Impact of Motivation on Multiple Sleep Latency Test and Maintenance of Wakefulness Test Measurements

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Background: The Multiple Sleep Latency Test (MSLT) and Maintenance of Wakefulness Test (MWT) are standard clinical tests used to measure sleep tendency in clinical populations in which test results may lead to significant life change for patients. Loss of a driving license or drug seeking may provide significant motivation to patients to obtain needed results on these tests. In the current study, the effect of motivation on the ability to fall asleep or stay awake was examined.

Methods: Twelve subjects spent 3 nights and the following days in the laboratory. On the day following the first laboratory night (screen), subjects performed an MSLT and 40-minute MWT with normal test instructions. On the second or third day, subjects were randomly motivated to appear as sleepy as possible (i.e., to fall asleep rapidly) on all of the tests. On the other day, subjects were motivated to be wakeful. The subject with the "best" performance in modifying their sleep latency was paid a bonus as the motivation.

Results: For the MSLT, latency was significantly longer than baseline in the Wakeful condition. For the MWT, latency was significantly shorter in the Sleepy condition, as compared to baseline.

Conclusions: Subjects have the ability to increase but not decrease sleep latency on the MSLT, and this implies that the MSLT is a better measure of sleepiness rather than alertness. Subjects have the ability to decrease but not increase sleep latency on the MWT, and this implies that the MWT is a better measure of alertness, as compared with sleepiness.

Keywords: Multiple sleep latency test, maintenance of wakefulness test, sleepiness, motivation, sleep disorders


The Multiple Sleep Latency Test (MSLT) and Maintenance of Wakefulness Test (MWT) are standard clinical tests used to measure sleepiness and alertness. The tests are often used to determine whether patients are alert enough to be allowed to drive. There is evidence that these tests are valid measures of sleepiness, but several recent studies have shown that the MSLT is also sensitive to various stimuli that increase central nervous system arousal. For example, it has been shown that MSLT values are longer in insomnia patients (who have higher arousal, as measured by heart rate) than MSLT values are after subjects have walked for 5 minutes. MSLT values are longer if subjects are asked to fall asleep while reclining at a 45° angle. MSLT values are longer if subjects are asked to lie in bed and stay awake. Such findings imply that the ability to fall asleep in laboratory settings may be dependent upon a range of physical and motivational factors. Both of these tests have been proposed as measures of underlying sleep tendency in clinical populations in which test results may result in the loss of a job, the loss of a license to drive, or diagnosis of a lifelong medical condition treated with potential drugs of abuse. Such outcomes may provide significant motivation to patients to obtain needed results on these tests. Unfortunately, little is known about the impact of motivation on the ability to fall asleep or stay awake on these tests.

One previous study has examined the effect of motivation on the MSLT by providing an incentive for normal subjects to fall asleep more quickly on an MSLT. In that experiment, subjects were able to fall asleep significantly more quickly during 1 of the 3 nap attempts (at 3:00 pm), but the average sleep latency across the day was only 1 minute less in the fall-asleep-quickly condition (not significant).

The current study was designed to be able to examine the use of motivation to either increase or decrease sleep latency in both MSLT and MWT paradigms. In this experiment, subjects took the MSLT and MWT tests under baseline conditions. On another day, they retook the tests under instructions to appear as wakeful as possible. On a different day, they retook the tests under instructions to appear as sleepy as possible. Subjects participated with the knowledge that the individual subject who was most successful at staying awake longer on the wakeful day and the individual who was most successful at falling asleep on the sleepy day would receive a participation bonus (motivation).

Disclosure Statement
Drs. Bonnet and Arand have indicated no financial conflicts of interest.

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MATERIALS AND METHODS

Subjects

Potential subjects were healthy, 18- to 35-year-old men and women without significant history of shift work or benzodiaz
Table 1—Daytime Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
<td>Breakfast</td>
</tr>
<tr>
<td>8:30 AM</td>
<td>MWT</td>
</tr>
<tr>
<td>9:40 AM</td>
<td>MSLT</td>
</tr>
<tr>
<td>10:30 AM</td>
<td>MWT</td>
</tr>
<tr>
<td>11:40 AM</td>
<td>MSLT</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:30 PM</td>
<td>MWT</td>
</tr>
<tr>
<td>1:40 PM</td>
<td>MSLT</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>MWT</td>
</tr>
<tr>
<td>3:40 PM</td>
<td>MSLT</td>
</tr>
</tbody>
</table>

Subjects were not used. Potential subjects using more than 250 mg of caffeine per day (more than three 8-ounce cups of instant coffee or 5 caffeinated soft drinks or cups of tea) were excluded. Selected subjects denied problems with their sleep. Specifically, they reported that their sleep latency was less than 30 minutes and that they were not bothered by frequent awakenings or early morning awakening. They did not usually take naps on weekdays. They reported that their usual time in bed on weekdays was between 7 and 9 hours. Individuals meeting these criteria and expressing an interest in participating in the study were invited to the laboratory to complete the informed consent and be scheduled for the study.

