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A New Paradigm for Dream Research: Mentation Reports Following Spontaneous Arousal from REM and NREM Sleep Recorded in a Home Setting

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The "Nightcap," a relatively nonintrusive and "user-friendly" sleep monitoring system, was used by 11 subjects on 10 consecutive nights in their homes. Eighty-eight sleep mentation reports were obtained after spontaneous awakenings from Nightcap-identified REM sleep and 61 were obtained from NREM awakenings. Sleep mentation was recalled in 83% of REM reports and 54% of NREM reports. The median length of REM reports was 148 words compared to 21 words for NREM reports. Twenty-four percent of the REM reports were over 500 words long; no NREM reports over 500 words were obtained. REM report lengths were lowest during the first 15 min of the REM cycle and longest 15–45 min into the period. In contrast, 7 of the 9 NREM reports more than 100 words long occurred within the first 15 min of NREM periods. The Nightcap thus appears to be an effective and efficient method of collecting large numbers of sleep mentation reports with correlated sleep staging under normal ecological conditions.

INTRODUCTION

Following the discovery of REM sleep by Aserinsky and Kleitman (1953), the modern scientific study of dreaming has relied heavily upon the paradigm of sleep laboratory controlled awakenings. In this paradigm, subjects are outfitted with scalp, face, and chin electrodes and put to bed, and the electrical signals from these leads are monitored by the experimenter who watches a polygraph trace in an adjoining room. At predetermined times of night or at the appearance on the polygraph of signs of particular sleep stages, the subject is awakened and reports of mental activity are elicited.

The sleep laboratory awakening paradigm has the advantages of permitting the precise control of setting and the identification of wake/sleep stages. On the other hand, it has several disadvantages. Subjects are known to sleep more lightly in the unfamiliar and relatively intimidating laboratory setting; the first and often second nights in the laboratory are normally considered "adaptation nights" and data collected on these nights must often be discarded. Even after adaptation is considered complete, the sleep laboratory setting continues to be found in a high percentage of dream reports (Dement, Kahn, & Roffwarg, 1965; Domhoff & Kamiya, 1964b; Snyder, 1970). Reports collected in the laboratory have been

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reported to have less physical and verbal aggression (Domhoff, 1969; Weisz & Foulkes, 1970), less sexuality and aggression (Domhoff & Kamiya, 1964a; Hall, Van de Castle, Hess, Dertke, Daverso, Dupont, Nordby, Scott, & Clark, 1966), less friendliness and good fortune, and were generally less dramatic (Hall et al., 1966) than reports collected in the home. It is our belief that awakenings in the sleep laboratory additionally create disorienation, confusion, and confabulation that could vitiate the validity of the subjective data and confound the identification of bizarre elements.

The difficulty involved in the collection of sleep laboratory data, in terms of space and equipment, the demands on technical staff, and the recruitment of subjects adds a second set of problems. First, there are few longitudinal studies that run for more than 3 to 5 consecutive nights. Second, studies of spontaneous awakenings are rare because of the risk of obtaining too little data in the time available. Studies that vary more than a single parameter are likewise rare because of the large amount of data that then becomes necessary to allow statistical analyses.

As an example of this problem, a single technician, running a two-bed sleep laboratory, working 5 nights a week, and allowing a single adaptation night per subject, could collect no more than 8 subject-nights of data per week. In order to collect 100 subject-nights, such a laboratory would have to run full-time for 3 months. We hesitate to estimate the financial cost of such a project, but point out that technicians earn as much as $120/night and that clinical sleep laboratories may bill up to $1,000 per subject-night.

Hoping to overcome some of the disadvantages of the sleep laboratory awakening paradigm, we have developed the "Nightcap," a simple, minimally invasive, home-based recording system that distinguishes between wake, NREM and REM sleep with high reliability (Mamelak & Hobson, 1989; Ajilore, Stickgold, Rittenhouse, & Hobson, 1993, 1994). Used alone, the Nightcap can record up to 30 nights of sleep for subsequent analysis, allowing the identification of sleep stages and the concomitant collection of subjective report data following spontaneous awakenings. Used in conjunction with a Macintosh personal computer, the Nightcap can perform instrumental awakenings based on real-time analysis of sleep stages. We report here the results of a sleep stage-based collection of dream reports recorded in the home after spontaneous awakenings using the Nightcap system.

