Dreaming During Non-rapid Eye Movement Sleep in the Absence of Prior Rapid Eye Movement Sleep

Hiroyuki Suzuki, PhD[1]; Makoto Uchiyama, MD, PhD[1]; Hirokuni Tagaya, MD, PhD,[1]; Akiko Ozaki, RN, RPSGT, PhD[1]; Kenichi Kuriyama, MD, PhD,[1]; Sayaka Aritake, RMT, RPSGT, MS,[1,2]; Kayo Shibui, MD, PhD,[1]; Xin Tan, MD, PhD,[1]; Yuichi Kamei, MD, PhD,[3]; Ryuichi Kuga, MA[4]

[1]Department of Psychophysiology, National Institute of Mental Health, National Center of Neurology and Psychiatry, Kohnodai; [2]Department of Life Sciences and Bio-informatics, Graduate School of Allied Health Sciences, Tokyo Medical and Dental University; [3]Department of Psychiatry, Kohnodai Hospital, National Center of Neurology and Psychiatry; [4]College of Humanities and Sciences, Nihon University, Japan

Study Objectives: There is a long-standing controversy surrounding the existence of dream experiences during non-rapid eye movement (NREM) sleep. Previous studies have not answered the question whether this "NREM dream" originates from the NREM sleep mechanism because the subject might simply be recalling experiences from the preceding rapid eye movement (REM) sleep.

Methods: We scheduled 11 healthy men to repeat 20-minute nap trials separated by 40-minute periods of enforced wakefulness across a period of 3 days. At the end of the nap trial, each participant answered questions regarding the formal aspects of his dream experiences during the nap trial, using the structured interviews.

Results: We obtained a total of 172 dream reports after naps containing REM sleep (REM naps) and 563 after naps consisting of only NREM sleep (NREM naps). Dream reports from NREM naps were less remarkable in quantity, vividness, and emotion than those from REM naps and were obtained more frequently during the morning hours when the occurrences of REM sleep were highest.

Conclusions: These results suggest that the polysomnographic manifestations of REM sleep are not required for dream experiences but that the mechanisms driving REM sleep alter experiences during NREM sleep in the morning. A subcortical activation similar to REM sleep may occur in human NREM sleep during the morning when REM sleep is most likely to occur, resulting in dream experiences during NREM sleep.

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INTRODUCTION

IN 1953, ASERINSKY AND KLEITMAN DISCOVERED HUMAN RAPID EYE MOVEMENT (REM) SLEEP AND DOCUMENTED THAT DREAM REPORTS WERE OBTAINED MOST FREQUENTLY WHEN SUBJECTS WERE AWAKENED FROM REM SLEEP.[1] Thereafter, many scientists conducted studies on dream and REM sleep and found a robust association between electrophysiologic phenomena and subjective experiences during REM sleep.[2–7] This well-documented association has led to the conclusion that dream experiences are psychological manifestations generated by the neural system controlling REM sleep,[8,9] yielding many innovative findings on the mind-body relationship. In contrast, researchers have also recorded dream reports from subjects upon awakening from non-REM (NREM) sleep; though the association has been shown to be weaker in comparison with that of dream reports upon awakening from REM sleep.[10–15]

Many human studies, together with some animal studies on REM sleep, have proposed a neural system responsible for human dream experiences. In the early pioneering studies on human REM sleep, researchers focused on the relationship between eye movements and visual experiences during REM sleep and postulated that REM and concomitant activation of the visual system of the brain account for human dream experiences.[2,4] Recent neurobiologic findings obtained from animal studies have led to the current understanding that phasic signals arising from the pons and impinging upon the cortex during REM sleep might give rise to dream experiences.[8,9]

Some studies have focused on dream experiences during NREM sleep; however, no documented findings have yet afforded an understanding of the mechanisms of dreaming during NREM sleep. Rather, researchers have generally made the assumption that dream reports upon awakening from NREM sleep may be a consequence of recalling dream experiences from the preceding REM sleep rather than indicate the existence of NREM-specific dream experiences.[7,16-17] However, only a few studies have aimed to determine whether dream reports after NREM sleep are derived from residuals of memory from the preceding REM sleep or actually arise from another type of dream experience during NREM sleep.