Design

Subjects spent 3 nights in the laboratory. On the following days, subjects remained at the laboratory to take part in an MSLT protocol and an MWT protocol. The daytime schedule is summarized in Table 1. During this day, subjects were fed breakfast and lunch (caffeinated beverages were not available) in the laboratory. Subjects were free to leave the laboratory after the final test. Most subjects were employed or students and therefore participated in the study on weekends. Typically, subjects would complete the first and second nights and days on 1 weekend and the final night and day on the following weekend. On the second and third days, subjects participated in 2 experimental conditions that were determined in a counterbalanced random order (ie, 6 subjects had one condition first and the other subjects had the second condition first). On one day, subjects were told that they were to appear as sleepy as possible on this day, and this meant that they were to fall asleep as rapidly as possible (short of causing themselves pain or discomfort) on all of the tests during the day. They were told that the subject (of 12 to participate in the study) who was able to fall asleep most quickly during the entire day would receive a $200 bonus at the end of the study. On the other day, subjects were told that they were to be as wakeful as possible on the tests. Subjects were told that they could not cause themselves pain or physical injury to stay awake, that they were not allowed to use muscle tone (hanging head out of the bed, jaw clenching, movement of arms or legs, etc.), and that their position and muscle tone would be monitored. If these activities occurred, they were told that the test would be started over.

All subjects were assigned their own room for the course of the study. Each room contained a standard hospital bed and furniture, including a desk with an Apple II GS computer. Subjects participated in the study in groups of 1 to 2 individuals. Subjects completed questionnaires at their individual computer workstation under technician observation. Meals were scheduled in another area of the laboratory that was also within technician observation.

Caffeinated beverages were not available.

All protocol and nap times cited in this paper were specified for a subject who normally went to bed at 11:00 pm and arose at 7:00 AM. However, some subjects normally went to bed somewhat later (or earlier) than these times based upon their stated weekday sleep times on the sleep questionnaire that they had completed when initially volunteering for the experiment. Therefore, bed time and wake-up time were adjusted to approximate normal weekday times for each individual subject so that subjects were able to continue to maintain their typical routine with circadian shifts. Sleep-laten
ty tests were correspondingly moved to maintain similar circadian timing for all subjects following all nights. However, subjects were chosen to normally spend about 8 hours in bed, and time in bed for all study nights for all subjects was 480 minutes.

Sleep recordings (from electroencephalogram sites left eye - A1, right eye - A2, C3 - A2, and O2 - A2, as specified by Rechtschaffen and Kales, chin electromyogram, electrocardiogram; and time code) were made during nocturnal sleep periods and sleep latency evaluations. All sleep and nap recordings were scored in 30-second epochs using Rechtschaffen and Kales criteria. Sleep latency was defined as time from lights out to the first epoch of any stage of sleep on all polysomnographs and sleep-latency tests. On the first night, a standard clinical polysomnogram, including 2 eye channels, central and occipital electroencephalogram channels, chin and leg electromyogram channels, electrocardiogram, airflow, chest movements (2 channels), and SaO2, was performed. Subjects with an apnea-hypopnea index greater than 10 or a periodic leg movement arousal index greater than 10 were disqualified.

The schedule of sleep latency tests is presented in the Table. MSLT and MWT observations alternated across each day so that both tests could be conducted at approximately normal intervals and circadian times during the study. The order of tests was the same for all subjects on all days. The MSLT followed standard research guidelines3 with subjects awakened at the first appearance of sleep spindles, K-complexes, or rapid eye movements. Subjects were put in bed 5 minutes prior to the MSLT start time to allow adequate time for calibrations and correction of any recording problems. Similar methods were used to prepare subjects for the MWT. For the MWT, subjects sat in bed and leaned against a foam wedge pillow that supported the upper body and head at approximately a 60° angle (for additional detail see Bonnet and Arand) with a dim room light to the side of the subject. The 40-minute version of the test was used, and the test was ended after either 40 minutes or with the same electroencephalogram/telemetry criteria that were used for the MSLT.

