Factors Related to the Occurrence of Isolated Sleep Paralysis Elicited During a Multi-Phasic Sleep-Wake Schedule

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Study Objectives: To further investigate mechanisms of isolated sleep paralysis (ISP) in normal individuals, we experimentally elicited ISPs by facilitating sleep onset REM periods (SOREMP), a prerequisite of ISPs, and examined behavioral and psychological measurements relating to ISP appearances.

Design: The multi-phasic sleep/wake schedule (MPS) began at approximately midnight and ended when net sleep reached 7.5 hours. Participants were awakened after every 5 min of REM sleep to obtain a maximum number of SOREMPs. Upon each awakening, mentation reports and subjective measurements were collected. Performance tests were then assigned.

Setting: Sleep lab, Tokyo Metropolitan Institute for Neurosciences, Japan.

Participants: Thirteen healthy Japanese students (10 males) with high self-reported frequencies of ISPs but no other narcolepsy-related symptoms.

Interventions: NA

Measurements and results: From 184 sleep interruptions, 8 ISP episodes were obtained. In within participant comparisons between episodes with and without ISPs, the vigilance task (VT) reaction times were elevated before SOREMPs with ISPs. In between analyses (ISP vs non-ISP), the ISP group showed poorer performance, more complaints of physical, mental, and neurotic symptoms, increased subjective fatigue and increased stage 1 throughout the entire schedule. VT hit rates remained constant in the non-ISP group, but dropped in the later part of schedule in the ISP group. Subjective sleepiness dropped over time in the non-ISP group while it slightly increased in the ISP group.

Conclusions: ISP is likely to appear as a phenotype of REM dissociation during SOREMP when participants with low tolerance for disrupted sleep-wake rhythms are placed in this type of schedule.

Key words: Sleep; sleep paralysis; normal; SOREMP; REM; sleep disruption; performance; sleep wake cycle; fatigue; sleepiness

INTRODUCTION

SLEEP PARALYSIS IS ONE OF THE TYPICAL SYMPTOMS OF NARCOLEPSY ALONG WITH CATAPLEXY, SLEEP ATTACKS, AND HYPNAGOGIC HALLUCINATIONS. According to the American Sleep Disorder Association (780.56-2; ICSD),1 the criteria for sleep paralysis are: 1) a complaint of inability to move the trunk or limbs at sleep onset or upon awakening; 2) a presence of brief episodes of partial or complete skeletal muscle paralysis; and 3) not associated with other medical or psychiatric disorders (e.g., hysteria/ hypokalemic paralysis).

Sleep paralysis has also been widely reported in healthy individuals from many different countries.2-13 Several studies have shown a high prevalence (approximately 40%) of isolated sleep paralysis without other narcoleptic symptoms.7,11,13 This isolated form of sleep paralysis (ISP) is thus a fairly common experience even though its mechanisms are unknown. In many cases, ISPs have been recognized in the form of folktale or myth that is specific to each culture (for review, see Fukuda 199414). There are psychological factors that have been hypothesized to affect ISP occurrences, such as passive-aggressive personality15,16 and panic disorder (DSM-lll; American Psychiatric Association)17-19 although no clear relationship has been found between ISP and standard psychological test scores.10,20 Biological influences such as gender, race, and some type of genetic factors have also been suggested;14,21 yet no clear evidence has been reported.

One empirical study that elicited ISPs by systematically interrupting participants’ NREM-REM cycles found that ISPs occurred specifically from sleep onset REM periods (SOREMPs).22 Furthermore, polysomnograms recorded during ISPs in this study showed the simultaneous appearance of indices of wakefulness and REM sleep at sleep onset. Considered together with previous empirical findings on narcolepsy paralysis,23,24 it was suggested that ISPs share a common physiological background with narcoleptic sleep paralysis.

