Ultradian, Circadian, and Sleep-Dependent Features of Dreaming

Chapter 49

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Abstract

Dreaming is influenced by many of the same types of chronobiologic and sleep-dependent factors that regulate sleep processes. These principally include the 90-minute REM–NREM ultradian rhythm, the 24-hour circadian rhythm, and the sleep-dependent increase in REM propensity. Different features of dreaming have been associated with these factors, such as the probability of recalling dream content, the length of dream reports, and the visual intensity of the dream experience. The interactions between ultradian, circadian, and sleep-dependent factors may provide a more complete portrait of chronobiologic influences on dream production.

INTRODUCTION

Previous reviews of dreaming and chronobiology[1,2] concluded that strikingly little convergence had occurred between chronobiology and the study of dreaming following publication of Aserinsky and Kleitman's work[3]—despite the substantial accumulations of research in both domains. This chapter focuses on new findings and formulations describing potential ultradian, circadian, and sleep-dependent influences on dreaming and evidence for their interactions.[4,5] The term *dreaming* is used in an inclusive sense equivalent to that of *sleep mentation*, that is, the occurrence of any subjectively experienced cognitive events during sleep.

ULTRADIAN FACTORS

Frequency and Length of Recalled Dreams

Just as the regular alternation between rapid eye movement (REM) and non-REM (NREM) sleep is thought to be governed by a 90-minute ultradian oscillator, so to do numerous studies support the notion that the amount and intensity of dream mentation fluctuates between a high in REM sleep and a low in NREM sleep. Figure 49-1 shows that peak dream recall (~80%) occurs from REM sleep whereas the lowest level of recall is from NREM sleep (~43%). Paralleling these differences are similarly large REM–NREM differences in dream report length; REM to NREM ratios in total recalled content (TRC) vary from 2 : 1 to 5 : 1.[6]

Beyond such dichotomous REM–NREM differences, the *oscillatory* nature of dream production becomes evident when it is sampled at multiple points within REM or NREM sleep stages. Figure 49-2 (left panel) shows that the length of dream reports, as reflected in TRC, fluctuates sinusoidally as a function of time spent in NREM sleep (blue bars) and time spent in REM sleep (red bars). For NREM sleep, reports are longest from 0 to 15 minutes and from 45 to 60 minutes into stage and shortest in between; for REM sleep the opposite pattern exists.[7] A similar sinusoidal fluctuation was found in a replication study (see Fig. 49-2, right panel).[6]

Other research supports these findings. Four separate studies[8-11] showed NREM dream reports to be either more prevalent or longer when awakenings took place close to a prior REM sleep episode (5 minutes) rather than far from one (10 minutes, 30 minutes, 12 minutes, and 15 minutes, respectively). A fifth study[12] showed that NREM sleep duration preceding an awakening was negatively correlated with report length.

Rosenlicht[13] reported that report lengths following awakenings from REM periods of 5-minute durations were marginally shorter ($P = .114$) than those of 10-minute durations. However, given the close proximity of these samples (5-minute difference) on the 90-minute ultradian cycle, such a trend remains consistent with the proposed ultradian oscillator.

In general, dream recall and report length findings support the possibility that dream imagery is determined by the natural variation of an imagery generator oscillating through REM and NREM sleep on a 90-minute frequency. If so, stricter dream sampling criteria that more consistently control for phase relationships between REM and NREM sampling points are needed to clearly demonstrate the relationship. On one hand, awakenings following a consistent delay for both stages (e.g., 10 minutes into the stage) may bias the size of differences between the two states. For example, using the results plotted in Figure 49-2 (left panel), awakenings conducted at 0 to 15 minutes post–stage-onset would clearly lead to a modest 2 : 1 ratio in REM : NREM word count (~200 words vs. 100 words), whereas awakenings conducted at 30 to 45 minutes post–stage-onset would lead to an enormous 20 : 1 difference (~500 words vs. 25 words). On the other hand, the common method of conducting each of several awakenings of the night progressively later into the target stage (e.g., 5 minutes into REM 1, 10 minutes into REM 2, 15 minutes into REM 3, etc.), confounds ultradian phase with circadian and sleep-dependent fluctuations (see later). More accurate assessments of the ultradian dreaming process will require experimental designs sensitive to these confounds as well as the implementation of protocols capable of separating ultradian, circadian and sleep-dependent factors, for example, forced desynchrony and ultrashort sleep–wake protocols (see later).

Quality of Dream Reports

Evidence also indicates that dream qualities such as vividness, intensity, and dreamlikeness oscillate with an ultradian frequency within and between REM and NREM sleep. Many studies (see reviews in Nielsen[14] and Hobson et al.[15]) demonstrate that REM sleep reports are 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.[16]

However, because REM reports are also consistently longer than are NREM reports, some argue that comparing the two is valid only if this difference is statistically controlled by, for example, selecting equal-length reports, calculating proportions with a common metric, or removing report length as a co-variate. Such procedures have been criticized on methodological grounds,[14,15,17] but there is nonetheless consistent evidence that qualitative REM-NREM differences are maintained even after report length is controlled (see review in Nielsen[14]). Even with length controls, REM dream reports surpass NREM dream reports on measures of emotional intensity,[18] self-reflectiveness,[19] bizarreness,[20,21] visual and verbal imagery,[20,22,23] movement imagery,[24] characters and self-involvement,[25,26] self-representation,[26] psycholinguistic structure,[27] and narrative linkage.[28]