This may be due to the methodologic limitations of the conventional intermittent awakening method, in which subjects under all-night polysomnography are awakened several times upon reaching the target sleep stage and asked about their dream experiences. However, investigation of NREM dreaming may require a method in which subjects enter a sleep period only consisting of NREM sleep separated by a sufficient period of wakefulness to exclude the influence of the preceding REM sleep. These prerequisites, however, have not been satisfied in most previous studies except for a study that examined dream experiences during a short and discrete sleep period.[18]

In the study reported here, we used a repeated-nap trial, in which 20-minute sleep periods separated by 40 minutes of enforced wakefulness were repeated for 78 hours to allow the

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This is not an industry supported study. Drs. Suzuki, Uchiyama, Tagaya, Ozaki, Kuriyama, Aritake, Shibui, Tan, Kamei, and Kuga have indicated no financial conflicts of interest.

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Address correspondence to: Makoto Uchiyama, MD, PhD, Department of Psychophysiology, National Institute of Mental Health, National Center of Neurology and Psychiatry, Kohnodai, Ichikawa, Chiba, 272-0827 Japan; Tel: 81 47 375 4756; Fax: 81 47 375 4771; E-mail: macoto@ncnp-k.go.jp

measurement of various REM-NREM parameters in association with reported dream experiences.

METHODS

Participants

Eleven healthy male volunteers aged 20 to 26 years (mean = 22.4, SD = 2.1) participated in the present study. They did not have any known sleep, physical, or psychiatric disorders or any history of using psychoactive drugs. The study protocol was approved by the Intramural Research Board of the National Center of Neurology and Psychiatry, and each participant gave his informed consent after the nature, purpose, and possible risks of the experiment had been explained in detail.

All the participants were instructed to abstain from alcohol, caffeine, and napping for a week prior to the laboratory experiment. They were asked to keep sleep logs for 2 weeks and to wear wrist activity recorders (Actiwatch-L; Mini-Mitter, Bend, Ore) for the second week. Consistent sleep-diary and activity data were obtained from all the participants.

Study Design

Each participant took part in a 4-day experimental laboratory session. The participants arrived at the laboratory at 11:00 AM and consumed a 700- to 800-kcal lunch at 12:00 PM on day 1. Electrodes for standard polysomnography were attached between 1:00 PM and 3:00 PM; electroencephalogram (C3–A2, C4–A1, O1–A2), electrooculogram (left and right), chin-surface electromyogram, and electrocardiogram electrodes were used. The light level was set at 200 lux from 11:00 AM to 4:00 PM.

The participants entered a repeated nap trial at 4:00 PM on day 1. This involved 20-minute nap trials every 60 minutes, with standard polysomnographic recordings performed as participants lay recumbent on a bed in a dark (< 0.1 lux) sound-attenuated room, and a 40-minute period of enforced wakefulness on a semi-upright sofa under conditions of dim light (< 8 lux). During the 40-minute periods, participants were kept awake and monitored closely by experimenters. At the end of the nap trial, each participant was awoken gently. While remaining in a recumbent position, each participant answered questions regarding the formal aspects of his dream experiences during the nap trial, using the structured interview form described below, and thereafter left the bed. This cycle was repeated 78 times until 10:00 PM on day 4 (Figure 1). In the repeated nap trial, saliva samples were taken every 60 minutes during the last 5 minutes of the 40-minute period using saliva collection tubes (Bühlmann Laboratories AG, Schönenbuch, Switzerland). During the repeated nap trial, the room temperature and humidity were controlled at 24.0°C ± 0.5°C and 60% ± 5%, respectively. Participants consumed a 150-kcal snack and 200 mL of water every 2 hours.

