulating evidence supports the 12-hour rhythm in sleep propensity (postlunch sleepiness), slow wave sleep expression,<sup>50</sup> EEG power,<sup>51</sup> and other processes.<sup>20</sup> Although this rhythm explains the global human tendency to nap in the early afternoon, research examining circasemidian characteristics of dreaming are few. A single study<sup>18</sup> using an ultrashort (20 min/40 min) sleep-wake schedule with dream sampling at each awakening over three consecutive days provides some support for a circasemidian oscillation in dream intensity (see the discussion in “Experimental Desynchronization of Circadian Factors” later). While the scale employed (0 = none, 1 = a little, 2 = a moderate amount, 3 = a lot) to the question “how much did you dream?” might have produced a ceiling effect for REM sleep reports, for NREM reports both an acrophase at 8:00 AM and a secondary peak at 4:00 PM are visible in the time-plotted results.

Because of the problem of undersampling, many results described in the next section could be explained as due to the influence of circasemidian—rather than circadian—factors.

### CIRCADIAN RHYTHMS

Circadian features of dreaming are difficult to validate because their measurement is typically limited to the nocturnal portion of the sleep-wake cycle. Either a waking counterpart of dreaming such as spontaneous fantasy or a 24-hour physiologic marker of dream propensity<sup>18,52</sup> is needed to convincingly demonstrate circadian oscillations in dreaming. Nonetheless, trends across the night can be assessed for whether they conform to known circadian influences. Such trends can be further evaluated for their temporal relationships to fluctuations in waking-state processes that may be dreaming counterparts, such as spontaneous fantasy or hemispherically lateralized processes.

The following sections summarize several converging lines of research that support a circadian mediation interpretation. First, research on across-the-night changes in dream length, content, organization, and memory sources demonstrates progressive increases or decreases consistent with a sinusoidal 24-hour rhythm in some cases, and exponential or switchlike changes<sup>53</sup> between reports from the first third of the night and all later sample points in others (Table 43-1). Second, these findings are complemented by evidence for

increased dream vividness in conditions of circadian phase advance, e.g., forced desynchrony protocols, depression, and PTSD jet lag. Third, circadian mediation is suggested by evidence of continuity between sleep and wake states on measures of left hemisphere (LH) and right hemisphere (RH) processes.

### Recall and Report Length Changes Across the Night

Measures of dream report length described earlier have also been applied to studies of dreaming across the night and provide information about potential circadian characteristics.

#### REM Sleep Effects

A study that experimentally varied both ultradian and circadian factors<sup>17</sup> found that dream reports from early REM periods (REM 2) were half the length (TRC) of those from later periods (REM 4), whether awakenings occurred 10 minutes into REM sleep ( $P = .001$ ) or 5 minutes into REM sleep ( $P = .07$ ). Similarly, a study of young adults' dream reports found an exponential lengthening in TRC from early (0.0 to 2.5 hours) to middle (2.5 to 5.0 hours) to late (5.0 to 7.5 hours) night awakenings—all conducted 4.8 to 5.0 minutes into REM sleep.<sup>5,54</sup> For older subjects, the increase in length occurred only in the middle-to-late comparison.

The previous effect was replicated<sup>55</sup> with mentation sampled from the first four REM periods in a study controlling for ultradian factors (awakenings all 9 minutes into each REM period). Time-of-night effects for several “story structure” measures included the number of statements in the event structure ( $P < .001$ ) and the number of episodes per story ( $P < .001$ ). For the former measure, REM 1 dreams possessed fewer statements than REM 2 to REM 4 dreams; for the latter measure, the order of means was REM 1 < REM 2 < REM 3, REM 4. No effect was obtained for the number of statements describing settings.

These findings are consistent with results from our study of 40 healthy subjects awakened from various REM sleep periods.<sup>56</sup> Measures of both probability of recall and mean TRC ( $N = 135$  reports total) were lower for REM 1 than for REM 2 to REM 5 (Fig. 43-3A). Since REM awakenings were implemented with a PTDIS protocol (5 minutes into REM 1; 10 minutes into REM 2; 15 minutes into REM 3; 20 minutes into REM 4 and REM 5), findings may be confounded by ultradian factors.

#### NREM Sleep Effects

Findings for NREM sleep mentation parallel those for REM sleep. In a study<sup>57</sup> with four NREM awakenings per night, the percentage of awakenings bearing some mental content was low for NREM 1 (45%), rose dramatically for NREM 2 (70%), and remained relatively high for NREM 3 (70%) and NREM 4 (74%; see Fig. 43-3B). Similarly, in a study described earlier<sup>5,54</sup> in which dream reports were evaluated for early, middle, and late NREM (stage 2) awakenings, NREM report length increased linearly across the three sample times for young subjects. For older subjects, however, length was uniformly high for early and middle samples and then dropped sharply in the late sample.

Table 43-1. Studies Showing Quantitative and/or Qualitative Changes in Sleep Mentation across the Night