In a study of the efficacy of the Nightcap, Ajilore et al. (1994) studied 10 subjects both in the sleep laboratory and in the home. Studies in the laboratory combined standard polysomnography with Nightcap recordings. Overall, 87% of 1-min epochs were scored the same by the two methods. Agreement for individual subjects varied from 81 to 93%. In contrast, interrater reliability for the manually scored polysomnograph data was 95%, a value only 8% higher than that of the Nightcap. Mean REM latency was 111 min based on polysomnographic records and 107 min based on Nightcap data.

In a second study, Pace-Schott, Kaji, Stickgold, and Hobson (1994) used the Nightcap to compare 21 self-described good and poor sleepers in the home. Significant differences between the groups were found in sleep onset times and overall sleep efficiency, with differences similar to those seen by other groups who studied good and poor sleepers in the laboratory. They also confirmed a previously reported trend toward increased densities of eye and body movements in the NREM sleep of poor sleepers. Thus, the Nightcap not only is able to accurately distinguish between wake, REM, and NREM, but can also detect differences between good and poor sleepers with an accuracy close to that seen with standard polysomnography (Ajilore et al., 1993).

Other systems for monitoring sleep in the home also exist. One, the wrist actigraph, monitors wrist movement to distinguish waking from sleep (Kupfer, Detre, Foster, Tucker, & Delgado, 1972; Kripke, Mullaney, Messin, & Wyborney, 1978). While both inexpensive and easy to use, it is unable to distinguish REM from NREM sleep. At the other extreme, the Oxford Medilog system is essentially a portable polysomnograph system for which a technician is still required for electrode attachment (see, for example, Sharpley, Solomon, & Cowan, 1990) and which involves analysis of very large amounts of digital data. By taking a middle position, obtaining more information than the wrist actigraph but less than a portable polysomnograph system, we have been able to identify REM and NREM stages of sleep with high reliability.

This demonstration project clearly reveals that subjects sleeping at home can self-apply the Nightcap (eliminating the need of an experimenter or technician) and that the data so obtained can be used to distinguish REM from NREM sleep. In this study, we obtained 132 subject-nights of data in a 5-week period, a highly efficient yield compared with the sleep laboratory paradigm. When subjects wore the Nightcap, there were 239 spontaneous awakenings, 157 of which yielded reports of sleep mentation. Word count analysis of the reports suggests that the home-based data can be used to extend, amplify, and even correct conclusions reached on the basis of sleep laboratory awakening studies.

METHODS

Subjects

Eleven adults, 5 male and 6 female, ages 22–59, served as subjects in this study. Three of the subjects were members of our laboratory team, and the other 8 were recruited from the community at large.

Protocol

On 12 consecutive nights, subjects used a hand-held audio tape recorder to record the times that they went to sleep and arose in the morning, as well as to report any mental activity that they remembered after spontaneous awakenings. Reports were also collected after nonspontaneous awakenings induced by factors such as children and alarm clocks.

On the 3rd through 12th nights, the subjects also wore the Nightcap (Mamelak & Hobson, 1989; Ajilore et al., 1993; Pace-Schott et al., 1994), and the two data sources were synchronized as discussed below.

Data Collection

All reports were collected on Sony M-770V dictaphones that continuously recorded the time and date on the tape. Sleep stages were determined from recordings made by the Nightcap.

The Nightcap consists of two sensors connected to a base monitor. The sensors, a piezoelectric film that is adhered to one eyelid and a cylindrical, multipolar mercury switch taped to the forehead, measure eye movements and head movements, respectively. The base monitor is contained in a 11.5 × 7.5 × 2.5 cm case and is powered by a self-contained 9-V battery (see Fig. 1). When the Nightcap is turned on, the monitor records the date and time. After each subsequent minute, it records the number of eye movements and the number of body movements detected during that minute. In this manner, up to 30 nights of data can be recorded in on-board memory. The data are subsequently transferred to an IBM or Macintosh personal computer for analysis.

Since both the dictaphone and the Nightcap time and date stamp each record, it was possible to align each report with a precise point in the night's sleep architecture. Figure 2 shows samples of the Nightcap's output from two subjects, their computer-scored sleep stages, and the times at which reports were dictated. A record, similar to those in Fig. 2, was constructed for each night and each subject.