Measures

Polysomnographic Measures

Polysomnograms obtained during the nap trials were scored in epochs of 30 seconds according to standard criteria.[19] A nap trial that contained stage REM was defined as a *REM nap*, whereas a nap trial containing no stage REM but NREM stages was defined as a *NREM nap*. Nap trials not containing any sleep stages were excluded from further analyses. The summed duration of NREM sleep stages (stage 1, 2, 3, and 4) and stage REM in the nap trial were termed *NREM duration* and *REM duration,* respectively.

Saliva Melatonin

Saliva samples were immediately refrigerated at -30°C for later analysis of melatonin concentration. Saliva melatonin was measured with a highly specific direct double-antibody radioimmunoassay kit (Saliva Melatonin RIA kit, Bühlmann Laboratories AG).[20] The time point where the saliva melatonin level crossed 3.3 pg/mL was defined as the dim-light melatonin onset, as outlined by Campbell and Murphy.[21] Dim-light melatonin onset was used for determining relative clock time as described below.

Dream Report Questionnaire

A structured questionnaire was developed to investigate the formal aspects of dreaming, such as dream duration and quality. We did not ask the participants about detailed dream content at a given nap trial because this would have influenced dream reports at successive nap trials. The questionnaire contained the following questions:

Q1. "How much did you dream?" (0: none, 1: little, 2: a moderate amount, 3: a lot)

When the reply to Q1 was 0, Q2-4 were not asked. Otherwise, Q1 was followed by Q2-4.

Q2. "How vivid was the dream?" (0: not vivid at all, 1: rather vivid, 2: moderately vivid, 3: very vivid)

Q3. "How pleasant was the dream?" (0: not pleasant at all, 1: rather pleasant, 2: very pleasant)

Q4. "How unpleasant was the dream?" (0: not unpleasant at all, 1: rather unpleasant, 2: very unpleasant)

The participant's responses to Q1 were averaged separately for REM naps and NREM naps (dream duration). Likewise, the participant's mean scores for Q2, Q3, and Q4 (vividness, pleasantness, and unpleasantness) after REM and NREM naps were calculated. Participants were considered to have had a dream experience if their response to Q1 was 2 or 3. Data from 4 nap trials were eliminated because of difficulties with electroencephalogram recordings.

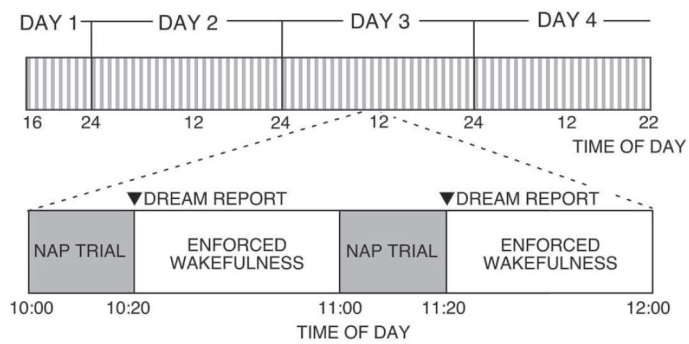

Figure 1—Experimental schedule. Participants followed a 60-minute sleep-wake cycle consisting of a 20-minute nap trial, followed by 40 minutes of enforced wakefulness. Standard polysomnographic recordings were made. This schedule was repeated for 78 hours from 4:00 PM on day 1 to 10:00 PM on day 4. At the end of each nap trial, a dream report was obtained using a structured interview.

Temporal Fluctuation

The data series obtained from the 78-hour experiment was time-locked to the dim-light melatonin onset, to which we designated a relative clock time of 10:00 PM. Thereby, we obtained standardized 72-hour data on all the participants. In this analysis, data obtained from only 9 participants were used, as melatonin measurements from 2 participants were not available because of lack of saliva samples.

Statistical Analyses

Paired *t* tests were performed to compare REM naps and NREM naps on measures of dream duration, vividness, pleasantness, and unpleasantness. For correlation analysis, we calculated Spearman correlation coefficients.