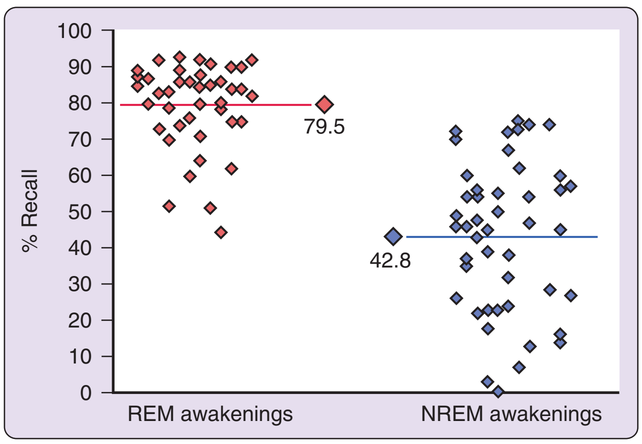

Figure 49-1 Percent recall of dreaming from rapid eye movement (REM) and non-REM (NREM) sleep awakenings in 50 studies from 1953 to 2007. Although fluctuations in recall can be attributed in some measure to varying definitions of dreaming from study to study, they are also consistent with the suggestion that dream formation is influenced by the natural variation of a 90-minute ultradian oscillator.

Clear within-stage sinusoidal variations of such qualitative measures are more difficult to demonstrate. Dream reports from "long" REM sleep episodes (9 minutes or more) are, relative to those from "short" episodes (1 minute or less), more active, distorted, dramatic, emotional, anxious, unpleasant, and vivid and contain more different scenes, more scenes with clear visualization, and more violence and hostility.[16] Similar results were obtained from a small sample (N = 4) of male students each awakened 12 times—twice each from REM 2 and REM 4 for each of six REM onset time delays: 0.5, 2.5, 5.0, 10, 20, and 30 minutes. Of 12 qualities rated, *emotion*, *anxiety*, *pleasantness*, and *clarity* all showed linear increases over time; *emotion*, *anxiety*, and *pleasantness* showed additional trends suggesting ultradian modulation with peaks at 10 and 30 minutes.[29-31]

For NREM sleep, two studies suggest an ultradian oscillation opposite to that in REM sleep. In one study,[32] dreamlike fantasy scale scores were lower (P < .10) for reports from 20-minute NREM (stage 4) episodes than they were for 5-minute NREM episodes matched within subjects and for time of night. In a second study,[10] NREM (stage 2) reports obtained from 12-minute episodes after the end of REM sleep episodes were rated as less dreamlike than were the NREM reports obtained 5 minutes after REM sleep episodes (P < .001).

Additional studies suggest that the types of memory associations that subjects produce as likely sources of their dreams oscillate with ultradian frequency. These are primarily biographical episodes (episodic memories) for NREM dream content, and a mixture of episodic and semantic memories for REM dream content.[33-35] The predominance of episodic sources for NREM dreams is independent of time of night and of corrections for report length.[33,35-38]

In contrast to much of the preceding, variables such as plausibility and sensibleness do not vary with time-in-stage.[39,40] A more exact determination of which qualitative

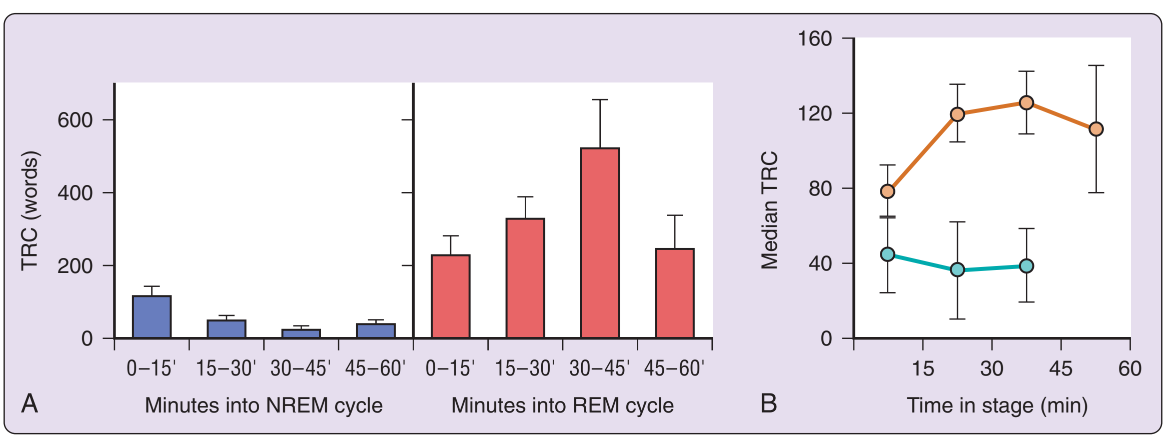

Figure 49-2 Dream report length following awakenings from NREM and REM sleep periods of different durations in two studies. **A,** Mean (±SEM) report length as a function of elapsed time in stage for 88 REM and 61 NREM reports. TRC, total recall count. (From Hobson JA, Pace-Schott E, Stickgold R. Dreaming and the brain: towards a cognitive neuroscience of conscious states. Behav Brain Sci 2000;23:793-842.); **B,** Median (±SEM) report length as a function of elapsed time in stage for 264 REM (red line) and 247 NREM (blue line) home reports (N = 16 subjects; From Stickgold R, Malia A, Fosse R, et al. Brain-mind states: I. Longitudinal field study of sleep/wake factors influencing mentation report length. Sleep 2001;24:171-179.).

dream features oscillate and which do not may provide clues as to the functional dynamics of dream imagery.