In this study, our goal was to examine factors in addition to SOREMP that may influence ISP occurrences. Based on the close relationship between SOREMPs and ISP,22 it was expected that repeatedly facilitating SOREMPs would increase opportunities to elicit ISPs. Therefore, we utilized a multi-phasic sleep-wake schedule (MPS), which was modified from the Sleep Interruption Technique (SIT),25 to obtain a maximum number of SOREMPs. We specifically investigated 1) whether distinct behavioral and/or psychological states during preceding wakefulness would influence subsequent ISP appearances, and 2) whether inter-subject differences in responses to the multi-phasic

Disclosure Statement
The first author was supported by the Japan Society for the Promotion of Science during this study. This work was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education and Culture, Japan.

Submitted for publication: June 2001
Accepted for publication October 2001
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SLEEP, Vol. 25, No. 1, 2002
Participants

A total of 13 healthy Japanese graduate and undergraduate students who had experienced sleep paralysis at least twice in their lifetime participated in the study (10 males, 3 females, mean age=20.9, S.D.=1.79 y). Participants had no history of psychosis or narcolepsy-related symptoms such as cataplexy and sleep attacks. Informed consent was obtained after an explanation of the study.

Multi-phasic Sleep-wake schedule (MPS)

Participants spent three consecutive (two adaptation and one baseline) nights and one complete night and day (in the MPS) in the sleep laboratory of the Tokyo Metropolitan Institute for Neuroscience. The MPS started at about midnight (mean initial light-off time: 23:48, S.D.=15 min) on the fourth night (Figure 1). The experiment ended when a participant’s net amount of sleep reached 7.5 hours (mean final awakening time: 19:33, S.D.=34min).

During the MPS, after 60 minutes of the first NREM period had elapsed, sleep was interrupted for one hour (Figure 1). Previous research using the SIT has indicated that this length of time is optimal for eliciting the maximum number of SOREMPs.26 Following this initial interruption, participants were awakened whenever five minutes of REM sleep appeared. Upon each awakening, participants assessed their mental activities prior to awakening on rating scales and subsequently provided oral reports (See “Collection of Mental Activities” below). They then filled out a questionnaire about their subjective state that assessed sleepiness, mood, and tiredness (See “Subjective Measurements” below) and were assigned performance tasks (See “Performance Tasks” below). Following the tasks, they again rated their subjective state and were allowed to return to sleep.

Cases where a REM period appeared within 25 minutes of sleep onset were defined as SOREMP and those where a REM period appeared later than 25 minutes after sleep onset were defined as REMP (typical REM period). After REMP episodes, participants were kept awake for an hour completing mentation reports and performance tasks (Long W). After SOREMP episodes, they were allowed to return to sleep immediately after assessing their mental activities and subjective state without any performance tasks (Short W). Short Ws were implemented to avoid overtiredness caused by repeated sleep interruption during the MPS observed during a pilot study.

During the MPS, participants were given no time cues and were confined to the bedroom except for bathroom breaks. Small meals and/or water were provided during the interruption periods whenever participants were hungry and/or thirsty. Participants’ behavior was monitored by experimenters through a video camera throughout the study.

Collection of Mental Activity

For each awakening, an experimenter awakened the participant by calling her or his name through an earphone. Participants were then asked to identify their state just before experimenters’ call. If any mentation such as dreaming, thinking, or sleep paralysis was reported, they were asked to rate their experiences using a questionnaire that contains rating scales to assess basic properties of mental activity (Dream Property Scale27,28). They then orally described the mental activity and these descriptions were recorded for later transcription.

Subjective Measurements

Participants were given questionnaires to assess aspects of their subjective state including sleepiness (Kuanswei-gakuin Sleepiness Scale; KSS),29 tiredness (Subjective Fatigue Scale; SFQ),30 and mood (Mood Adjective Check Lists; MACL).31 The KSS consists of 22 statements that were modified from the Stanford Sleepiness Scale and adapted for Japanese participants. In the KSS, each statement has its own weighted score between 0—7 with higher scores indicating greater sleepiness. Participants were asked to check all statements that describe various aspects of their current sleepiness. The item scores were summed to obtain a total score which indicated the level of current “sleepiness” of the participants.