For analysis of temporal fluctuation, we used 72-hour data on REM duration, NREM duration, and dream duration. These were evaluated using 2-way repeated-measure analysis of variance (day and time of day) with a Huynh-Feldt epsilon correction. When a day effect was not observed, the 72-hour data was averaged into 2-hour bins in order to observe the 24-hour fluctuation of these measurements. For all the statistical analyses, the level of significance was set at $P < .05$. Statistical analyses were performed using StatView v5.0 (SAS Institute Inc., Cary, NC) and Super ANOVA (Abacus Concepts, Inc., Berkeley, CA).

RESULTS

Overview

Administering the structured questionnaire just after each 20-minute nap trial, we obtained a total of 854 dream reports from 11 participants. We excluded those reports obtained after nap trials without any sleep stages (n = 119); all the 30-second epochs were scored as stage wake. Finally, we had a total of 172 dream reports after REM naps and 563 after NREM naps.

Dream Reports from REM and NREM Naps

First, we compared the formal aspects of dream experiences between the REM naps and the NREM naps. Dream experiences were reported for 51.2% of the REM naps and 17.9% of the NREM naps. Dream experiences were more frequently found in the REM naps compared with the NREM naps (χ^2 (1) = 76.13, $P < .0001$). It was noted that dream experiences did occur during naps consisting of NREM sleep only. When dream experiences were averaged across participants, dream experiences were also more frequent in the REM naps than in the NREM naps (REM: 47.7%, NREM: 18.5%, $df = 10$, $t = -4.58$, $P = .0010$).

Table 1—Dream reports of NREM and REM naps

Dream report scores (range)	NREM NAP	REM NAP	*P* value
Dream duration (0-3)	0.47 ± 0.46	1.22 ± 0.76	.0003
Vividness (0-3)	0.46 ± 0.46	1.41 ± 0.93	.0003
Pleasantness (0-2)	0.41 ± 0.40	0.94 ± 0.47	.0057
Unpleasantness (0-2)	0.12 ± 0.22	0.41 ± 0.46	.0670

NREM refers to non-rapid eye movement; REM, rapid eye movement.

Subjective dream duration during the REM naps was significantly higher than that during the NREM naps ($df = 10$, $t = -5.41$, $P = .0003$) (Table 1). Dream experiences during the REM naps were more vivid and more pleasant than those during the NREM naps ($df = 10$, $t = -3.73$, $P = .0047$; and $df = 8$, $t = -3.74$, $P = .0057$, respectively). The level of dream unpleasantness during the REM naps was higher than that during the NREM naps, but this difference was not significant ($df = 8$, $t = -2.118$, $P = .067$). Dream experiences during NREM sleep seemed to be less