For each report, the following parameters were determined from the dictaphone time stamps and Nightcap records: (1) time of night, (2) time since sleep onset, (3) sleep stage preceding awakening, (4) duration of sleep stage preceding awakening, and (5) time awake before dictation began.

The time of night was determined from the time stamps on the dictaphone

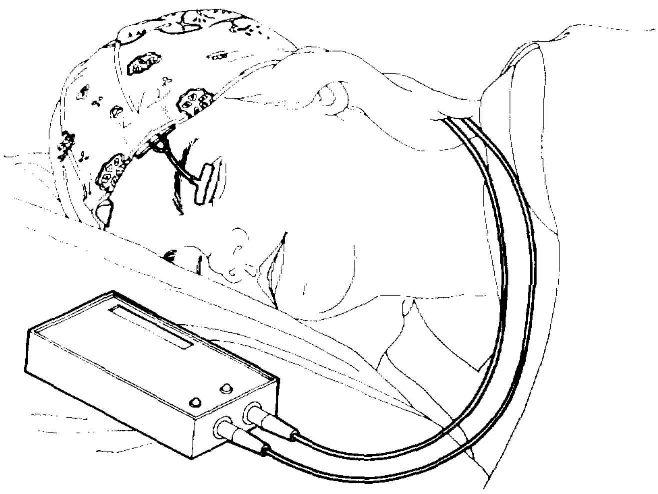

FIG. 1. The Nightcap. Line drawing made from a photograph of a human subject sleeping with the Nightcap. The eye movement sensor is applied to the left eyelid. The head movement sensor is on the right forehead (under the bandanna). Leads from the two sensors travel behind the subject's head to the battery-operated recording unit lying on the bed covers next to the subject.

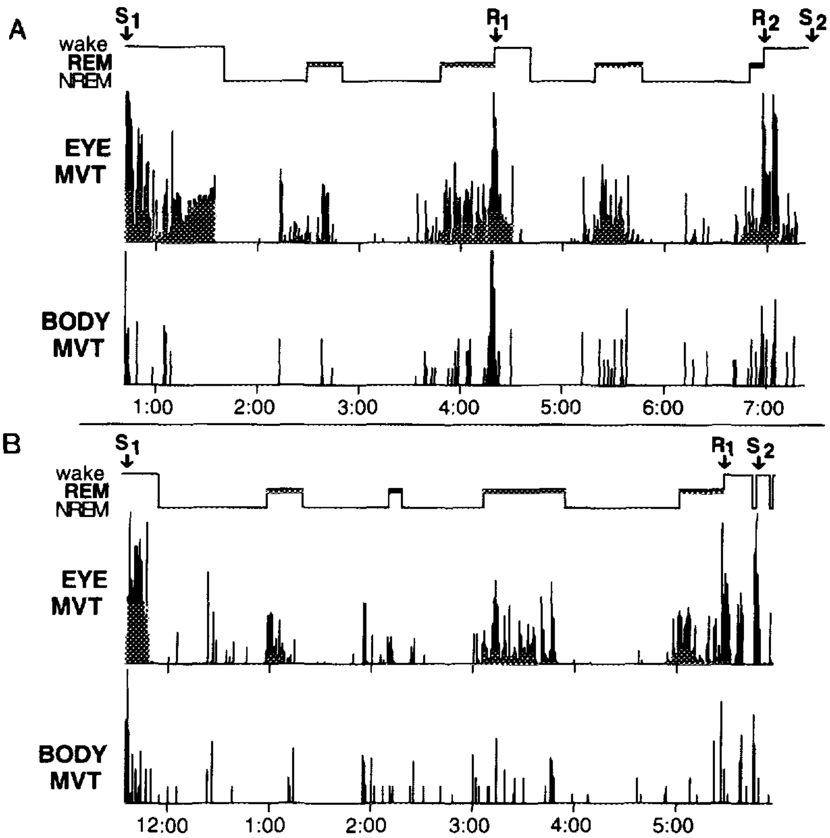

FIG. 2. Sample recordings and analyses of Nightcap data. Data from two subjects are shown. For each night: (Top trace) Sleep hypnogram. Sleep stages were determined by the computer using a scoring algorithm-derived from that of Mamelak and Hobson (1989) and described in detail in Ajilore et al. (submitted). The three stages of wake/sleep—wake, REM sleep, and NREM sleep—are displayed from top to bottom in the hypnogram (REM sleep line thickened). Arrows represent report times as recorded on the dictaphone (S_1 = evening summary of day's activities, R_1, R_2 = first and second reports of sleep mentation, S_2 = morning summary of the night's sleep). (Middle) Eye movements. The number of eye movements recorded during each minute of the night is shown. Full scale is 150 eye movements. (Bottom) Body movements. The number of body movements recorded during each minute of the night is shown. Full scale is 30 body movements. (A) Subject took 45 min to fall asleep and then awoke and gave reports during the second and fourth REM periods. (B) Subject fell asleep in 15 min and awakened only once, during the fourth REM period.