In sum, most results from quantitative and qualitative assessments of REM and NREM dream reports support the assumption that dream production is influenced by processes with ultradian rhythmicity. The differing prevalence, length, and qualities of REM and NREM dream reports likely reflect the output of one or more imagery generation processes that are sampled at varying points along their rising and descending slopes.

Oscillatory transitions between *and* within REM and NREM dreaming are both clearly paralleled by regular physiological oscillations, that is, by ultradian-determined variations in REM sleep propensity. Within-stage changes include variations in EEG power, and autonomic and hormonal measures. The clearest variations occur in stage 2 sleep: autonomic activity increases for stage 2 sleep that precedes REM sleep and decreases for stage 2 sleep that precedes SWS.[41] Similarly, fast EEG events such as arousals and stage 2 cyclic alternating pattern A2 and A3 phases often begin well before REM sleep.[42] Even more basic regulatory systems, like pontine REM-on neurons, demonstrate a graduated oscillation that begins well before EEG-defined REM sleep onset.[43] Such variations led to the speculation[41] that stage 2 sleep is fundamental to the ultradian oscillatory process of sleep deepening and lightening. I have linked such changes to the gradual and imperceptible onset and offset of REM sleep processes ("covert REM processes"[12,14]), but they may equally well be considered ultradian variations in REM sleep propensity that reflect ultradian oscillations in the presence and intensity of dream imagery.

CIRCADIAN AND SLEEP-DEPENDENT FACTORS

Purely circadian features of dream production are difficult to ascertain because their measurement is usually limited to the nocturnal portion of the sleep–wake cycle and because across-the-night changes that are identified could be due to sleep-dependent processes, circadian influences, or a combination of the two. How might sleep-dependent and circadian influences on dreaming be distinguished? As suggested in the previous section, a useful heuristic is to use the close ultradian coupling of dreaming and REM propensity to evaluate across-the-night changes in dreaming. Using a forced desynchrony protocol, sleep-dependent and circadian-driven patterns of REM sleep propensity (REM%) have been isolated (Fig. 49-3).[44] Figure 49-3 (panel A) shows that circadian-driven fluctuations in REM% are characterized by abrupt "switch-like"[45] transitions, that is, rapid increases in the middle of the night, whereas sleep-dependent changes (panel B) are gradual and linear in nature.

Applying these REM propensity patterns to dreaming, the following sections examine whether across-the-night changes in dreaming may be identified that are characterized by circadian (abrupt, switchlike) and sleep-dependent (gradual, linear) oscillations. Some changes in dream length, content, organization, and memory sources suggest circadian-style changes whereas others suggest sleep-dependent changes. In the case of circadian changes,

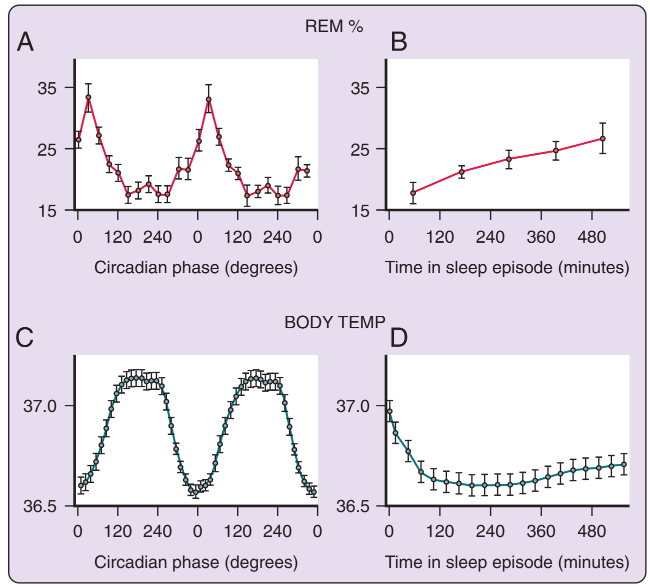

Figure 49-3 Using a forced desynchrony protocol, Dijk and Czeisler[44] showed that the sleep-dependent increase in REM propensity **(B)** parallels a gradual sleep-dependent increase in core body temperature **(D)** and is distinct from a circadian oscillation in REM propensity (**A,** double-plotted). The latter tends to vary inversely with body temperature, reaching its acrophase at about 8 AM, roughly 6 hours before onset of the core body temperature plateau (**C,** double-plotted).

marked differences are noted between reports from the first third of the night and all later sample points (see reviews in Nielsen 2004[1] and Nielsen 2005[2]).