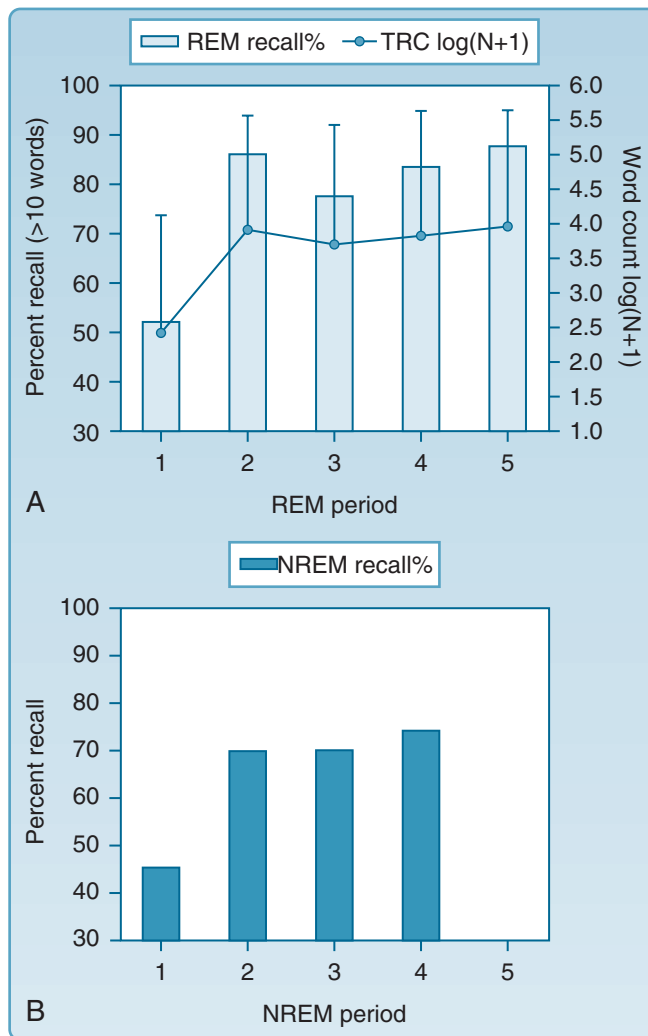
Study; Sleep Stage	No. of Subjects	Methods and Awakenings	Quantitative Findings	Qualitative Findings
Dornhoff and Kamiya (1964) <sup>58</sup> ; REM	22 college students (14 male, 8 female)	Total N = 219 reports (73/R)		R1 > R2, R3 (characters, aggression/misfortune, buildings as settings) R1 > R2, R3 (terrain/country as settings) R1, R2 > R3 (room settings) R1, R2 < R3 (sexual acts, food elements) R1 < R2, R3 (perceptual content)
Foulkes (1966), <sup>21</sup> Foulkes and Rechtschaffen (1964) <sup>59</sup> ; REM	22	PTDIS schedule (5R1, 10R2, 20R3)		
Pivik and Foulkes (1968) <sup>57</sup> ; NREM	20 male college students	2 consecutive nights 4 WU/night-SO30, 30NR1-30NR3	NR1 < NR2, NR3, NR4 (recall %)	NR1 < NR2, NR3, NR4 (Df score)
Van de Castle (1970) <sup>64</sup> ; REM	15 male college students	Multiple series: 273 reports/R Single series: 196 reports for R1-R4		Multiple series: R1-R3 < R4-R8 (clarity, misfortunes, bizarreness, female characters, color elements) Single series: R1 = R2 = R3 = R4 (all measures) NR <sub>EARLY</sub> < NR <sub>LATE</sub> (Df scale)
Tracy and Tracy (1974) <sup>27</sup> ; NREM	11 male, 10 female young adults (mean age = 21 yr)	3 nonconsecutive nights 5-min samples each of descending stage 2 and stage 4 sleep; also 20 samples of stage 4		
Cohen (1977) <sup>63</sup> ; REM	10-23 male college students	LH processes: dream recall quality, presence of verbal activity, high ego functioning, positive emotion, active participation RH processes: music, spatial salience, bizarre events, negative emotion		5 replication studies LH: increase across night in all studies RH: few or inconsistent changes in all studies
Arkin et al. (1978) <sup>14</sup> ; NREM	40 male college students (18-26 yr)	1 night each NR (S <sub>2</sub> ) reports during R deprivation and NR-control deprivation, first and second halves of night		NR <sub>EARLY</sub> < NR <sub>LATE</sub> (DLQ)
Kramer et al. (1980) <sup>60</sup> ; REM	25 (14 male, 11 female; 20-25 yr)	20 consecutive nights WU at "end" of R1-R4		Hall and Van de Castle (1966) frequency scales R1 to R2: Increase in 15/41 variables R2 to R3: Increase in 6/41 variables R3 to R4: Increase in 7/41 variables

Continued

Table 43-1. Studies Showing Quantitative and/or Qualitative Changes in Sleep Mentation across the Night—cont'd

Study; Sleep Stage	No. of Subjects	Methods and Awakenings	Quantitative Findings	Qualitative Findings
Waterman et al. (1992, 1993) <sup>5,54</sup> ; REM	24 males: 12 elderly (mean age 65.1 yr), 12 young (mean age 22.9 yr)	4 consecutive nights 4.8-5.0 min into all R nights 3 and 4 = three WU/night: early (0.0-2.5 hr), middle (2.5-5.0 hr), late (5.0 hr)	Young subjects: $R_{EARLY} < R_{MIDDLE}$ , $R_{LATE}$ (TRC) $NR_{EARLY} < NR_{MIDDLE} < NR_{LATE}$ (TRC) Elderly subjects: $R_{EARLY}, R_{MIDDLE} < R_{LATE}$ (TRC) $NR_{EARLY}, NR_{MIDDLE} < NR_{LATE}$ (TRC)	Young subjects: $R_{EARLY} < R_{MIDDLE}$ , $R_{LATE}$ (visual imagery) $NR_{EARLY} < NR_{MIDDLE} < NR_{LATE}$ (visual imagery) Elderly subjects: $R_{EARLY}, R_{MIDDLE} < R_{LATE}$ (visual imagery) $NR_{EARLY}, NR_{MIDDLE} > NR_{LATE}$ (visual imagery)
Rosenlicht et al. (1994) <sup>17</sup> ; REM	22 (12 male, 10 female, 19-27 yr)	2 consecutive nights 3 WU/night in SO, R2, R4 5 or 10 min into REM, counterbalanced across nights	$R_{EARLY} < R_{LATE}$ (% recall) $NR_{EARLY} < NR_{LATE}$ (log TRC) $R2 < R4$ (TRC)	$R_{EARLY} = R_{LATE}$ (visual imagery) $NR_{EARLY} < NR_{LATE}$ (visual imagery)
Casagrande et al. (1996) <sup>32</sup> ; REM, NREM	20 right-handed college students (4 female, 16 male, 20-27 yr)	5 consecutive nights; dream recall: 5R2 (REARLY), 5R3 (RLATE), 5S22 (NR <sub>EARLY</sub> ), 5S24 (NR <sub>LATE</sub> )	$R1 < R2, R4$ (no. statements in event structure) $R1 < R2 < R3$ , $R4$ (no. episodes/story) $R1 = R2 = R3 = R4$ (no. setting statements)	Increase in DLQ from early to late half of the night Suicidal: $R_{EARLY} < R_{LATE}$ (freq. negative affect) $R_{EARLY} > R_{LATE}$ (freq. positive affect); more DLQd, i.e., Df decrease $R_{EARLY}$ to $R_{LATE}$ Nonsuicidal: more DLQd+
Cipolli et al. (1998) <sup>55</sup> ; REM	16 male college students (19-24 yr)	5 nights Nights 2, 3, 4 = 4 WU/night (9 min into R1-R4)		
Agargun and Cartwright (2003) <sup>62</sup> ; REM	26 (10 male, 16 female) with major depression (13 suicidal, 13 non-suicidal)	3 consecutive nights night 2: baseline night 3: PTDIS schedule (5R1, 10R2, 15R3, 20R4)		

Df, dreamlike fantasy; DLQ, dreamlike quality; DLQd, dreamlike quality difference; LH, left hemisphere; NREM, non-REM; PTDIS, progressive temporal delay into stage; R, REM period (5R1, 5 min into first REM period); REM, rapid eye movement; RH, right hemisphere; SO, sleep onset; S<sub>2</sub>, stage 2; TRC, total recall count; WU, wake up.