Analyses

The major outcome variable in this study was sleep latency on the MSLT and MWT across conditions. Repeated measures analysis of variance with effects for condition (Baseline, Wakeful, Sleepy) and time was performed with the hypothesis that there would be main effects for Condition. When nonsignificant interactions were found, data were pooled to test the main effects. Pairwise comparisons were performed with the Newman-Keuls test at the .05 significance level using the Huynh-Feldt corrected degrees of freedom. All reported results in the text refer to statistically significant differences (p < .05), except where noted otherwise.
RESULTS

All 12 subjects (5 women) who enrolled in the study completed the experiment. No subject had sleep apnea or periodic limb movements. The subjects were 23.5 years of age (range 21-25 years).

Nocturnal Sleep

Because subjects had undisturbed sleep on all laboratory nights, differences in nocturnal sleep parameters other than possible first-night adaptation effects were not expected. Analyses of the nocturnal sleep data by experimental condition did show 1 significant effect. Total sleep time was significantly reduced on the first study night (adaptation) compared with the night prior to the demand to appear sleepy ($F_{1,31} = 4.43, p < .05$). Condition means for total sleep time were 421, 442, and 434 minutes on adaptation (prebaseline), prior to the Sleepy day, and prior to the Wakeful day, respectively.

Multiple Sleep Latency Test

The analysis of variance for the MSLT showed a significant main effect for Condition ($F_{2,31} = 6.42, p < .005$) without a significant interaction. These data are plotted in Figure 1. Condition means and SD were 10.9 (6.6), 11.2 (6.2), and 14.6 (6.9) minutes, respectively for Baseline, Sleepy, and Wakeful conditions. The 14.6-minute latency was significantly longer than both of the others.

Maintenance of Wakefulness Test

The analysis of variance for the MWT showed a significant Condition-by-Time interaction ($F_{1,18} = 2.25, p < .05$). These data are plotted in Figure 2. Condition means and SD were 26.6 (12.8), 11.6 (8.4), and 21.3 (13.4) minutes, respectively, for Baseline, Sleepy, and Wakeful conditions. Latencies in the Sleepy condition were significantly shorter than in both of the other conditions at all time points. Latency in the Wakeful condition was significantly shorter than the Baseline condition at times 10:30 AM and 2:30 PM. However, the overall means for these conditions were not significantly different.

Means from the 40-minute MWT were not directly comparable with the MSLT means because the length of the tests differed. However, it was possible to simulate a 20-minute MWT from the 40-minute MWT data by analyzing only the first 20 minutes of the MWT. By doing this, it was possible to compare sleep latencies from the baseline MWT to the MSLT with the Wakeful demand (as these conditions could be viewed as similar). This analysis of variance showed a significant main effect for condition ($F_{1,31} = 8.46, p < .01$) without a significant interaction. The Baseline MWT latency mean (17.1 minutes) was significantly longer than the Wakeful MSLT latency mean (14.6 minutes). It was also possible to compare the Baseline MSLT value with the MWT with the Sleepy demand. This analysis of variance showed a significant condition by time interaction ($F_{1,31} = 3.07, p < .05$). However, pairwise comparisons showed no significant mean differences between the 2 conditions at any time point (the overall respective means were 10.9 and 10.4 minutes).

DISCUSSION

The terms sleepiness and alertness are essential concepts in sleep disorders research but have been defined in many ways. It is relatively easy to specify objective sleep latency in electroencephalographic terms, but, unfortunately, objective sleep latency is also dependent upon subjective motivation and a number of other internal and external parameters. The MSLT was developed as a measure that was supposed to minimize factors other than underlying sleep-system effects (process S) and circadian effects (process C). Because the MSLT has been found to have smaller than expected responses to therapy in very sleepy people and has not been thought to be representative of workplace conditions, the MWT was developed as a more representative measure. However, the MWT measures a combination of sleep-system effects along with procedural effects, including sitting position, light, and a different intention. Recognition that these variables play a significant role in sleep latency implies that other variables may also play a role in the determination of sleep onset. Both the MSLT and MWT have standard instructions that are given to participants. However, because there are no direct measures of physiologic response to these instructions or physiologic
measures of the actual motivations that patients may bring to the test environment, the current study sought to vary and examine how contrary motivational sets that could exist in patients would modify standard sleep-latency test results. The results of this study show that it is possible for subjects to increase their sleep latency on the MSLT, probably by varying their intention to sleep, in a way that would not be noticeable to technical personnel. However, subjects were not able to significantly decrease their MSLT latency. One report in the literature did show a significant decrease in latency on an MSLT at 1 nap attempt (3:00 PM) in subjects motivated to fall asleep quickly, but a significant difference was not found across the entire day (overall, the MSLT was decreased by 1 minute). Harrison et al. speculated that subjects might have been able to fall asleep more quickly with motivation at times of increased sleepiness (postlunch dip in their study), and data from the current study showed that sleep latency was nonsignificantly shorter than baseline in the MSLT with the Sleepy demand condition for the first and fourth nap. These times corresponded to a morning time (9:40 AM) not tested by Harrison et al. and the final nap, which was found to have a significantly shorter latency in the Harrison et al. study. Together, these results might support a marginal ability to decrease sleep latency at some points, but the amount of reduction was small and would not have moved subjects near the range of pathologic sleepiness in either study.