The SFQ consists of three major categories (mental complaints, physical complaints, and neurotic complaints) and one nine-point Likert Scale for assessing fatigue in general. Each of the three categories includes ten items as follows; 1) physical complaints—my head feels heavy, my legs feel heavy, my head is fuzzy, my eyes are strained, I am unsteady on my feet, I feel my whole body is sluggish, I have to yawn, I am sleepy, my actions are stiff, I’d like to lie down; 2) mental complaints—I cannot shape up my ideas, I am irritated and feel jittery, I cannot become eager about anything, my mistakes are increasing, I have difficulty in doing things neatly, I feel tired of speaking, my attention is distracted, I cannot remember a trivial matter, I am nervous about things, I am unable to carry on any longer; 3) Neurotic complaints—I have a headache, I have a pain in my waist, my mouth feels dry, I feel dizzy, my hands and feet tremble, I have stiff shoulders, I have difficulty in breathing, my voice is hoarse,
my eyelids and muscles of my temple twitch, I feel sick. Participants checked all statements that pertained to them at that time. The total number of items checked within each category was regarded as a category score. Participants were also asked to rate their fatigue on a nine point scale in the SFQ (where 1 is “feel very refreshed and no fatigue” and 9 is “feel very tired and cannot work anymore”).

Performance Tasks

During the Long W participants were assigned grip tests with both hands, six trials of flicker tests, and 30 minutes of auditory vigilance tests (VT). During the VT, participants sat on a chair and listened to tones through earphones and pressed a button as quickly as possible whenever they detected a longer tone. The VT consisted of three sequential ten-minute blocks. Each block contained 20 long (target; 1000Hz, 700msec) and 280 short (non-target; 1000Hz, 500msec) tones which were randomly presented. Grip tests, flicker tests, and blood pressure were measured both before and after the VT.

Mean values for both grip weights, for the six trials in the flicker test, and for two consecutive recordings of systolic and diastolic blood pressure were calculated.

Recording

Sleep periods and interruption periods during the experimental night and day were polygraphically monitored with EEG (Cz and Oz referred to averaged mastoids), EOG, mentalis EMG, and autonomic nervous system variables (rectal temperature, heart rate, respiration rate, skin potential responses and levels, and plethysmogram).

Definitions

Each sleep stage was scored in 30-second epochs using standard criteria.22 Sleep onset was defined as the first 30-second epoch of continuous stage 1, 2, or REM sleep. For the purpose of this study, a REM episode (either SOREMP or REMP) was defined as the time from sleep onset following the last sleep interruption to the last complete 30-second epoch before an experimental awakening in REM sleep.

ISP was defined as “an inability to move and/or speak while lying fully conscious or in a dreamlike state, with or without visual and/or auditory hallucinations.”22

Statistical Analyses

SPSS 10.0 for Windows was used for the statistical analyses.

RESULTS

Total Number of SOREMP and REMP Episodes

None of the participants showed either SOREMPs or ISPs in the baseline night.

During the MPS, following a total of 184 sleep interruptions, 91 SOREMP and 90 REMP episodes were observed (three were unidentified).

Five participants reported a total of eight ISP. Four participants reported one ISP episode each and one participant reported four. In two of these four episodes of the last mentioned participant, he woke up voluntarily before the next REM period appeared (Unidentified, Table 1). These two ISPs were reported immediately after sleep onset and their polysomnograms showed signs that a REM episode was imminent, (e.g., persistent atonia with twitch movements and alpha-dominant desynchronized EEG patterns although they could not be scored as stage REM by standard criteria). Except for these two episodes, all ISPs were reported from SOREMPs and no ISPs were reported from REMP. Among 69 SOREMPs elicited following a Long W, 62 appeared after the alternating pattern of Short and Long Ws, for example, SOREMP Short W - REMP - Long W-SOREMP. Two ISPs were obtained from this pattern (2/62). While, interestingly, among only seven SOREMPs appearing after more than one consecutive Long W, such as; REMP - Long W - REMP - Long W - SOREM, three ISPs were observed (3/7). This can be construed to imply that ISPs are likely to appear more often following long episodes of NREM sleep and wakefulness without REM appearances.