**Figure 43-3.** Percent recall and mean total recall count (TRC) for dream reports collected across the night from rapid eye movement (REM) sleep (**A**) and non-REM (NREM) sleep (**B**). Exponential (“switchlike”) increases from first to second sleep cycles appear in both graphs. Values for NREM period 5 are not available. (**B**, Adapted from Pivik T, Foulkes D: NREM mentation: Relation to personality, orientation time, and time of night. *J Consult Clin Psychol* 1968; 32:144-151.)

## Quality of Report Changes across the Night

Much research indicates that dreaming is more subjectively realistic and engaging in later sleep cycles and that dreams sampled in the first or second sleep cycles differ markedly from those in subsequent cycles. These qualitative changes are typically confounded by changes in report length, and the same caveats about length described earlier for ultradian rhythms also apply.

### Qualitative REM Sleep Effects

An early study<sup>58</sup> of 73 dreams collected from each of the first three REM periods found REM 2 and REM 3 reports differed from REM 1 reports for several scales: Dream reports from later REM stages had more characters, more aggression and

misfortune elements, more buildings, and fewer terrain settings. For some scales, a change occurred only from REM 2 to REM 3: REM 3 dreams had more sexual acts, more food elements, and fewer room settings.

Several groups have conceptually replicated these types of across-night changes. First, there are positive correlations between time of night of the REM period awakening and ratings of mentation vividness ( $P = .01$ ) and emotionality ( $P = .05$ ).<sup>26</sup> Second, subject ratings on several variables reveal that REM 1 dream reports differ more from REM 2 reports than the latter do from REM 3 reports.<sup>21,59</sup> Third, dream reports from young adults show marked changes from REM 1 to REM 2 (increases in 15 of 41 variables) and less-marked changes from REM 2 to REM 3 (6 of 41 variables) and REM 3 to REM 4 (7 of 41 variables).<sup>60</sup> Fourth, the dream reports of healthy volunteers increase in dreamlike quality (DLQ)\* from early (REM 1 and REM 2) to late (REM 3 and later) sleep,<sup>62</sup> including an increase in *strongly emotional* content (from 16.7% to 23.1%) and *positive emotion* (from 15.4% to 38.5%) and a decrease in *neutral emotion* (69.2% to 46.1%).

Ultradian factors confound the preceding results, which unfortunately limits their generality. Two studies<sup>21,62</sup> confounded REM period order with prior stage duration due to a PTDIS protocol (waking 5 minutes into REM 1, 10 minutes into REM 2, and 20 minutes into REM 3 and later). Another study<sup>60</sup> likely confounded REM period order with length because all awakenings targeted the “end” of the REM episodes (early REM episodes are shorter than later ones). In another study,<sup>26</sup> a partial PTDIS protocol was used: REM 1 awakenings were always short (i.e., at 5 minutes), whereas all other REM awakenings were counterbalanced between short and long (i.e., 5 minutes versus 12 minutes).

Despite potential confounding factors in these studies, their results are consistent with findings from studies that have controlled for such factors. When the ultradian confounding factor was controlled by conducting awakenings 4.8 to 5.0 minutes into each REM period,<sup>5</sup> a visual imagery (VI) measurement—a count of visual nouns, action words, modifiers, and spatial relations—clearly increased across the night, with marked changes for the early- to middle-night comparison but not for the middle- to late-night comparison. Confounding effects are also mitigated by evidence<sup>34</sup> that circadian and ultradian factors do not interact statistically in subjective ratings of dream vividness and other features (see later).

Another early series of five replication studies<sup>63</sup> that minimized ultradian confounding factors (awakenings all 5 to 10 minutes into REM sleep) reported a within-night pattern of increases in LH, but not in RH, processes. In all studies of the series, a combined LH score increased significantly across the night. The pattern is consistent with the influence of a LH circadian process with an early morning acrophase, whereas the lack of variation in RH processes suggests either no circadian variation or a possible rise and acrophase later in the day. The latter case would imply that LH and RH influences on dreaming are modulated by separate circadian oscillators.

\*Dreamlike quality is measured on a five-point scale: 1 = no recall; 2 = a nonperceptual report; 3 = a single visual image; 4 = two or more images with some story connecting them; and 5 = two or more images with an elaboration of detail and a well-developed narrative.<sup>61</sup>

## 542 Psychobiology and Dreaming

Mixed support for circadian effects is found in a study<sup>64</sup> of male college students. A “multiple” series of dream reports ( $N = 273$ ) collected after every REM period for several nights indicated change over REM periods using both objective and subjective measures: Later REM dreams had more lone female characters, had more misfortunes, had more clarity, were easier to recall, were more bizarre, and had more color elements. In contrast, a “single” series of reports collected from subjects ( $N = 196$ ) awakened only once per night for the first four REM periods gave no comparable evidence of change. These findings might question whether the within-night changes seen in laboratory studies are artifacts induced by multiple awakening schedules; however, the methods of the study remain unpublished and cannot be evaluated for rigor and potential confounding variables.

Two studies<sup>32,34</sup> that showed no differences between “early” and “late” REM dreams on measures of visual and auditory imagery and bizarreness sampled “early” REM dreams only from REM 2 and “late” dreams only from REM 3. These studies therefore may have failed to detect the switch-like change found to occur prior to REM 2 in other studies. Another possible confounding variable in laboratory studies<sup>34</sup> (see also later) is that the vividness of some dreams is more pronounced when sleep onset is delayed by 3 hours—presumably because dreaming is forced farther along the rising edge of a circadian activation process. Thus, to the extent that a subject’s normal bedtime is inadvertently delayed by electrode installation, equipment calibration, questionnaire administration, and other routine tasks, dream vividness may be affected proportionately.

### Qualitative NREM Sleep Effects

Within-night patterns similar to those reported for REM sleep have been observed for NREM reports in several studies that control ultradian confounding factors. First,<sup>57</sup> Df ratings are low in NREM 1 compared with NREM 2 through NREM 4. Second, there is an increase in NREM (stage 2) DLQ from the first to the second half of the night in male college students’ dreams.<sup>14</sup> Third, NREM (stage 2) visual imagery scores in healthy young adults increase linearly across early, middle, and late thirds of the night.<sup>5</sup> Fourth, visual imagery ratings of NREM (stage 2) reports are higher in NREM 4 than in NREM 2—even after covarying report length.<sup>32</sup>

### Memory Sources

Memory source studies provide additional information about possible circadian influences on dream formation. Studies use either objective markers of memory sources, such as laboratory incorporations, or subjective markers, such as subject associations to recalled contents. The memory features most often evaluated are informational quality of the sources (semantic versus episodic) and temporal recency of the sources (recent versus remote events).