Dream Recall and Report Length Changes Across the Night

Some studies reveal gradual across-the-night changes that resemble sleep-dependent effects. There is a lengthening of young adults' dream reports sampled from early (0 to 2.5 hours) to middle (2.5 to 5 hours) to late (5 to 7.5 hours) night when awakenings are conducted at a constant 4.8 to 5 minutes into REM sleep.[23,46] However, for older subjects the increase in length occurs only between middle- and late-night samples. Similarly, when mentation is sampled from the first four REM periods (awakenings all 9 minutes into each stage), a gradual increase across the night is observed for one story structure measure, the number of episodes per story ($P < .001$; order of means: REM 1 < REM 2 < REM 3 = REM 4) but not another, the number of statements in the event structure ($P < .001$; order of means: REM 1 < REM 2 = REM 3 = REM 4).[47]

Other findings more consistently suggest circadian switchlike changes similar to those for REM propensity and core body temperature (CBT). Our assessment of 40 subjects (135 reports)[48] found that both probability of recall and mean word count were lower for REM 1 than for REM 2 through REM 5 with no difference among the latter (Fig. 49-4, A panel). Because REM awakenings were made progressively later into each REM period (5 minutes into REM 1, 10 minutes into REM 2, 15 minutes into

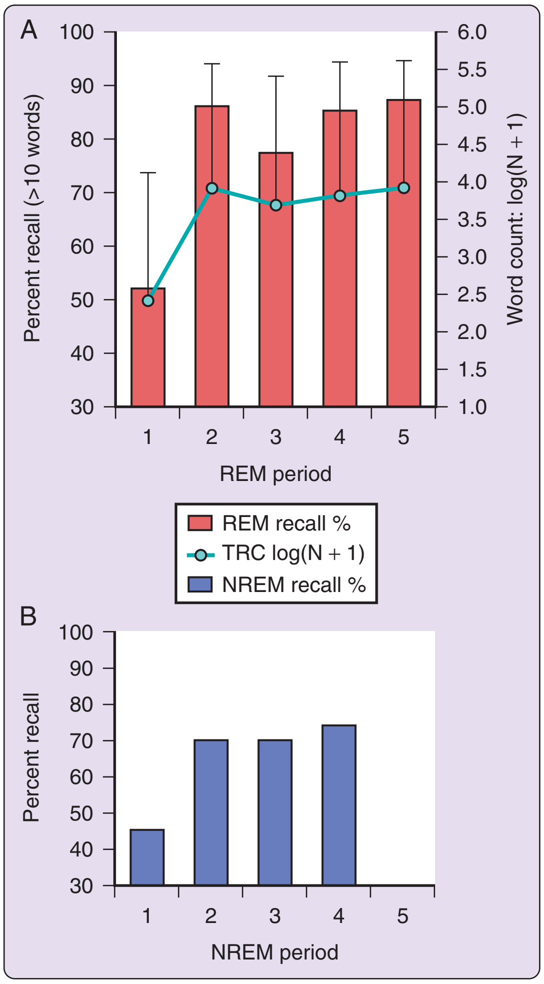

Figure 49-4 Percent recall and mean total recall count (TRC) for dream reports collected across the night from REM sleep (**A**), and NREM sleep (**B**). Exponential (switchlike) increases from first to second sleep cycles similar to those for circadian rhythms of REM propensity and core body temperature appear in both graphs. Values for NREM period 5 not available. (**A,** From Nielsen TA, Germain A, Zadra AL, et al. Physiological correlates of dream recall vary across REM periods: eye movement density vs heart rate. Sleep Res 1997;26:249. **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.)

REM 3, 20 minutes into REM 4 and REM 5); however, these findings may be confounded by an ultradian oscillation.

Other studies reporting length differences for REM dreams sampled early and late in the night are limited to only two sample points per night, and no clear inference about temporal morphology can be made. For example, REM 2 reports are half the length of REM 4 reports, whether awakenings occur 10 minutes (P = .001) or 5 minutes into REM sleep (P = .07).[13] Similarly, late night REM reports have higher word information counts than do early night REM reports (P < .001).[18,22]

Across-the-night changes for NREM dreaming parallel those for REM sleep, some displaying changes that are gradual, others abrupt. In a study described earlier[23,46] in which dreams were evaluated for early, middle, and late stage 2 awakenings, report length increased linearly across the three times for young subjects, but it was uniformly high for early and middle samples then dropped sharply in the late sample for older subjects. In contrast, awakenings from four different NREM periods per night revealed an abrupt increase in awakenings producing content from a low for NREM 1 (45%) to a plateau for NREM 2 (70%), NREM 3 (70%), and NREM 4 (74%; see Fig. 49-4, panel B).[49]

The ingenious application of an ultrashort sleep–wake protocol isolated a clear circadian oscillation of dreaming for NREM sleep.[50] Subjects were entrained to a 20-minute nap–40-minute wake schedule over 78 hours while dream content and salivary melatonin were sampled after every awakening (Fig. 49-5A). Subjects scored dream content in response to the question *How much did you dream? 0: none, 1: little, 2: a moderate amount, 3: a lot*. Dreaming scores for awakenings from naps containing no REM sleep (NREM naps) varied sinusoidally over the 24-hour cycle with an acrophase at 8:00 AM (see Fig. 49-5, panel B, bottom). Dreaming scores for naps containing REM sleep (REM naps) increased and decreased rather abruptly at 06:00 and 16:00 respectively (see Fig. 49-5, panel B, middle). A remarkable finding for the NREM naps was that dreaming scores paralleled the curve for REM (but not NREM) sleep propensity (Fig. 49-5, panel B, top), correlating positively at r = 0.87 (P < .0001). Why NREM dreaming would possess a sinusoidal morphology and REM dreaming a switchlike one is not clear. One possibility is that ultradian and circadian oscillations interact such that more abrupt circadian changes are enabled in REM but not NREM sleep. Another methodological concern is that the dreaming measure is not equally sensitive for the two states; the elevated plateau for REM dreaming scores may reflect a ceiling effect for the relatively crude 4-point scale used. Nonetheless, the high degree of synchrony observed between NREM dreaming and REM sleep time (r = 0.87) is consistent with the possibility that dreaming during REM and NREM sleep are influenced by the same underlying circadian oscillator.