Specific States During Interruption Predicting ISP Episodes

Figure 2 shows the sleep diagrams of five participants who reported ISPs during the study.

Four ISP episodes were observed in the morning while four were observed in the afternoon. Nevertheless, these were distributed over the experimental period and sample size was not sufficient to draw any conclusions regarding when (clock time) ISPs are likely to occur.

To examine how specific states contributed to ISP episodes, behavioral measurements (nap; number of 30-second-epochs of any sleep stage except for W, hit rate, and reaction time in the vigilance test (VT); blood pressure; flicker; and grip) and subjective states (physical, mental, and neurotic complaints; fatigue; and sleepiness) during interruption periods, and sleep and REM latencies before SOREMPs with ISP were compared to those without ISP (Table 2). Data from the five participants who reported ISPs during the MPS were used for this analysis.

There was a marginal difference in the VT reaction time
(t(4)=2.775, p=.05) and a significant difference in the diastolic blood pressure (t(4)=3.565, p<.023). That is, participants’ reaction times and diastolic blood pressure were likely to increase before SOREMPs with ISPs compared to SOREMPs without ISPs. Although the potential for Type I errors caused by the number of tests must be considered, the consistent direction observed among measurements in the VT—lower hit rates and more napping in SOREM with ISP—seems to suggest that these measurements during VT might be associated with ISP.

**Table 2—Behavioral and subjective measurements for participants reporting ISP**

<table>
<thead>
<tr>
<th></th>
<th>SOREM</th>
<th>SOREM with ISP</th>
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<tbody>
<tr>
<td></td>
<td>Mean (S.D.)</td>
<td>Mean (S.D.)</td>
</tr>
<tr>
<td>Interruption length (min)</td>
<td>61.05 (6.60)</td>
<td>55.87 (7.26)</td>
</tr>
<tr>
<td>Nap during VT (min)</td>
<td>1.38 (3.09)</td>
<td>3.57 (4.85)</td>
</tr>
<tr>
<td>Hit rate (%)</td>
<td>41.20 (34.69)</td>
<td>39.56 (35.24)</td>
</tr>
<tr>
<td>Reaction time (msec) +</td>
<td>475.01 (79.91)</td>
<td>620.72 (155.80)</td>
</tr>
<tr>
<td>Systolic blood pressure (mm/Hg)</td>
<td>103.55 (10.00)</td>
<td>105.43 (9.79)</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm/Hg) *</td>
<td>70.73 (3.43)</td>
<td>75.13 (5.85)</td>
</tr>
<tr>
<td>Flicker (Hz)</td>
<td>37.30 (2.13)</td>
<td>37.30 (2.10)</td>
</tr>
<tr>
<td>Grip (Kg)</td>
<td>31.24 (9.57)</td>
<td>28.70 (12.13)</td>
</tr>
<tr>
<td>Physical complaints</td>
<td>5.20 (1.40)</td>
<td>4.27 (2.24)</td>
</tr>
<tr>
<td>Mental complaints</td>
<td>3.33 (1.71)</td>
<td>1.60 (2.07)</td>
</tr>
<tr>
<td>Neurotic complaints</td>
<td>1.54 (0.74)</td>
<td>1.13 (0.87)</td>
</tr>
<tr>
<td>Fatigue</td>
<td>6.26 (1.11)</td>
<td>6.10 (1.82)</td>
</tr>
<tr>
<td>Sleepiness</td>
<td>5.03 (0.43)</td>
<td>4.86 (0.60)</td>
</tr>
<tr>
<td>Sleep latency (min)</td>
<td>12.31 (14.42)</td>
<td>5.27 (3.81)</td>
</tr>
<tr>
<td>SOREM latency (min)</td>
<td>3.84 (2.29)</td>
<td>4.35 (6.42)</td>
</tr>
</tbody>
</table>