#### INFORMATION QUALITY OF MEMORY SOURCES

In one study<sup>42</sup> dreams were reported after 5 minutes into REM 1 and REM 3 and after an unspecified time into NREM 1 and NREM 3 while dream sources were elicited and rated by judges as being strict episodes, semantic knowledge, or

abstract self-references.\* For REM reports, only semantic sources were less frequent for early (16.4%) than for late (31.9%) awakenings ( $P = .027$ ), even when report length was controlled. However, when the raw data from this study were combined with those from other studies, this effect disappeared,<sup>41</sup> whereas the absence of other effects (episodic, self-reference) was confirmed. Further, a significant within-night effect for NREM sleep reports was observed ( $P = .014$ ), but its morphology was unfortunately not specified. Finally, a stage difference in episodic sources (NREM greater than REM) was found to be constant throughout the night.

These studies provide conflicting evidence for modulation of access to semantic memory sources across the night, but they concur in supporting an *absence* of such modulation for either episodic or self-reference source types.

#### TEMPORAL RECENCY OF MEMORY SOURCES

Studies evaluating the timing of memory sources provide findings discordant with those assessing their informational quality. Several early studies indicate that memory sources referring to temporally recent (presumably episodic) events are preferentially associated with early-night (versus late-night) dream reports. For example, a case study<sup>65</sup> reported that early-night dreams often refer to the laboratory experiment, whereas later dreams refer to early childhood or adolescent memories.

Two studies confirmed this finding. In one,<sup>66</sup> subjects associated recent memory elements to their early-night REM dreams and remote elements to their late-night REM dreams. In another,<sup>26</sup> recent elements were associated with dreams from the first 3.5 hours of sleep, remote elements to dreams from 3.5 to 7.5 hours, and moderately recent elements to dreams from later than 7.5 hours. Temporal remoteness of associations was also correlated with body temperature.

A subsequent study<sup>67</sup> (Table 43–2, second study) confirmed these findings among subjects who wore red-tinted goggles over 5 consecutive days and reported dreams after multiple REM period awakenings. On the first postexposure night, colors from the red end of the spectrum (“goggle” incorporations) occurred only in REM 1 dreams. On subsequent nights (nights 2 and 3), incorporations spread to REM 2 and REM 3 dreams, and on nights 4 and 5 they spread to REM 4 and REM 5 dreams. Thus, incorporations of new experiences were restricted to *early* REM periods; progressively older experiences were processed in *later* REM periods.

In contrast to the preceding, negative findings were reported<sup>58</sup> in an assessment of “elements from the past” among 219 dreams from 22 subjects. Although the proportion of elements increased in the expected direction from REM 1 to REM 3 (11%, 18%, 19%), the change was not statistically significant. However, later REM periods were not sampled and statistical tests were admittedly too conservative.

\*The ratings are defined as: strict episode = discrete episode in the life of the dreamer, with precise spatial and/or temporal coordinates; abstract self-reference = memories not connected to any particular spatiotemporal context, referring to the dreamer’s general knowledge of him- or herself and his or her own habits; semantic knowledge = elements of general knowledge of the world, including episodes from the biographies of others (adapted from Cavallero et al.<sup>42</sup>).



Table 43-2. Studies Showing Circaseptan Factor in Dream Memory Sources

Study	No. of Subjects	Mean Ages (SD)	Stimulus	No. of Dreams	Design	Peak Incorporations Identified
Jouvet (1979) <sup>103</sup>	1 researcher	Not specified	Retrospectively identified events (unspecified type) Change surroundings (Leave on trip or return from trip)	400 total	Within subject	On day 9 following event 7.8 days after leaving on trip 6.5 days after returning from trip
Roffwarg et al. (1978) <sup>67</sup>	9 (3 male, 6 female) 18-28 students		Goggles with red filters for 5 consecutive days	Not specified (605 to 640- $\mu$ m bandpass)	Within subject	On day 1 after first wearing goggles 5 days after first wearing goggles
Nielsen and Powell (1989 study 1) <sup>98</sup>	69 undergrads	Not specified	Retrospective self-selection of most significant events of prior week	55, 43, 41, 31, 14, 8 (days 1 to 7)	Within subjects	On days 1 and 6 after event
Nielsen and Powell (1989 study 2) <sup>98</sup>	34 undergrads	Not specified	Overnight stay in sleep laboratory	24, 20, 27, 22, 17, 21, 22 (days 1 to 7)	Within subjects	On days 1 and 6 after event
Nielsen and Powell (1992) <sup>99</sup>	84 undergrads	Not specified	Daily self-selection of emotionally meaningful events	Range: 59 (day 1) to 11 (day 14); mean: 34.9/day	Within subjects	On days 1, 6, and 12 after negative event
Powell et al. (1995) <sup>102</sup>	10 male, 9 female undergrads	Total: 24.9 (8.4)	30-min water buffalo sacrifice film with friends on 21-inch TV	Range: 17 (day 1) to 13 (day 7)	Within subjects	On days 1 and 7 after film for high incorporators
Nielsen and Powell (1995) <sup>100</sup>	9 male, 12 female undergrads	Female: 21.4 (2.4) Male: 22.8 (2.8)	30-min water buffalo sacrifice film alone in lab bedroom on 21-inch TV	Range: 10-16; mean: 12.2/day	Within subjects	On days 4 and 11 after film
Nielsen et al. (2004) <sup>101</sup>	212 undergrads	Male: 20.4 (7.4) Female: 20.1 (5.0)	Self-selection of events from one specific day	50, 38, 26, 25, 27, 26, 20	Between subjects	On days 1 and 7 after event for women; day 1 for men

## Experimental and Pathologic Desynchronization of Circadian Factors

Some of the most compelling evidence for the existence of circadian influences on dreaming is found in studies in which relationships between circadian factors and dreaming are desynchronized by experimental design, by pathologic factors such as depression and posttraumatic stress disorder (PTSD), or by jet lag or aging. In all cases, dreaming becomes atypically intensified early in the sleep episode, and circadian rhythms appear to be phase-advanced relative to the habitual sleep period. These findings underline the potential value of forced desynchrony protocols for investigating circadian factors in dreaming.