tapes. The remaining measures were determined using a computerized scoring algorithm that identified the start of each wake/sleep stage (wake, REM, or NREM) from the Nightcap data (Ajilore et al., 1994).

All dictaphone tapes were transcribed *verbatim*, with word fragments, nonverbal utterances (e.g., laughing, yawning), and pauses indicated. The dream-related word count, which is the number of words that specifically and uniquely describe the content of sleep mentation, was determined for each report. This word count excluded all comments pertaining to the recall process, to waking experiences, and to interpretation of the "meaning" or waking relevance of a dream and excluded repetitious accounts of dream events. This count is analogous to the Total Recall Counts (TRCs) of Antrobus (1983), which he defined as "the count of all words in sentences or phrases in which the subject was describing something that had occurred just before waking. It excluded 'ahs,' 'uhms,' repeated and corrected words, and all commentary on the experience, the report, or the current status of the subject."

RESULTS

Report Collection

In 132 subject-nights, the 11 subjects produced 297 reports (Table 1); 239 were reported on nights when the Nightcap was worn (2.2 per night). Of these, 157 (66%) included some report of sleep mentation, with Total Recall Counts (TRCs) ranging in length from 2 words to over 2500 words. Of the 58 reports collected without the Nightcap (2.6 per night), 43 (74%) included some report of sleep mentation.

While the report rate was slightly greater for the first 2 nights without the Nightcap (2.6 vs 2.2 reports per night), the difference was not statistically significant (ANOVA subject × Nightcap [11 × 2], $F_{Nightcap} = .38$; $p = .54$). Nor did the Nightcap significantly affect the frequency of recall of sleep mentation (ANOVA subject × Nightcap [11 × 2], $F_{Nightcap} = 1.07$; $p = .29$). The Nightcap had no significant effect on report lengths (ANOVA subject × Nightcap [11 × 2], $F_{Nightcap} = .20$; $p = .65$ for log[TRC + 1]; see Fig. 3), although there was a tendency toward longer reports when the Nightcap was worn (17% vs 9% longer than 400 words). All told, reports with recall had a median TRC of 145 words. (Total report length had a median value of 220 words.)

Computer-Scored Sleep Stages

Of the 239 Nightcap-monitored reports obtained from our 11 subjects, 45 could not be reliably classified as to sleep stage. Thirty-two of these came from one subject who had an electronically defective Nightcap, a problem that is not surprising since we are still using prototype devices. With this Nightcap excluded,

TABLE 1
Report Frequencies

	Ss	Nights	Reports	Reports/ Subjects	Reports/ Night	% Recall
Total	11	132	297	27.0	2.2	67%
w/o Nightcap	11	22	58	5.3	2.6	74%
w/ Nightcap	11	110	239	21.8	2.2	66%

Note. Data were collected from subjects for 2 nights without the Nightcap and 10 nights with the Nightcap. % Recall, the percentage of reports in which information about prior sleep mentation was provided.