Note: * p<.05, +p<.1

**Comparison of Behavioral Measurements, Psychological Measurements, and Sleep Stages Between Participants With and Without ISPs**

We then checked for the presence of any specific traits in participants who did and did not report ISPs during the MPS. We compared sleep parameters, behavioral measurements, and subjective measurements among the five participants who reported ISPs (ISP group) and the eight participants who did not reported ISPs (non-ISPs group). Considering that elapsed time and/or circadian rhythms could influence these parameters, ANOVAs were performed dividing data into the early and the later part of the
As indicated in Table 3, there were significant main effects of time on physical complaints (F(1,11)=8.117, p<.05), mental complaints (F(1,11)=8.507, p<.05), fatigue (F(1,11)=11.838, p<.01), sleep latency (F(1,11)=7.290, p<.05), and amount of slow-wave sleep (SWS; F(1,11)=31.638, p<.001). For both ISP and non-ISP groups, there was a decrease in the numbers of physical and mental complaints, the levels of fatigue, and the amounts of SWS and slow-wave sleep latency over the course of the MPS. There were significant or marginal main effects of ISP on VT reaction time (F(1,11)=5.587, p<.05), blood pressure (systolic; F(1,11)=3.872, p=.075, diastolic; F(1,11)=6.274, p<.05), physical complaints (F(1,11)=4.690, p<.053), neurotic complaints (F(1,11)=13.009, p<.005), fatigue (F(1,11)=3.180, p=.102) and the amount of stage 1 (F(1,11)=. p<.05). That is, over the course of the MPS, the ISP group showed delayed reaction times, lower systolic blood pressure and higher diastolic blood pressure, more physical and neurotic complaints, more severe fatigue, and increased stage 1 compared to the non-ISP group. Marginal trends for an interaction between Time and ISP were also observed for the VT hit rate (F(1,11)=3.422, p=.091) and sleepiness scores (F(1,11)=4.782, p=.051). VT hit rates for the non-ISP group remained constant, but for the ISP group it dropped in the late part of the schedule. The level of subjective sleepiness dropped over time for the non-ISP group while they remained almost the same (slight increase) for the ISP group.

## DISCUSSION

None of the current participants evidenced any clinical signs of narcolepsy either in their history (cataplexy, sleep attack) or by PSG (SOREMPs in the 1st NREM-REM cycle in the baseline night). Since we did not test their HLA typing, we cannot exclude a possible genetic predisposition to narcolepsy. Yet, at least none of the current participants were symptomatically diagnosed as having narcolepsy when this study was conducted.

### SOREM as a Prerequisite State for ISP

During the MPS, 8 ISPs were successfully induced. As mentioned, two ISP episodes were terminated before the appearance of clear signs of REM sleep. The polysomnograms showed signs that a REM episode was imminent (e.g., persistent atonia with twitch movements and alpha-dominant desynchronized EEG patterns). However, these would not be scored as stage REM by standard criteria. These cases appear to be similar to one of the six ISP cases reported in a previous study by Takeuchi and may be examples of Covert-REM as hypothesized by Nielsen. It should be emphasized that none of the eight ISPs observed were reported from REM sleep, with latencies longer than 25 minutes. Overall, our current results reaffirmed a close relationship between SOREM episodes and ISP occurrences.