### Experimental Desynchronization of Circadian Factors

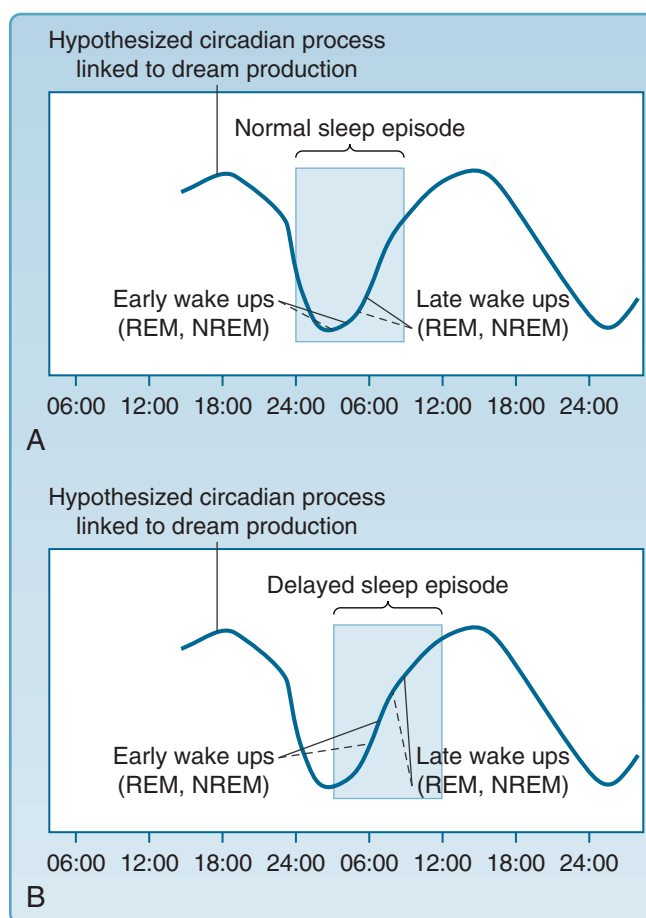
A study<sup>34</sup> using partial forced desynchrony created a phase delay of dreaming relative to a hypothesized circadian influence by delaying sleep onset and offset by 3 hours. REM and NREM dreaming both occurred 3 hours later than usual—coincident with the rising phase of the circadian influence (Fig. 43-4). Comparison of REM and NREM dream reports from the phase-delayed condition with control reports from nondelayed sleep revealed the relative contributions of an ultradian factor (early versus late awakenings) and a circadian factor (control versus delayed sleep). Sleep-delayed dream reports were longer and more visually intense, especially when collected later at night. Habitual REM greater than NREM differences were also shown, but REM and NREM reports were both affected by the circadian factor independent of this stage difference. For a visual imagery measure, the circadian effect size (.23, or small) was about 30% of the ultradian effect size (.70, or large). The results prompted the authors to claim that ultradian and circadian sources of cortical and subcortical activation are independent but combine to enhance dreaming, as in this study.

This finding was subsequently replicated by the same group<sup>34a</sup> using a more precise estimate of circadian phase. The effect size of the expected difference in this case was much larger (.51) than that for the sleep stage difference (.40).

One study<sup>18</sup> (described earlier) that employed 20-minute sleep/40-minute awake schedules to sample dream content from REM and NREM naps provides even more convincing evidence for circadian oscillation in dreaming propensity (Fig. 43-5). Subjective dreaming scores elicited for NREM reports were distributed sinusoidally across the 24-hour day, with an acrophase at 8:00 AM. REM report scores were elevated for the entire diurnal period of 6:00 AM to 4:00 PM, followed by a marked drop. Whereas REM dream scores likely reflect a ceiling effect on the four-point scale used, the fact that the curve for NREM dreaming parallels the curve for REM (but not NREM) sleep propensity and is robustly correlated with it ( $r = .87$ ,  $P < 0.0001$ ) suggests that dreaming propensity for REM and NREM sleep is influenced by the same underlying circadian oscillator.

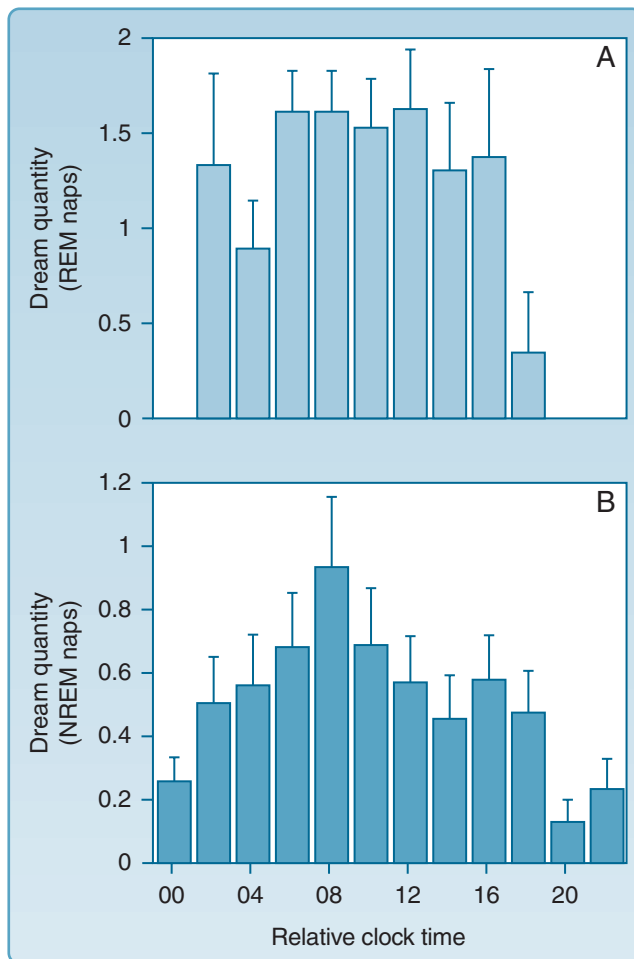
### Depression

In many depressed patients there may be a disruption of circadian factors affecting the REM-NREM sleep cycle<sup>68,69</sup> and



**Figure 43-4.** Theoretical model underlying partial forced asynchrony protocol used to manipulate hypothesized circadian influences on dream formation. Awakenings for report collection in the normal sleep, no delay condition (**A**) were made early and late in the sleep episode. Awakenings in the delayed sleep condition (**B**) were made at the same times relative to sleep onset and thus at different phase relationships to the hypothesized circadian process (i.e., on its rising phase). As predicted, dream vividness was increased for the late-night reports in the delayed condition. REM, rapid eye movement; NREM, non-REM. (Adapted from Antrobus J, Kondo T, Reinsel R, et al: Dreaming in the late morning: Summation of REM and diurnal cortical activation. *Conscious Cogn* 1995;4:275-299.)