Qualities of Dream Reports Change across the Night

Studies of across-the-night changes in dream qualities for the most part suggest that dreaming becomes more abruptly realistic and engaging in late relative to early sleep cycles, with dreams sampled in the first or second sleep cycles differing markedly from those in subsequent cycles. However, these qualitative changes are typically confounded by differences in report length, so the same earlier caveats about length for ultradian rhythms also apply.

In the case of REM sleep, several studies converge in demonstrating abrupt early night changes consistent with a switchlike circadian influence. First, one study of 73 dreams found that REM 1 reports differed from REM 2 and REM 3 reports on several scales: REM 2 and 3 dreams had more characters, more aggression and misfortune elements, more buildings, and fewer terrain settings.[51] However, for some scales, REM 1 and REM 2 reports

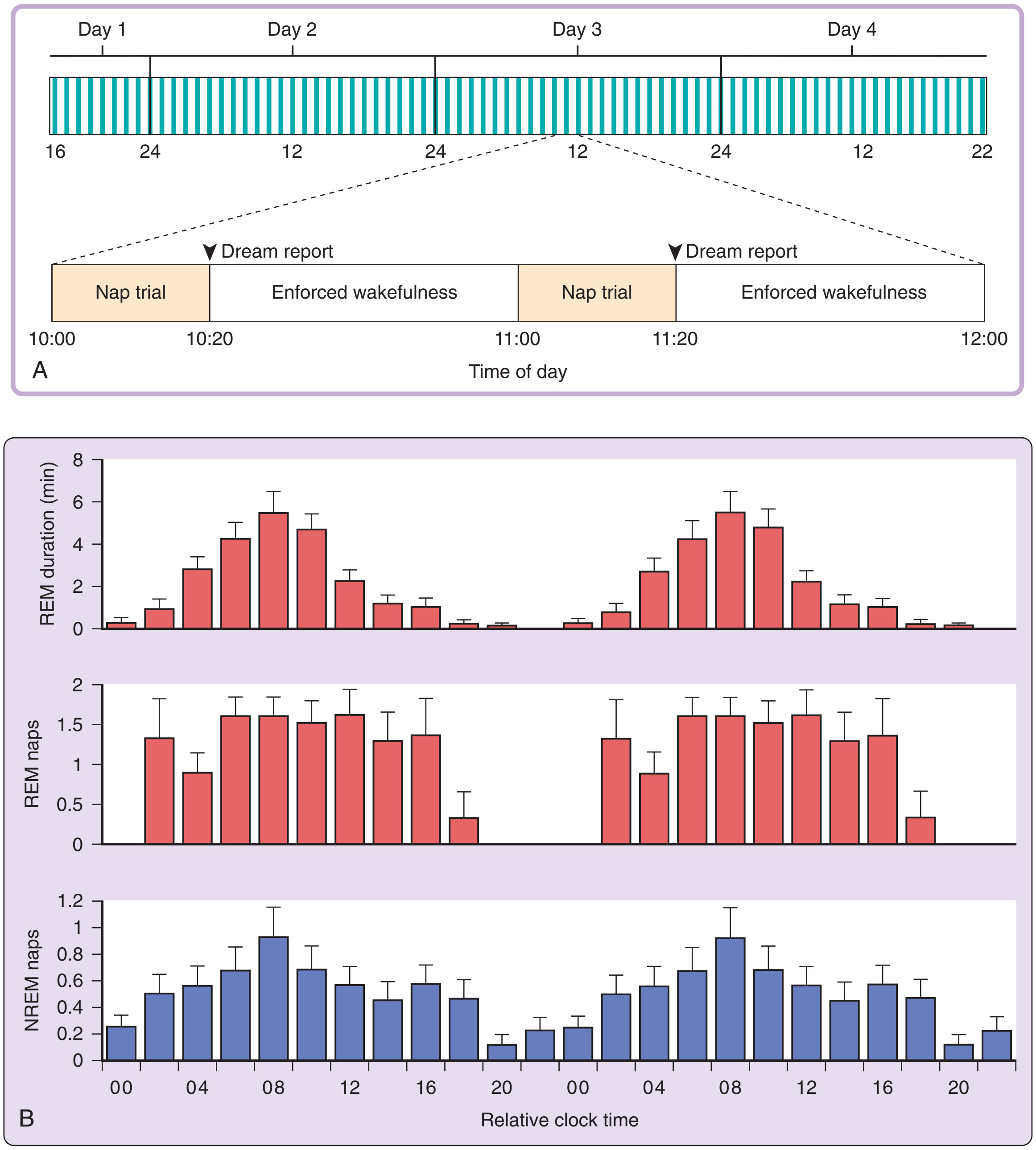

Figure 49-5 **A,** Experimental schedule for ultrashort sleep–wake study.[50] At the end of each 20-minute nap, a dream report was obtained and rated. **B,** Double-plotted REM time and nap dreaming scores for subjects on the ultrashort sleep–wake protocol. Three-day means are displayed by 2-hour blocks time-locked to the onset of melatonin release (22:00). Dream scores for naps yielding REM reports *(middle panel)* show some circadian variation with switchlike transitions and a plateau spanning 06:00 to 16:00. Dreaming scores for NREM reports *(bottom panel)* clearly conform to a sinusoidal circadian oscillation with an acrophase at 08:00. The NREM dreaming score acrophase coincides with the acrophase of REM propensity (*top panel*, $r = 0.87$, $P < .0001$) but not of NREM propensity (not shown). A further, circasemidian component is suggested by the secondary NREM peak at 16:00. (Adapted from Suzuki H, Uchiyama M, Tagaya H, et al. Dreaming during non-rapid eye movement sleep in the absence of prior rapid eye movement sleep. Sleep 2004;27:1486-1490.)