On the basis of questionnaires completed by nightshift nurses, Folkard et al. reported that night shift paralysis (equivalent to sleep paralysis) occurred most often during the night shift, with a peak occurrence at 05:00. In the current study, ISPs were almost equally distributed across 21 hours of the experiment. These differences seem to reflect a different distribution of SOREMPs based on the protocols. SOREMPs are usually facilitated by an increase in the REM propensity, which is regulated by circadian factors. Therefore, it allows us to speculate that sleep paralyses reported in the former study were facilitated by SOREMPs that

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**Table 3**—Behavioral and subjective measurements for participants with and without ISPs

<table>
<thead>
<tr>
<th></th>
<th>Early (Midnight—10:00)</th>
<th>Late (10:00—evening)</th>
<th>ANOVA Effects</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>ISP (Mean) (SD)</td>
<td>non-ISP (Mean) (SD)</td>
<td></td>
</tr>
<tr>
<td>SOREM occurrence (%)</td>
<td>73.33 (25.28)</td>
<td>73.96 (23.33)</td>
<td></td>
</tr>
<tr>
<td>VT Hit rate (%)</td>
<td>45.58 (30.42)</td>
<td>72.40 (27.47)</td>
<td></td>
</tr>
<tr>
<td>VT Reaction time (msec)</td>
<td>497.80 (97.87)</td>
<td>398.78 (103.94)</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure (mm/Hg)</td>
<td>104.03 (9.31)</td>
<td>110.51 (11.50)</td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure (mm/Hg)</td>
<td>72.98 (5.83)</td>
<td>66.67 (6.05)</td>
<td></td>
</tr>
<tr>
<td>Flicker test (Hz)</td>
<td>36.88 (1.95)</td>
<td>35.64 (2.66)</td>
<td></td>
</tr>
<tr>
<td>Grip (g)</td>
<td>24.38 (13.77)</td>
<td>36.29 (10.42)</td>
<td></td>
</tr>
<tr>
<td>Physical complaint score</td>
<td>5.10 (2.07)</td>
<td>3.97 (0.96)</td>
<td></td>
</tr>
<tr>
<td>Mental complaint score</td>
<td>3.20 (2.02)</td>
<td>3.24 (1.33)</td>
<td></td>
</tr>
<tr>
<td>Neurotic complaint score</td>
<td>2.55 (1.99)</td>
<td>0.60 (0.56)</td>
<td></td>
</tr>
<tr>
<td>Fatigue scale score</td>
<td>6.32 (0.81)</td>
<td>5.52 (0.61)</td>
<td></td>
</tr>
<tr>
<td>Sleepiness score</td>
<td>4.16 (2.03)</td>
<td>4.99 (0.18)</td>
<td></td>
</tr>
<tr>
<td>Sleep latency (min)</td>
<td>3.78 (2.39)</td>
<td>9.05 (7.01)</td>
<td></td>
</tr>
<tr>
<td>SOREM latency (min)</td>
<td>6.13 (3.75)</td>
<td>5.54 (4.15)</td>
<td></td>
</tr>
<tr>
<td>Stage W (min)</td>
<td>268.70 (42.66)</td>
<td>292.44 (36.96)</td>
<td></td>
</tr>
<tr>
<td>Stage 1 (min)</td>
<td>46.30 (7.15)</td>
<td>33.63 (12.96)</td>
<td></td>
</tr>
<tr>
<td>Stage 2 (min)</td>
<td>112.20 (8.42)</td>
<td>102.75 (23.87)</td>
<td></td>
</tr>
<tr>
<td>SWS (min)</td>
<td>64.30 (15.14)</td>
<td>79.75 (28.61)</td>
<td></td>
</tr>
<tr>
<td>Stage REM (min)</td>
<td>33.30 (12.63)</td>
<td>31.31 (16.13)</td>
<td></td>
</tr>
<tr>
<td>Total amount (min)</td>
<td>524.80 (48.32)</td>
<td>539.88 (48.20)</td>
<td></td>
</tr>
</tbody>
</table>