accompanying dreaming.<sup>62</sup> For dream content, this disruption is a reversal of the normal increase in DLQ within a night. In one study,<sup>62</sup> all nondepressed subjects displayed the expected DLQ increase within the night for REM reports, but 46% of suicidal subjects displayed a DLQ decrease ( $P = .015$ ). This “reversed DLQ” pattern may signal an abnormal phase advance of circadian processes. Similarly, Wehr’s *internal coincidence* model of depression<sup>70</sup> stipulates that mood in depressed persons is affected by a phase-angle discrepancy between a phase-advanced circadian clock and the sleep-wake cycle. Manipulations of the sleep-wake cycle, such as sleep deprivation or phase advance of the sleep period, may alleviate depression symptoms.<sup>71</sup> A circadian-based explanation of depression is still contentious, and alternative models could account for the early-night changes in dreaming among the depressed. Some alternatives propose a deficiency in sleep need or “process S”<sup>72</sup> or, even more specifically, a diminution of the “delta sleep ratio.”<sup>73</sup>



**Figure 43-5.** Dreaming scores for subjects on a 20-min sleep/40-min awake schedule for 3 consecutive days, with dream sampling at each awakening. Three-day means are displayed by 2-hour blocks time-locked to the onset of melatonin release (11:00 PM). Dream scores for non-rapid eye movement (NREM) sleep reports (*panel B*) clearly conform to a circadian oscillation with an acrophase at 8:00 AM, whereas scores for rapid eye movement (REM) sleep reports (*panel A*) remain elevated from 6:00 AM to 4:00 PM, possibly a ceiling effect for the rating scale used. Interestingly, the NREM dream score acrophase coincides with the acrophase of mean REM (but not NREM) stage duration. A further, circasemidian, component is suggested by the secondary NREM peak at 4:00 PM. (Adapted from Suzuki H, Uchiyama M, Tagaya H, et al: NREM dreaming in the absence of prior REM sleep. *Sleep* 2004;27:1486-1490.

### Posttraumatic Stress Disorder

An imbalance of early versus late sleep like that observed in depression also appears to characterize PTSD; there is an apparent phase advance in dreaming such that vivid nightmares, which in nightmare disorder usually occur in late REM sleep, occur in PTSD patients also early in the sleep episode<sup>74</sup> and even during NREM sleep.<sup>75-77</sup> A circadian phase advance is also suggested by sleep anomalies such as reduced REM latency, increased REM density,<sup>78</sup> circadian phase-specific hypocortisolemia,<sup>79</sup> and increased autonomic responsivity during both REM and NREM in the first versus the second half of the night.<sup>80</sup> These changes all suggest that there has

occurred a shift in the circadian regulator of REM sleep and dreaming such that their intensification takes place much earlier in the night than is normally the case.

### Jet Lag

In a similar manner, transmeridian travel may affect dreaming by desynchronizing dream-related circadian processes and sleep time. This possibility is consistent with the observation that jet lag produces more frequent sleep paralysis episodes,<sup>81</sup> which are usually accompanied by vivid, frightening dream images. Further, the physiologic prerequisite for sleep paralysis, sleep-onset REM (SOREM),<sup>82</sup> is more probable when REM sleep pressure is elevated, as it may be when the circadian propensity for REM sleep is phase advanced. Thus, the frequency of sleep-onset REM, sleep paralysis, and intensified frightful dreaming should all be increased immediately after east-to-west transmeridian travel that induces a temporary phase delay of the sleep episode and thus a relative phase advance of the circadian oscillator. Research is lacking on this question, but a report on two travelers who both underwent long transatlantic flights and both experienced anxious, isolated sleep paralysis events<sup>81</sup> is consistent with this suggestion.

### Aging

Evidence that circadian rhythms are phase advanced in older subjects<sup>83</sup> may similarly explain a resurgence in sleep paralysis events among 40 to 80 year olds<sup>84</sup> as well as a decrease in retrospectively estimated dream recall with advanced age.<sup>85</sup> If dream intensification is phase advanced, then spontaneous morning recall of dreams (the presumed basis for retrospective recall) should be lower. Patterns of dream vividness within a night among older subjects<sup>5,54</sup> partially support this notion. The vividness of older subjects' NREM dreams peaks early then decreases—a pattern opposite to that of younger subjects and consistent with a phase advance. However, a similar vividness pattern for REM-sleep dreams is not observed, possibly because circadian variation of REM and NREM dreaming is more dissociable with age (see Yoon et al.<sup>83</sup> and Broughton<sup>86</sup> for reviews).

### Continuity of Processes across Sleep–Wake States

Just as the propensity for REM sleep continues into wakefulness,<sup>87</sup> circadian factors affecting dreaming may also continue to influence waking-state processes that may be functionally related to dreaming. Studies<sup>63</sup> described earlier demonstrate within-night increases in LH content but no changes in RH content, a pattern that suggests LH processes may reach a peak in the morning, concomitant with REM sleep propensity, while RH processes reach a peak only later in the day. In fact, during wakefulness, LH processes such as spelling proficiency are more engaged in the early morning,<sup>88</sup> whereas RH processes such as consonant-vowel voicings and melodies are more engaged only later in the day.<sup>89,90</sup> Such LH-RH phase discrepancies are true of physiologic systems more generally.<sup>91,92</sup> Thus, although some aspects of dream production, such as total dream output, may have a single circadian oscillator, other more specific aspects may be modulated by separate circadian oscillators.