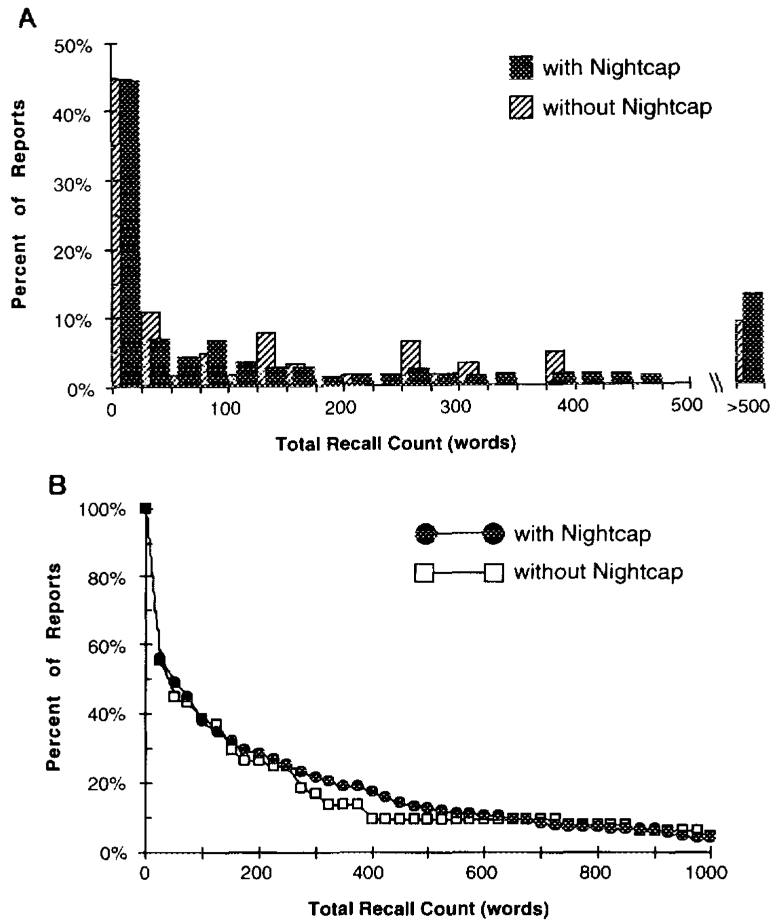

FIG. 3. (A) Distribution of report lengths. The percentages of reports with various TRCs on the first 2 nights without the Nightcap are compared to those for reports collected on the final 10 days, when the Nightcap was worn. (B) Dream length cumulative histogram. The percentage of dreams that were collected with or without the Nightcap that are longer than the indicated TRC.

194 of the 207 Nightcap-monitored awakenings could be unambiguously classified as to sleep stage, a 94% success rate.

Forty-five of the classified reports were eliminated from data analysis because more than 9 min had elapsed between the time of awakening and the time of the report. These were almost exclusively morning reports given after the Nightcap had been turned off, making their correlation with physiology uncertain. The final sample used for subsequent analysis thus consisted of 149 sleep stage-defined reports.

Distribution of REM and NREM Reports

In the sample of 149 reports, 88 (59%) were from REM awakenings and 61 (41%) were from NREM awakenings. Seventy-five reports (51%) came from awakenings between 3 and 6 h after the start of the Nightcap recordings (Fig. 4).

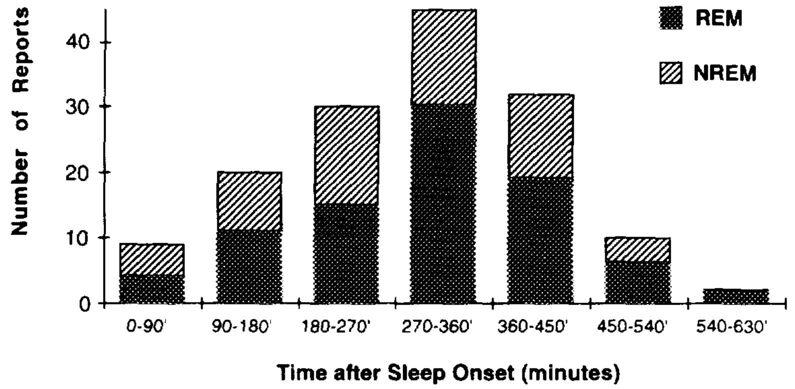

FIG. 4. Time of REM and NREM reports. The number of reports from the final sample of 149 that were obtained from each 90-min period of the night.