1 Residual scores were used to partial out influence of each diastolic and systolic level.

Note: all df = 1,11; ****p<.001, *** p<.005, ** p<.01, * p<.05, +p<.1

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**Folkard et al. 8 reported that night shift paralysis (equivalent to sleep paralysis) occurred most often during the night shift, with a peak occurrence at 05:00. In the current study, ISPs were almost equally distributed across 21 hours of the experiment. These differences seem to reflect a different distribution of SOREMPs based on the protocols. SOREMPs are usually facilitated by an increase in the REM propensity, which is regulated by circadian factors. Therefore, it allows us to speculate that sleep paralyses reported in the former study were facilitated by SOREMPs that...**
followed a natural circadian course. In contrast, ISPs in the current study occurred from SOREMPs that were artificially induced throughout the experimental period (Table 3) of the MPS in accordance with our goal to elicit as many SOREMPs as possible. Therefore, it can be suggested that the relationship between ISPs and time is mediated by the occurrence of SOREMP.

Other Conditions Predicting ISPs

Considering the fact that SOREMP does not always entail ISP, SOREMP is a necessary but not sufficient condition for ISP. Thus, there must be further factors leading to ISP occurrences in addition to SOREMPs. Carskadon et al. observed a high frequency of SOREMPs (79 of 110) from five participants using the 90-minute sleep-wake protocol yet they explicitly mentioned that no hallucinations or sleep paralysis episodes were reported. Likewise, no ISPs have been reported in any experimental studies examining SOREMPs with non-24-hour sleep/wake patterns with non-narcoleptic participants, (e.g., a free-running schedule, a shifted sleep-wake schedule, and a multiple sleep/wake schedule). Partial sleep deprivation, and a standard procedure of the Multiple Sleep Latency Test, in studies using questionnaires, ISP episodes are hypothesized to be associated with sleep disruption, REM deprivation or jet-lag syndrome. Given that no ISPs have been observed in the various protocols listed above, these specific sleep-wake patterns are likely to be a secondary correlate of SOREMP episodes rather than a direct determinant of ISP appearances, as Fukuda has suggested.

In the current MPS, we modified the Sleep Interruption Technique (SIT) to elicit a maximal number of SOREMPs and ISPs. In the SIT, parameters for the timing to awaken participants such as duration of the preceding NREM period and interruption and circadian phase are manipulated to systematically elicit SOREMPs during sleep onset following the interruptions in normal participants. Considering the fact that ISPs have been experimentally elicited only with use of the SIT in previous and current studies, we would expect that there are some distinct components of the SIT that promote ISPs, (i.e., one-hour sleep interruptions with a VT and an interaction with individual responses to the MPS). These components will be considered individually below.

Sleep Interruptions Preceding SOREMP

We hypothesized that some specific conditions in the interruption period prior to SOREMP would affect ISP. The delay in VT reaction time observed before SOREMP with ISP suggests a lower performance level preceding ISP experiences. Other measurements related to the VT tended to show consistent changes in terms of a potential for “lapses,” such as more napping and lower hit rates preceding ISPs. Similarly, other objective measurements were in a similar consistent direction: shorter sleep latency and weaker grip strength before ISPs. However, there were no consistent changes in subjective evaluations of state, such as tiredness and sleepiness. These findings suggest that some physiological components underlying “physiological lapses” during the interruption might reflect specific physiological precursors of SOREMP as a prerequisite state of ISP appearances.

REM sleep has been reported to be “fragile” under unfamiliar stressful exogenous conditions. For instance, there is evidence of reduced paradoxical sleep latencies and REM rebound when rats are stressed, and a missed first REM period in the first night effect. Moreover, some REM sleep components are observed before clear stage REM appears, such as heart rate variability, suppression of sweating effector activity, and cortical process of N300 attenuation, which can occur up to 15 minutes prior to REM sleep. The fact that ISP shows a similar dissociation pattern of REM sleep—simultaneous appearances of awakening EEG, atonia, rapid eye movements, and participants’ awareness of their surroundings—it may be that some of these REM components appear during or even prior to participants’ falling asleep. In particular, it is interesting to speculate that the delay in reaction times on the VT observed before SOREMP with ISP might reflect “lapses” caused by physiological mechanisms related to REM sleep atonia.