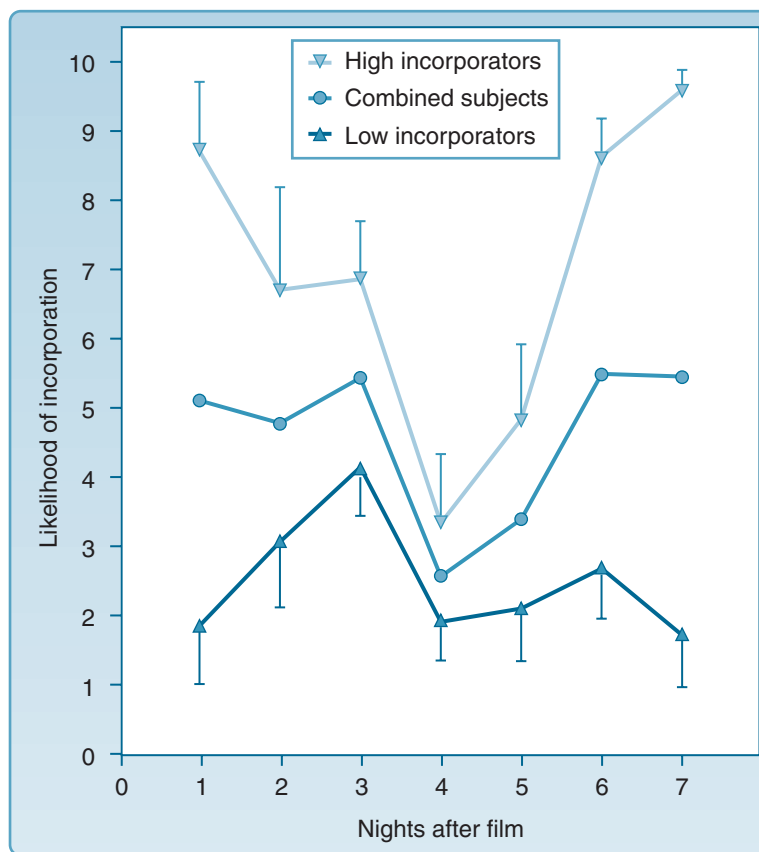
Alternative Explanations

Some of the evidence for circadian mediation of dreaming could be explained by alternative, nonoscillator models, such as the possibility that dream vividness is an inverse function of sleep propensity across the night. For example, delta EEG power, a common marker of sleep propensity, decreases clearly between the first and second NREM periods but much less so between the second and subsequent NREM periods. Dream vividness changes follow an inverse pattern. Nonetheless, an “inverse sleep propensity” explanation does not easily account for all the experimental and pathophysiologic findings reviewed earlier, nor does it easily explain why the changes in a process tied to NREM sleep should affect both NREM and REM dreaming.

CIRCASEPTAN RHYTHMS

Accumulating evidence implicates circaseptan factors in processes of dream formation. Circaseptan oscillators have been described for several biologic systems, including heart rate, blood pressure, and body weight,<sup>93</sup> and for cognitive phenomena such as reaction time.<sup>94</sup> Similarly, circaseptan interval timers (also known as hourglass clocks) that are reactive to endogenous or exogenous events have been identified for several adaptive and compensatory responses,<sup>95</sup> including changes in sleep architecture following learning.<sup>96,97</sup> At least seven studies indicate that the memory sources of sleep mentation are modulated by circaseptan factors (see Table 43–2).

Six studies were conducted by our group using both within- and between-subjects designs.<sup>98-102</sup> In the within-subjects



HIGH INCORPORATORS

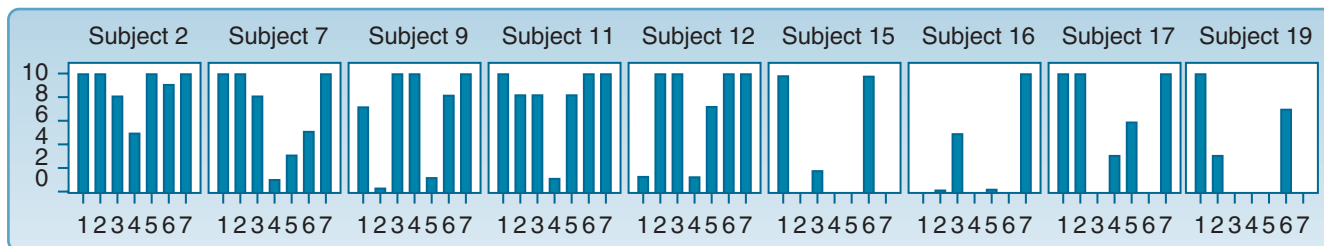
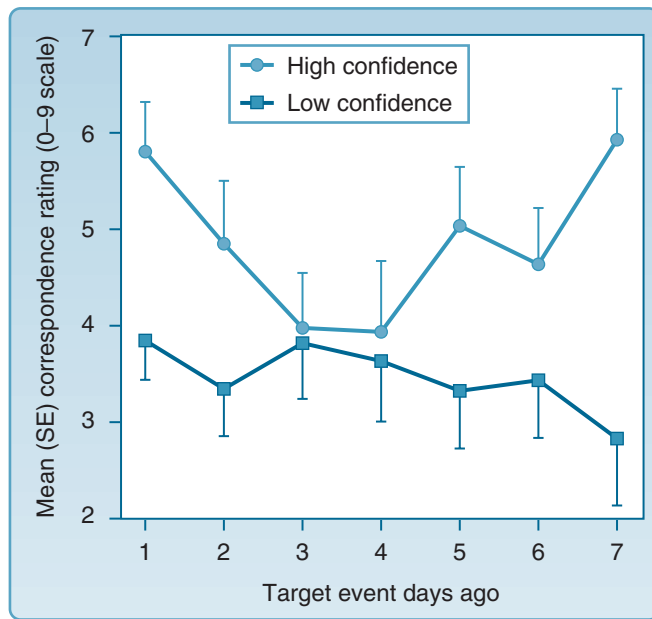


Figure 43–6. Mean (SEM) judge ratings of likelihood that film elements were incorporated into dreams for high (N = 9) and low (N = 10) incorporating subjects. The U-shaped circaseptan effect is apparent only for high incorporating subjects. Bottom panel illustrates the U-shaped curve for ratings for these nine subjects. (From Powell RA, Nielsen TA, Cheung JS, et al: Temporal delays in incorporation of events into dreams. Percept Mot Skills 1995;81:95-104.)



**Figure 43-7.** Mean (SEM) subject ratings of likelihood that prior events correspond to some element of the target dream for each target day for low (squares) and high (circles) confidence groups. The typical U-shaped curve is apparent only for the high confidence group. (From Nielsen TA, Kuiken D, Alain G, et al: Immediate and delayed incorporation of events into dreams: Further replication and implications for dream function. *J Sleep Res* [2004;13:327-336]).

design, dreams recorded for 7 to 12 days are rated by judges for their correspondence with a recent, traceable memory source, such as a current concern, a disturbing film, or a laboratory stayover. When correspondence ratings are plotted against days prior to the dream of the memory source, a sinusoidal U-shaped curve is observed. Peak scores occur for dreams following the source by 1 day (day-residue effect) and by 6 to 7 days (“dream-lag” effect; Fig. 43-6). The latter is consistent with a circaseptan hourglass clock.

In the between-subjects design,<sup>101</sup> subjects randomly distributed into groups are asked to find memory sources for a selected dream on a single specific day prior to the dream. They evaluate their certainty of recall and the correspondence between memory sources and the dream. This design again produces a clear U-shaped curve in dream-memory correspondence for subjects who are relatively certain of their recall (Fig. 43-7). Randomization and other controls minimize the possibility of confounding by the 7-day societal schedule and other factors.