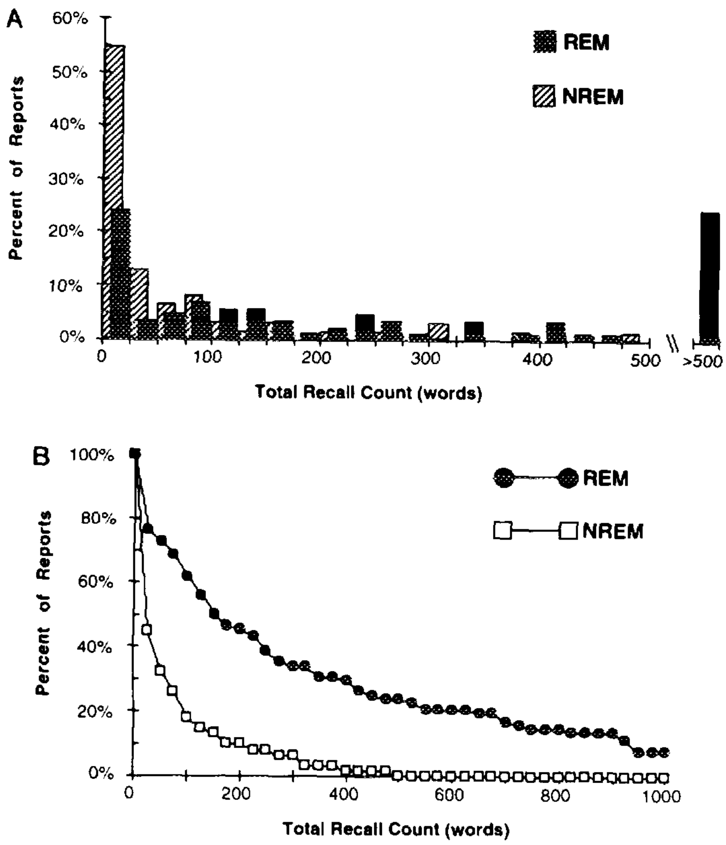

FIG. 5. (A) Relative distribution of REM and NREM reports. The percentages of reports with various numbers of dream-related words for reports collected after REM awakenings are compared to those for reports collected after NREM awakenings. (B) Dream length cumulative histogram. The percentage of dreams collected after REM or NREM awakenings that are longer than the indicated TRC are shown.

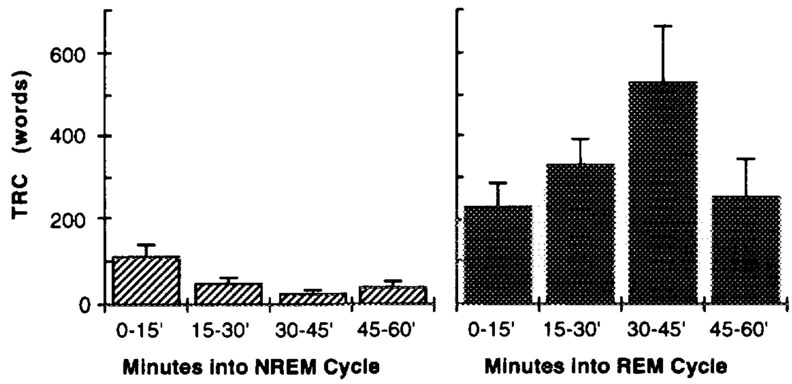

FIG. 6. Temporal distribution of report lengths in NREM and REM cycles. Times indicate minutes after the start of a NREM (left) or REM (right) period. Bars indicate mean SEM for each sample.

Report lengths after REM and NREM awakenings. When the total number of words related to dream content (TRC) was determined for each report, REM reports were found to be significantly longer than NREM reports (ANOVA subject × stage [11 × 2], $F_{stage} = 30.7$, $p < .0001$ for log[TRC + 1]). The median TRC for REM reports was 148 words compared to 21 words for NREM reports, a ratio of 7 to 1. Mean TRCs were 317 words for REM reports and 65 words for the NREM reports, a ratio of 5 to 1. While 44% of the REM reports were over 200 words long, only 10% of the NREM reports exceeded this length. In addition, while 24% of the REM reports were longer than 500 words, only one of the NREM reports was this long. Conversely, 54% of NREM reports were less than 25 words long, compared to 25% of REM reports. The overall histograms for REM and NREM reports are shown in Fig. 5.

Sixty-one of the 88 REM reports (83%) contained some recalled sleep mentation. In contrast, only 33 of the 61 NREM reports (54%) recalled any prior sleep mentation. This difference is statistically significant (ANOVA subject × stage [11 × 2], $F_{stage} = 5.14$, $p < .05$).