The MPS and Sleep Structure

There was also a decrease in SWS and longer sleep latencies. However, there was no significant main effect of time on amount of REM sleep in spite of the fact that amount of REM sleep is known to increase later in the sleep period as a result of circadian influences. This is similar to the finding that REM sleep episodes were likely to appear mainly between 7:00 to 14:00 during a 90-minute sleep-wake protocol while they appeared mainly between 3:00 to 8:00 on baseline nights. One possible interpretation for delayed REM appearances over time during the MPS would be due to a cumulative REM propensity attributed to the procedure itself. In the current study, amount of REM sleep in the early part of study was only 33.3 minute (ISP) and 31.31 minute (non-ISP) respectively (Table 3). Thus, partial REM deprivation by repeated sleep interruption might have led to the extended REM appearance in later part of the MPS.

Interaction Between Individual Differences and the MPS

We also examined whether any specific traits characterized participants who did and did not show ISPs during the experiment. In both the ISP and non-ISP group, a decreased number of physical and mental complaints and level of fatigue were observed over time. Increased sleep latencies seem to reflect accumulation of sleep amount in the later part of the MPS. It suggests that participants’ physical and mental feelings were subjectively improved by decreased physical sleep debt over time. However, the number of main effects of ISP suggested that the ISP group had further detriments reflected in poorer performance, more complaints, less improvement of subjective fatigue and less efficient sleep compared to the non-ISP group. Furthermore, interactions observed between time and ISP suggest that performance level in the ISP group kept dropping in accordance with their consistent subjective sleepiness throughout the MPS, whereas the non-ISP group showed a consistent performance level and less subjective sleepiness in the later part of study. Thus, despite the fact that all current participants were selected based on the same criteria (frequency of past ISP experience), the ISP and non-ISP groups responded differently to the MPS schedule. This may mean that there were individual differences in “tolerance” as one endogenous potential factor for ISP appearances when they were exposed to the MPS as an exoge-
nous factor. This notion supports the findings obtained in a previous study\(^4\) that respondents who experienced night shift paralysis in their survey were likely to be less tolerant of changes in sleep schedule. Drawing on the finding that sleep paralysis appeared primarily during the night shift after a morning shift, Folkard & Condon\(^4\) suggested that a relationship between individual sleep type and difficulty in coping with specific shift work patterns accounts for the occurrence of sleep paralysis. Therefore, it may be possible that participants who showed ISPs during the MPS had endogenously less tolerance for the MPS schedule than the participants who did not show ISPs. Such “inflexibility” in adapting to the external conditions may have caused more stress and less efficient sleep. As a result, these conditions were likely to promote REM dissociation in SOREMP, which appeared as ISP during the MPS. Further investigation including genetic predispositions to ISP that may be reflected in the individual differences in response to this type of schedule will give more a more complete explanation regarding the crucial conditions to observe ISP.

**Conclusion**

Our current results using the MPS reaffirmed previous findings that SOREMPs are a prerequisite condition for ISP. Delayed VT reaction times prior to ISPs may reflect “physiological lapses” related to REM atonia as a result of REM dissociation caused by sleep disruption. The participants who showed ISP during the MPS showed poorer performance, more complaints as well as less efficient sleep over the entire schedule compared to the participants who did not show ISPs. Furthermore, performance levels in the participants who showed ISPs kept dropping parallel with their increased subjective sleepiness throughout the MPS, whereas the participants who did not show ISP maintained consistent performance levels and less subjective sleepiness later in the MPS. Taken together with previous findings, these results support the suggestion that ISP is a phenotype of REM dissociation when participants with low tolerance for sleep disruption are placed in this type of sleep-wake schedule.

**ACKNOWLEDGMENTS**

We thank Pat Moore and Dr. Tore A. Nielsen for their useful comments and suggestions with this manuscript.

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