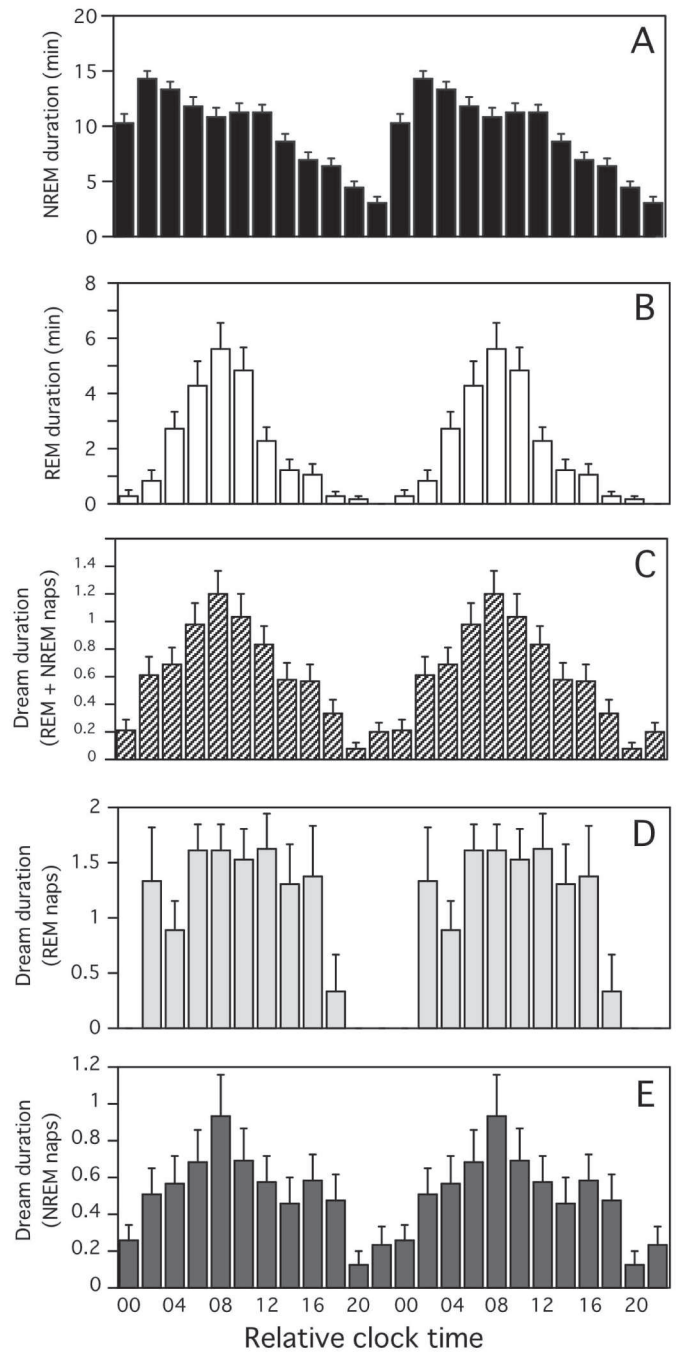

Figure 2—Temporal fluctuations in sleep duration and dream duration. All data are depicted in double-plot style and time-locked to the onset of melatonin release at a relative clock time of 10:00 PM. The peak of rapid eye movement (REM) duration (B) follows that of non-REM (NREM) duration (A) and coincides with that of the dream duration of REM + NREM naps (C). The dream duration of REM naps (D) shows no clear peak, whereas that of NREM naps (E) has a clear peak that coincides with the peak of REM duration but not with NREM duration.

remarkable in quantity, vividness, and emotion than those during REM sleep.

Temporal Fluctuations

Since it has long been recognized that REM sleep occurrence shows temporal characteristics across the day,[22] we then investigated the temporal fluctuations in NREM and REM duration and dream quantities across 2 days (72 hours). Two-way repeated analyses of variance (day and time of day) revealed a significant time-of-day effect on these 3 measures (NREM: $F = 8.64$, $P < .0001$, REM: $F = 3.92$, $P = .0055$, dream duration: $F = 2.75$, $P = .025$) but no day effect nor interaction, such that the 24-hour fluctuation curves did not differ in shape across the 3 days. We then averaged the data across the 72-hour period to obtain 24-hour fluctuation curves.

NREM duration increased sharply from 12:00 AM to 2:00 AM, where a clear peak on the fluctuation curve was evident (Figure 2, A). Thereafter, NREM duration showed a gradual decrease towards the late evening hours with a small peak at 12:00 PM. NREM duration was shortest during the late evening hours (10:00 PM). In contrast, REM duration gradually increased in the midnight and morning hours, showing a maximum at 8:00 AM and a gradual decrease thereafter (Figure 2, B). Dream duration of REM plus NREM naps (the mean value averaged across all REM and NREM reports) increased in the midnight and morning hours and reached a peak at 8:00 AM, followed by a gradual decrease towards the late evening hours (Figure 2, C). The peak in dream duration of REM plus NREM naps coincided with that of REM duration but not with that of NREM duration, which appeared 6 hours earlier. The fluctuation curve of dream duration of REM plus NREM naps appeared similar to that of REM duration in shape, but its distribution was wider.

Next, we constructed figures of the temporal fluctuations in dream duration with respect to the REM and NREM naps, separately. The dream duration of REM naps was high during the period 6:00 AM to 12:00 PM and showed no clear peak (Figure 2, D). In contrast, there was a clear peak at 8:00 AM with the dream duration of NREM naps (Figure 2, E). Surprisingly, this peak coincided with the peak in REM duration but not with that of NREM duration. Correlation analysis between REM duration and the dream duration of NREM naps revealed that REM duration explained a remarkable 75% of the temporal fluctuation of the dream duration of NREM naps ($r = .87$, $n = 11$, $P < .0001$, $r^2 = .75$).