The data are stronger in showing that motivated subjects can increase their MSLT latencies. This replicates an earlier study that explicitly used MWT instructions in an MSLT environment (ie, lying down in the dark) and found a significant increase in sleep latency. As such, the MSLT is not the best measure of alertness and might be a poor measure of treatment response, since a patient who wishes to get his driver's license back would be motivated to produce longer sleep latencies without any underlying treatment improvement.

The results are also consistent in showing that it is possible for subjects to decrease their sleep latency on the MWT, probably by varying their intention to fall asleep, in a way that would not be noticeable to technical personnel. However, subjects were not able to significantly increase their MWT latency in this study. It should be noted, however, that care was expended to be sure that participants did not use movement or muscle tone (which can be detected by a careful technician) because these means almost certainly could be used to increase latency on the MWT. The implication is that the MWT, with careful technician observation, is an adequate measure of alertness (ie, ability to stay awake) but that it is not the best alternative to measure sleepiness. However, with the exception of diagnosing narcolepsy, current clinical interest is generally directed toward the ability to remain awake, rather than the ability to fall asleep, in sedentary situations. The current data suggest that the MWT is a better choice than the MSLT for measuring alertness because it is less affected by motivation from the participant.

The mean increase in the MSLT with the Wakeful demand was about 3.7 minutes. In terms of effect size, this increase would be considered moderate (effect size was 0.54). However, even small increases in MSLT are considered clinically significant, as can be seen by the report that a significant increase in MSLT of approximately 1 minute, found when modafinil was given to individuals with shift work sleep disorder, was used to support the use of this therapy for these patients. The mean decrease in the MWT with the Sleepy demand of 15 minutes is both numerically larger and representative of a much larger effect size than is the MSLT finding (effect size was 1.42). The effect size was not reduced in the data set with the MWT terminated at 20 minutes, so this effect is not related to the length of the test. A recent review from the American Academy of Sleep Medicine concluded that a reasonable normal value for the MWT 40-minute test was 30.4 ± 11.2 minutes; that a patient with a 10-minute latency (in comparison with the 11.6-minute latency reported in the Sleepy condition for this study) would compare with the lowest 2% to 6% of the normal population; and that "a patient with such a low MSL is not likely 'normal.'"

It might be asserted that the current results do not apply to patients because they are based on data from normal young adults. Of course, it would be of value to replicate the current findings in patients with narcolepsy, but it is also important to realize that some patients who appear at sleep disorder centers, such as those seeking stimulant medication, may actually be normal adults. In addition, the norms that are typically used for the MSLT and MWT have primarily been constructed based upon experience with normal sleepers. Therefore, knowledge of effects of motivation in normal individuals is an important first step.

Additional analyses in the study showed that sleep latency was significantly longer on the baseline MWT as compared with the MSLT with the wakefulness demand. This implies that the additional arousal in the MWT protocol from the upright position and room light account for the longer MWT latency. However, by the same reasoning, sleep latency after the baseline MSLT should have been significantly shorter than the sleep latency after the MWT with the sleepy demand. This was not found. One reason for this might have been a tendency for subjects in the MWT with the sleepy demand to close their eyes (thereby eliminating stimulation from light in the room).

A number of studies have suggested that there are many internal and external factors in addition to amount of lost sleep and circadian time that influence sleep latency on these tests. Improved diagnostic capability is dependent upon understanding of the various sources of arousal in the environment and controlling as many factors as possible. These data have shown that participants cannot shorten latencies on the MSLT and cannot increase latencies on the MWT based upon the level of motivation provided in this study. This suggests that the MSLT is a more appropriate test to measure how quickly one can fall asleep, whereas the MWT is a better measure of the ability to remain awake. The clinician must assess each clinical situation to determine whether the interest is to demonstrate how rapidly a patient can fall asleep or to demonstrate how long the patient can remain awake. The choice of the MSLT in the former situation and the MWT in the latter situation can help control internal motivational factors that may be present in some patients undergoing sleep-latency testing.

One suggestion that can cover several outcomes would be to perform both the standard MSLT and MWT on the day following the first sleep test for patients with a sleepiness complaint. The MSLT would be used to rule out narcolepsy and the MWT would provide a 'pre-treatment' baseline. After treatment, the MWT could be repeated to assess treatment response (increasing alertness).