Evidence consistent with the previous findings—and thus with a circaseptan influence on dream memory sources—was reported by Jouv<sup>103</sup> in an analysis of 400 of his personal dreams. One analysis of 130 dreams and their memory sources revealed a sinusoidal U-shaped curve with peak correspondences occurring for memories 1 day (34.6%) and 9 days (10%) prior to the dream. A second analysis of 270 dreams recorded during and after travel abroad revealed that spatial elements of the new environments began to appear in recorded dreams on average 7.8 days after leaving on the trip and ceased occurring 6.5 days after returning home. Jouv<sup>103</sup> suggested that the delayed incorporations into dreams demonstrated a process responsible for spatial memory of environments, a suggestion that we subsequently confirmed.<sup>101,104</sup>

The “goggles” study<sup>67</sup> described earlier, in which subjects wore red-tinted goggles for a 5-day period, also supports a circaseptan process in dream memory access. The “goggle effect” (percentage of dream objects containing red, orange, or yellow) was most apparent for the first REM episode of each night and—for these episodes—was sinusoidally distributed over nights in a circaseptan fashion.

Our group also has evidence that the circaseptan pattern of memory access may be implicated in dream function.<sup>101</sup> On the one hand, delayed incorporations into dreams treat spatial location preferentially<sup>103</sup> relative to immediate incorporations. On the other hand, delayed incorporations are related to interpersonal problem solving—specifically, interpersonal relationships, positive emotions, and resolved problems.

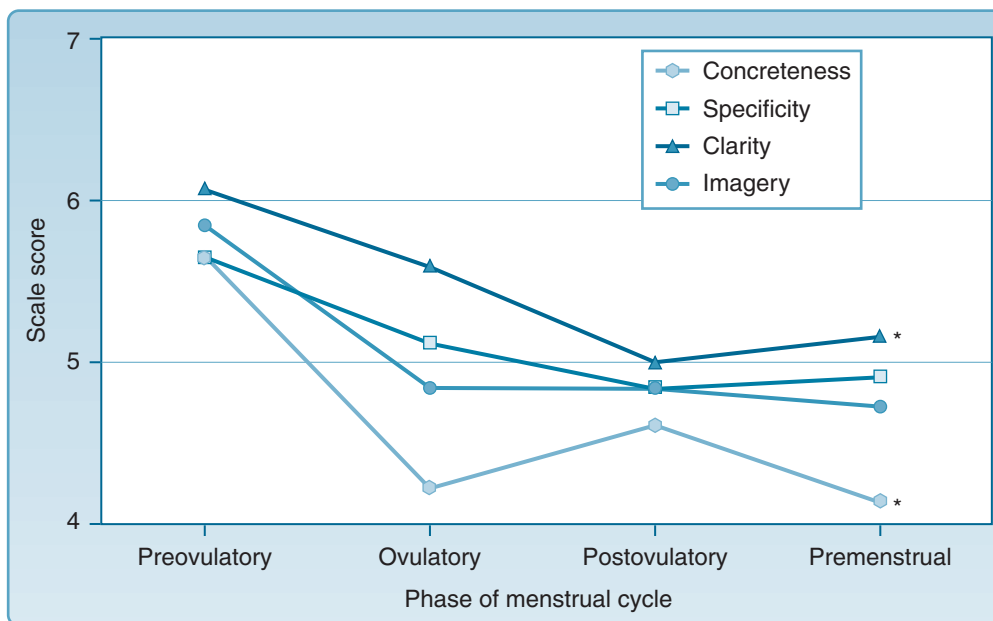
### CIRCATRIGINTAN RHYTHMS

Circatriginan influences on dreaming are feasible in light of observed circatriginan modulation of the menstrual cycle, including changes in sleep parameters (see reviews in Carrier<sup>105</sup> and in Driver and Baker<sup>106</sup>). The possibility is also consistent with the demonstration of monthly fluctuations in, for example, implicit memory,<sup>107</sup> person perception,<sup>108</sup> and spatial ability.<sup>109</sup> These changes are for the most part linked to circatriginan oscillations in the hormones estrogen and progesterone.<sup>107,110</sup>

Although the research is not completely consistent, changes in dream recall and content have been reported for different temporal positions in the menstrual cycle. Several studies converge in suggesting that dream emotion is modulated on a monthly basis, with an intensification occurring during menses. One early study<sup>111</sup> revealed that dreams recalled during menses displayed more expressed emotional conflict than midcycle dreams. A second study<sup>112</sup> with 11 weekly polysomnographic (PSG) recordings replicated this finding: Specifically, manifest sexuality and overt hostility in dreams were both more frequent during menses; however, dream imaginativeness did not vary with menstrual cycle phase. The finding for sexual content, but not for hostility, was replicated in a case study.<sup>113</sup> Finally, a study of more than 450 dreams from 50 first-year nursing students<sup>114</sup> revealed changes during menses consistent with the prior studies: increased references to blood visible on females, increased aggressions toward males, and increased initiation of social interactions of all types.

Two other studies reported changes with menstrual phase that are not necessarily consistent with the previous findings.<sup>115,116</sup> Dreams with active sexual and libidinal impulses were correlated with preovulatory estrogen dominance, whereas dreams with passive receptivity and preoccupations with the self were correlated with postovulatory progesterone dominance. A reanalysis<sup>117</sup> revealed a further link between estrogen dominance and an enhanced capacity to retrieve and communicate concrete, specific, and clear dream images (Fig. 43-8).

Negative findings have also been reported<sup>118</sup> suggesting that conclusions about circatriginan rhythms in dreaming should be drawn cautiously. Although relationships may exist between hormonal fluctuations and dreaming that parallel relationships for the waking state (see earlier), it remains unclear whether dream changes are due to the biologic fluctuations, to concomitant changes in self-perception, stress, and mood, or to both types of factors. Additionally, this type of research so far is limited to female subjects.



**Figure 43-8.** Mean scores for four psycholinguistically based dream content scales for dreams reported at four phases of the menstrual cycle; asterisks indicate significant effects for menstrual phase. (Adapted from Severino SK, Bucci W, Creelman ML: Cyclical changes in emotional information processing in sleep and dreams. *J Am Acad Child Adolesc Psychiatry* 1989;17:555-577.)

#### Clinical Pearl

*Atypical recall of vivid dreams from early in the sleep period may be a marker of underlying phase advance of circadian processes implicated in dreaming.*

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## 550 Psychobiology and Dreaming

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