Effect of Time in Cycle on Report Lengths

Not only does the time of night have an influence on report length, but the time within the REM or NREM epoch at which the report is given is also important. The mean report lengths for different times in REM and NREM cycles are shown in Fig. 6. NREM reports are longest during the first 15 min of the cycle and are shorter thereafter. In contrast, REM report lengths are lowest during the first 15 min of the REM cycle and peak 30–45 min into the cycle. Seven of the 9 NREM reports more than 100 words long occurred within the first 15 min of NREM periods ($\chi^2 = 9.7$, $df = 1$, $p < .01$).

DISCUSSION

The features of sleep mentation that have been reported to differentiate REM from NREM sleep, early from late night mentation reports, and REM with bursts of rapid eye movement from periods between bursts remain hotly contested issues (see Pivik, 1991, for review). It is our hypothesis that one obstacle to resolving these issues is the sleep laboratory paradigm itself. Because the sleep laboratory of necessity constitutes an unfamiliar, intimidating, and highly intrusive environment where subjects normally spend 2 to 5 nights being monitored by strangers, it would not be surprising to find poor sleep, relatively extreme disorientation on awakening, and constrained dream content. All of these phenomena are in fact observed.

This being the case, the value of laboratory-based dream reports is limited. Clearly it would be preferable to collect such reports in the home. The major objection to such a protocol—the inability to identify sleep stages in the home environment—is largely eliminated by the use of the Nightcap. But the Nightcap has its own limitation; while it accurately and reliably distinguishes REM and NREM sleep, it cannot distinguish among NREM stages 2, 3, and 4. For studies where such distinctions are crucial, the Nightcap would not be suitable. On the other hand, the Nightcap produces quantitative measures of the amount of eye movements during each minute of the night, so it is ideally suited for studies of the relationship between the amount of eye movements preceding awakenings and subsequent sleep mentation reports.

Long reports (>100 words) were by no means restricted to REM awakenings; 17% of such reports were from NREM awakenings. But the times within REM and NREM cycles during which they were obtained differed significantly. While the longest REM reports were obtained 15 to 45 min after the start of REM cycles, the longest NREM reports, including seven of the nine that were over 100 words long, were obtained within the first 15 min of NREM periods, reminiscent of the sleep onset Stage I EEG characteristically correlated with dreamlike mentation (Foulkes & Vogel, 1965). This lends credence to the idea that long NREM reports reflect transitional periods when some aspects of REM physiology continue to exert an influence. It is also possible that reports given early in NREM periods actually reflect sleep mentation from the preceding REM period.

The Home-Based Nightcap Paradigm

The availability of a home-based system that monitors sleep stages and permits stage-dependent awakenings can reduce or eliminate many of the problems associated with sleep laboratory studies. Several studies have confirmed the efficacy of the Nightcap (Pace-Schott et al., 1994; Ajilore et al., 1993; Czeisler et al., unpublished results). In our longitudinal study, 110 nights of Nightcap data with dream reports were collected from 11 subjects in less than 6 weeks. In improved circumstances, the study could have been completed in half of that time.

In conjunction with the relative ease of data collection, we were able to collect reports from a varied set of conditions. In addition to information on the variation in report length as a function of the time within the REM or NREM epoch (Fig. 6), we have data on the variation in report length as a function of time of night and time since sleep onset. Furthermore, we have quantitative data on the amount of eye and body movement in the minutes preceding each awakening. Analyses of these parameters will be the subject of a subsequent paper.

A third advantage of home recording is our ability to obtain longer reports. In a sleep laboratory study of Antrobus (1983), the longest of 72 REM reports contained 254 words (Antrobus, personal communications). In contrast, 33 of our REM reports (38%) were over 250 words in length. Several factors could have contributed to this difference. Perhaps there is less disorientation upon spontaneous arousals than when one is awakened by a technician, or longitudinal studies may allow subjects to improve their reporting skills. It should be pointed out that all of our subjects had an expressed interest in recording their dreams and most had prior experience recording their dreams. We have not yet analyzed subject differences that might provide information on the relative importance of these factors. Preliminary analysis suggests that there is no significant variation in the mean or median TRC for REM and NREM reports over the course of the 10-day study.

Reliability of home-based studies. It is not possible to confirm the sleep staging done by the Nightcap in the home environment. But studies in the sleep laboratory where the Nightcap was used in conjunction with standard polysomnography demonstrate that the Nightcap correctly scores 87% of all minutes. With the average night being 405 min long, this amounted to an average of 53 min per night misscored. Incorrect scores were relatively evenly distributed among the wake (15 min/night), REM (16 min/night), and NREM (20 min/night) stages; most discrepancies involved the identification of the precise boundaries between stages (Ajilore et al., 1994). Since interrater reliability for the interpretation of polysomnographic data was only 95%, compared to 87% Nightcap–polysomnograph agreement, we believe that the advantages of the home-based system far outweigh this small decrement in accuracy of scoring sleep stages.