DISCUSSION

In the present study, we conducted 20-minute nap trials every hour for 78 hours (repeated nap trial), calculated sleep indexes during the nap trials, and obtained dream reports at the end of each nap trial. Using the repeated nap trial, we compared the quantity and quality of dream experiences between REM sleep and NREM sleep and investigated the temporal fluctuations in dream duration.

Use of the repeated nap trial allowed us to determine that dreams reported at the end of a given nap trial were experienced exclusively during the period of that nap trial. In contrast, use of the conventional study methods—in which investigators typically monitor an all-night polysomnogram and wake subjects at targeted sleep stages—fail to determine when reported dreams were actually experienced. We found that the quantity, vividness, and emotional changes in dreams occurring during the REM naps were more marked than those experienced during the NREM naps and that dream experiences also occurred more frequently in REM naps than in NREM naps, the figures being comparable to those of previous studies conducted using the conventional paradigm.[17]

It was noted that 17.9% of the NREM naps were associated with dream experiences, suggesting that participants did experience dreams during nap trials consisting of NREM sleep only. Researchers conducting studies using the conventional paradigm have postulated that such NREM dreams do occur. However, no study has yet confirmed in which sleep stage dreams reported by subjects actually occurred, except for a study by Takeuchi et al,[18] in which experiences during short naps (about 10 minutes) were examined. Their results—that experiences during NREM sleep were strongly influenced by the duration of wakefulness contaminated in the nap—may suggest that 10 minutes are not enough to assess experiences during NREM sleep accurately. The fact that human dream experiences can occur during a sleep period without REM was first properly confirmed systematically in the present study, due to the advantage of using a 20-minute repeated nap trial.

Temporal Fluctuations of Dreaming

Dream duration showed an apparent peak in the morning hours, coinciding with peaks in REM duration but not NREM duration. It seems that humans are most likely to experience dreams in certain morning hours of the day.

When a differential analysis was undertaken on dream duration in the REM naps and NREM naps, the NREM curve showed a clear peak in the morning hours, whereas no clear peak was observed in the curve representing the REM naps. The present finding that dream duration in the NREM naps fluctuated across the day in parallel with REM duration suggests that human dream experiences in NREM sleep are strongly influenced by the REM sleep-generating mechanism. Prior animal studies on REM sleep and pontogeniculooccipital activity may provide an explanation for this assumption. In a study by Callaway et al, pontogeniculooccipital activity, which is generated in the brain stem and characterizes animal REM sleep, was observed to also occur in NREM sleep preceding the REM sleep period, even when the cortical electroencephalogram displayed characteristics of NREM patterns such as slow waves.[23] Pontogeniculooccipital activity observed in animal REM sleep is considered to be the most robust factor activating the visual cortexes and generating dream experiences.[9] Similar activation of the visual cortexes may occur in human NREM sleep, especially during the morning hours when REM sleep is most likely to occur, resulting in dream experiences during NREM sleep.

There is a long-standing controversy surrounding the existence of dream experiences during NREM sleep. Some researchers have assumed that dreams recalled upon awakening from NREM sleep are a consequence of the mnemonic effects of prior REM sleep.[7,16] Others have postulated that NREM dreams are different from REM dreams, possibly because the loci of REM and NREM sleep generation are exclusively independent.[24-26] Our results appear to support both early suggestions that NREM dreaming

may be due to activation of REM-related processes during NREM-REM transition periods[16,27] and the more recent suggestion that REM sleep processes can operate covertly to produce NREM dreaming at any time.[17] The results obtained from the repeated nap trial reported here provide understandings of the relationship between dream experiences and NREM sleep. The remarkable correlation we observed between REM duration and NREM dream duration suggests that increases in REM sleep propensity may lead to increased dream production even during NREM sleep.

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