both differed from REM 3 reports: REM 3 dreams had more sexual acts, more food elements and fewer room settings. In a second study, subject ratings on an array of variables differentiated REM 1 reports from REM 2 and REM 3 reports.[16,52] Third, dreams from young adults changed more markedly from REM 1 to REM 2 (increases in 15 of 41 variables) than from REM 2 to REM 3 (6 of 41 variables) and REM 3 to REM 4 (7 of 41 variables).[53] Finally, dreams increased in dreamlike quality from REM 1 and REM 2 to all later REM periods; this included 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* (from 69.2% to 46.1%).[54] Positive correlations between time of night of REM awakenings and dream vividness ($P = .01$) and emotionality ($P = .05$) ratings have been reported,[40] but such correlations would be expected for either a circadian or a sleep-dependent influence.

It is noteworthy that time-in-stage (ultradian) confounds exist in many of the preceding studies. Two procedures[16,54] progressively increased time-in-stage before awakening for successive REM periods (5 minutes, 10 minutes, 20 minutes, etc.). A third study[40] used short (5 minute) REM 1 awakenings whereas all later awakenings were either short or long (5 vs. 12 minutes). A fourth study[53] targeted the end of REM episodes for awakenings, but early REM episodes are usually shorter than later ones.

Altogether, however, the preceding results are surprisingly consistent with findings that are free of similar confounds. When ultradian factors were controlled by limiting awakenings to 4.8 to 5.0 minutes into each REM period,[23] the number of visual nouns, action words, modifiers, and spatial relations in reports increased abruptly from the first to the second third of the night but not from the second to the third third of the night. Similarly, in a series of five studies[55] that minimized ultradian confounds by limiting awakenings to 5 to 10 minutes into REM sleep, within-night increases in left hemisphere, but not right hemisphere, processes in reports were observed.

Importantly, two studies[20,22] that failed to demonstrate differences between early and late night REM dreams only compared REM 2 and REM 3 dreams. As for ultradian sampling protocols that separate samples by only 5 minutes along a 90-minute curve, REM 2 and REM 3 may be too close on the 24-hour circadian curve to reveal consistent phase differences—especially if the most abrupt transition tends to take place near REM 1.

In the case of NREM dreaming, across-the-night increases in dream quality have also been observed in studies that controlled ultradian confounds. Findings are mixed as to whether the changes are gradual or abrupt. First, dreamlike fantasy scale scores of dream reports are low in NREM 1 but then are abruptly higher in NREM 2, NREM 3, and NREM 4 (see Fig. 49-4, panel B).[49] Second, NREM visual imagery scores increase linearly across the early, middle, and late thirds of the night.[23] Two additional studies of only two samples per night both found increases from early-to-late night.[10,20]

To summarize, numerous studies demonstrate increases in dream recall or intensity across the night, although the time course of these changes is variable. Abrupt changes occur predominantly in REM sleep and are associated almost exclusively with REM 1-to-REM 2 or REM 2-to-REM 3 transitions. Although it is possible that these subtly different transition points reflect different, slightly out of phase circadian processes, for example, left hemisphere and right hemisphere influences,[55] it also may be that they arise from methodologic differences. Specifically, variations in the timing of lights-out relative to circadian phase may advance or delay the point at which a transition takes place. It might be that bedtimes are later than usual in most laboratory studies due to the complications of polysomnography setup and calibration; thus, most studies report earlier-than-normal transitions (i.e., REM 1 to REM 2) in dreaming. This is an easily testable possibility. As described next, some evidence suggests that delaying bedtime can, in fact, alter the circadian phase relationships of successive REM or NREM periods.