It is natural to wonder whether some of the reports collected in this study actually reflect dream mentation that occurred in association with gradual awakenings. Three related facts argue against this hypothesis. First, all subjects were instructed to report sleep mentation as quickly as possible upon awakening. Second, many of our subjects were experienced self-observers who were motivated to make subtle distinctions between mental states and to describe them in detail. Finally, the longest and most bizarre reports were obtained on awakenings from REM episodes that showed eye movement densities much higher than is seen in gradual awakenings. We are thus left with no reason to believe that such gradual awakenings contributed any significant number of reports to our sample.

Dream Reports Collected in the Home

In the present study, we have shown that use of the Nightcap affects neither the number of spontaneous reports nor the frequency of recall of sleep mentation in these reports. The lengths of recall reports showed similar distributions both with and without the Nightcap. Over all the nights of our study, there were only two reports of sleep mentation that themselves referred to sleep, and only one that referred to the Nightcap. In sum, we found no evidence that the wearing of the Nightcap in any way affected the quantity or quality of dream recall. We therefore believe that the dream reports collected represent a truly normative sample of sleep mentation reports available after spontaneous awakenings. Further support for this conclusion is the fact that the median total report length for all reports with recall of 220 words was virtually identical to the value of 224 words obtained in a study of spontaneous awakening reports done without the Nightcap (Merritt, Stickgold, Pace-Schott, Williams, & Hobson, 1994).

REM reports differed significantly from NREM reports in a manner similar to that of sleep laboratory awakening studies. REM reports recalled prior sleep mentation in 84% of all awakenings while NREM reports showed only a 54% recall rate. While precise numbers are not available from the study of Antrobus (1983; personal communications), 79% of his REM awakenings and only 43% of his NREM awakenings yielded reports with total recall counts of more than 10 words. If these are taken to reflect the frequency of recall, then our recall frequencies are quite similar.

In addition, report lengths differed significantly, with the median TRC for REM reports being 7.0 times greater than that for NREM reports. This agrees well with the results of Antrobus (1983; personal communications), who found a ratio of 6.4 between the median length of REM and NREM reports. However, our mean report length was 5.2 times longer than that of Antrobus (5.6-fold greater in REM and 4.6-fold in NREM).

Thus our REM and NREM reports show the two most consistent differences found in laboratory studies: an increased report rate and an increased report length for REM reports. In terms of absolute report rates in REM and NREM, our results are very similar to those of Antrobus (1983; personal communications) and near the top of the ranges reported in a review of Pivik (1991). The relative lengths of reports from REM and NREM in our study is again very similar to those of Antrobus (1983; personal communications), but our overall report lengths in both REM and NREM sleep average five times those of Antrobus.

CONCLUSIONS

The purpose of this study was to demonstrate the value of the Nightcap in conducting home-based studies of sleep mentation. In this initial study, 88 REM reports and 61 NREM reports were collected from 11 subjects over a 6-week period with only minimal effort on the part of technicians and researchers. Even in this initial study, less than 30 min was spent collecting each night's sleep stage and dream report data. This is almost certainly a first for sleep studies.

One important finding of this report is that reports obtained from spontaneous awakenings are more commonly from REM sleep than NREM sleep. In addition, by setting minimum word counts, an even greater enrichment of REM reports can be obtained. For example, there were 54 REM reports and only 11 NREM reports over 100 words long, a ratio of almost 5 to 1; there were 64 REM reports and only 20 NREM reports over 50 words long, a ratio of over 3 to 1. Since the following papers in this series report the analysis of home-based reports at least 50 to 100 words long, most of which were spontaneous morning awakenings, it is reassuring to know—on the basis of word counts alone—that at least three-quarters of these reports most likely came from REM sleep.

We believe that this initial analysis of our first Nightcap-based sleep mentation study demonstrates the power of our new home-based protocol for the study of REM and NREM sleep mentation. Additional analyses of these data as well as future studies with the Nightcap will demonstrate the full power of this paradigm.

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