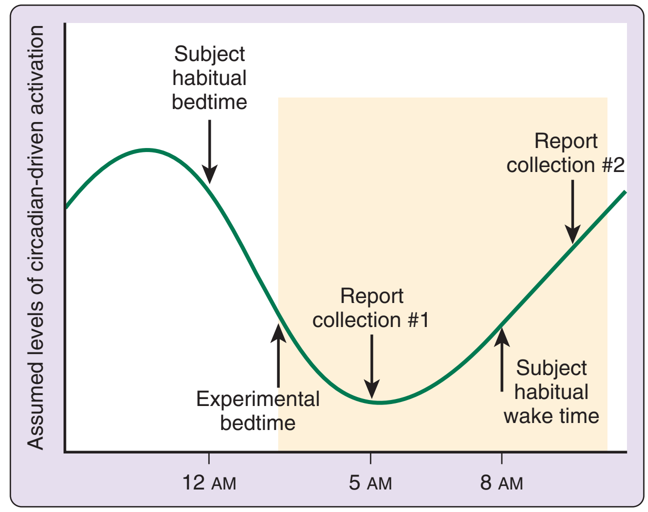

Figure 49-6 Forced desynchrony protocol applied to dream collection. Hypothetical subject has a typical bed time of 12:00 AM and typical wake time of 8:00 AM. Experimental bed time is delayed by 3 hours and sleeping in is allowed. If the circadian influence on dreaming parallels that for core body temperature, then awakenings for report collection are shifted so as to occur at the nadir of the curve for report collection #1 (5:00 AM) and along its rising phase for report collection #2 (~10:00 AM). As predicted, dream length and vividness were increased for reports on the rising phase of the curve. (From Wamsley EJ, Hirota Y, Tucker MA, et al. Circadian and ultradian influences on dreaming: a dual rhythm model. Brain Res Bull 2007;71: 347-354.)

A forced desynchrony protocol has been used to clarify the separate roles of ultradian and circadian influences.[18,22] (See Fig. 49-6 for conceptual basis of protocol.) The hypothesized circadian-driven influence on dreaming reaches its nadir near 5:00 AM, its rising phase at habitual wake up time (8:00 AM) and its acrophase around 12:00 PM. This rhythm is assumed to be in close phase relationship with core body temperature (CBT), whose nadir typically occurs in the early evening and whose morning rising phase correlates with decreased REM-related alpha power,[56] NREM spindle density,[57] and waking performance.[58] On experimental nights, subjects in this protocol go to bed 3 hours later than their typical bedtime and are allowed to sleep late in the morning. This forces early night NREM dreaming to occur closer to the circadian nadir and late night NREM dreaming to occur higher on its rising slope.

The first use of this protocol[22] found large differences between REM and NREM dream reports on total word count, visual and verbal imagery, and bizarreness regardless of where along the hypothesized circadian curve the reports were collected. However, a circadian effect was also observed that was independent of the ultradian effect: Late night dream reports of both types were longer and more visually intense than early night dream reports. For visual imagery, the circadian effect size (.23, or small) was about 30% of the ultradian effect size (.70, or large). The authors concluded that ultradian and circadian sources of cortical and subcortical activation are independent but additive in their effects on dreaming.

The second study tested a more nuanced "dual rhythm" model of chronobiological interactions.[18] This model stipulates that some features of dream formation are, as in the previous study, due to a summation of ultradian and circadian variations in general cortical activation whereas other features are due to regional activation patterns unique to the NREM–REM ultradian rhythm. Consistent with this model, measures of dream length, dreamlike quality, dream speech, and content bizarreness proved to be additive functions of ultradian and circadian factors, that is, they were more elevated for REM than for NREM reports and for late than for early reports—without interactions between the effects. However, other features such as visual brightness, visual clarity, and emotion intensity varied only as a function of the NREM–REM factor, that is, they were more elevated for REM than for NREM reports.

A third study in this series was designed to extend the dual rhythm model, but it mainly contradicted the expected results.[18] NREM dreams were collected from subjects who took naps around 12:30 PM, that is, near the acrophase of the hypothesized circadian process and higher on the curve than any of the sample times in the previous study (Fig. 49-7A). NREM nap dreams were compared with dreams collected from early and late NREM periods in the previous study. The predicted elevations in length and vividness of nap dreams relative to late morning NREM dreams were not observed. Rather, nap dreams resembled dreams from early night NREM awakenings, that is, near the nadir of the hypothesized curve (see Fig. 49-7B).[4]

The authors conclude that a circadian influence resembling that of CBT is inadequate to explain the findings, and they propose several circadian processes with an earlier acrophase than the CBT rhythm, for example, 8:00 AM, that could account for the unexpected diminution of NREM dream vividness. They reject REM sleep propensity—the most obvious candidate—in favor of other circadian processes, such as cortisol, which follows a time course similar to that of REM propensity[59] and influences memory encoding and retrieval.[60,61] Cortisol has been put forward as a major influence on dreaming not only because its across-the-night increase parallels that of dream prevalence and intensity, but also because it is implicated in memory consolidation functions.[5] Specifically, evidence that glucocorticoid administration interferes with episodic memory led to the proposition[5] that rising levels of nocturnal endogenous cortisol similarly interfere with episodic memory consolidation during sleep. By virtue of the same mechanism, cortisol produces dreaming that lacks coherence, context, and episodic detail. Although this model accounts for the finding that episodic memory sources of dreaming are less numerous late, rather than early, in the night, it is inconsistent with other findings. For example, episodic memory performance is typically *better* in the morning than it is at later times,[62-65] yet endogenous cortisol reaches its acrophase around 8:00 AM when the *worst* performance levels would be expected. Further research is needed to examine whether endogenous and exogenous cortisol, in fact, have similar effects on memory processes and dreaming as assumed.

A more parsimonious explanation for the finding of unexpectedly low dreaming scores for afternoon naps[4] is that dream formation is tied to circadian oscillations of REM propensity. REM propensity reaches its acrophase

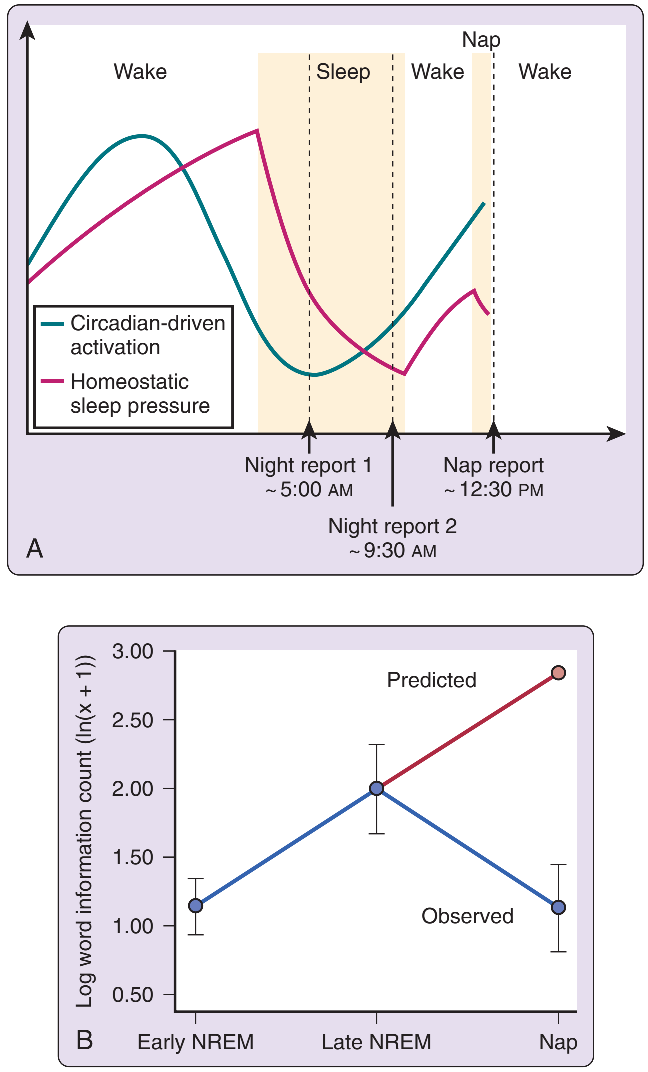

Figure 49-7 **A,** Timing of three NREM report collection conditions in relation to presumed time courses of circadian-driven activation and homeostatic sleep pressure. Afternoon nap reports (~12:30 PM) were collected when circadian-driven activation was presumably much higher than during night report 1 (~5:00 AM) or night report 2 (~9:30 AM). However, homeostatic sleep pressure during naps was presumably also at least equal to that during night report 1. **B,** Word information count of NREM dream reports collected after awakenings from the three conditions. The predicted result, based on the notion that NREM dreaming is influenced by a circadian process with an acrophase paralleling that of core body temperature, was not observed. NREM dream reports were shorter, and dream imagery less vivid and bizarre, than were dreams reported at night report 2. The finding suggests rather that nap dreams were influenced by the descending phase of a circadian factor with an earlier acrophase (~8:00 AM) than that of core body temperature. Both REM sleep propensity and cortisol have such morphologies and have been discussed as possible causal factors. (Adapted from Wamsley EJ, Antrobus JS. Homeostatic and circadian influences on dreaming: NREM mentation during a short daytime nap. Int J Dream Res 2008;1:27-32.)

at around 8:00 AM, so its influence would be waning in parallel with the decrease in NREM dream intensity during afternoon naps. Evidence reviewed earlier[50] indicates that NREM dreaming is remarkably strongly correlated with REM%, a primary marker of REM propensity.[66] Furthermore, studies have shown that increases in REM propensity by REM sleep deprivation increases the dream-like quality of both nighttime REM dreams and sleep onset NREM dreams the following evening.[67]

SUMMARY

Quantitative and qualitative studies reveal robust variations both within and between REM and NREM dreams that suggest ultradian influences, whereas robust across-the-night changes in REM and NREM dreams suggest circadian and sleep-dependent influences. Most of the latter studies, especially those concerning REM sleep, suggest that across-the-night changes are abrupt and occur early—as might be expected by analogy to the rising phase of the circadian rhythm of REM propensity at this time. However, gradual linear increases analogous to sleep-dependent increases in REM% have also been observed, particularly for NREM dreams. At present, only one study has clearly demonstrated that circadian modulation of NREM dreaming and, to a lesser extent REM dreaming, is independent of sleep-dependent modulation.

The literature is thus consistent with the claim that the quantity and qualities of dreaming are influenced by ultradian, circadian, and sleep-dependent factors. However, much more work is required to describe the nature of these factors and their interactions for a range of normal and abnormal populations. Several findings suggest that this work may be profitably guided by concurrently examining REM sleep propensity, which is modulated by the same three sets of factors. Particularly intriguing is evidence that NREM dreaming may be modulated by the circadian oscillation of REM sleep propensity. If REM propensity, in fact, determines variations in dream frequency and intensity in both REM and NREM sleep, then research would clearly benefit from developing better markers of REM propensity. Reduced muscle tone[68] and EEG alpha (8.25 to 11.0 Hz) power[69] have both been partially validated as possible markers. REM-related alpha power reductions may even be detectible during the waking state.[70]

Attention should also be given to the selection of dream quantity and quality measures as these vary considerably in sensitivity with different types of dream mentation. Indeed, different measures may be needed to accurately capture the oscillations of dream content in different sleep stages across the night.

❖ Clinical Pearl

Atypical recall of vivid dreams may be the result of phase desynchrony between ultradian and circadian influences on dreaming.

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