INTRODUCTION

MANY METHODS HAVE BEEN DEVELOPED TO MEASURE SLEEPINESS. THE CURRENT STANDARD IS THE MULTIPLE SLEEP LATENCY TEST (MSLT), which measures the objective EEG latency to sleep onset at several discrete times during the day. The MSLT can differentiate several types of partial and complete sleep deprivation occurring on either an acute or chronic basis.1-3,4 The test has also been shown sensitive to sleep fragmentation, time of day, and to several different types of medication.5,6,7 However, the MSLT is relatively less sensitive in extremely sleepy individuals or patients because sleep onset is very rapid and there is little variability in sleep latencies. Some investigators also believe that the ability to stay awake is inherently “different” from the ability to fall asleep and that measurement of the ability to stay awake, as in the Maintenance of Wakefulness Test (MWT), may be more valid when occupational safety is a major concern.7

The MSLT and MWT operationally measure the same thing – latency to sleep onset. It could be hypothesized that the two tests are differentially sensitive to sleepiness (with the MSLT being more sensitive because subjects fall asleep more rapidly). However, both tests typically move in the same direction after manipulations such as sleep deprivation, sometimes the change in MWT is greater than the change seen in MSLT,8 and at least one study suggests that the MWT is actually a more sensitive measure than the MSLT.9 Others believe that the tests measure different abilities (that is falling asleep is a different ability from staying awake). The argument that some people are more skillful at falling asleep has also been used to explain why some non-sleep-deprived individuals characteristically fall asleep more quickly on the MSLT than others. However, there is little data to support these hypotheses. Conversely, there is much data showing that some people have longer latencies on the MSLT9-12,13 secondary to chronic physiological arousal associated with their psychophysiological insomnia. As such, the ability to fall asleep quickly may simply be related to lower arousal. The ability to maintain wakefulness on an MWT is related to both the degree of sleepiness and also to the level of arousal where arousal can be operationally defined based upon posture change,14 trait level of arousal (above), state level of arousal,14,15 or any number of environmental sources of stimulation such as sound8 or bright light.16 In many studies, heart rate has been used as an independent measure of arousal and has been found to be a significant correlate of sleep latency.17,18,19,14,15,8

Several studies have compared MSLT and MWT results with the general conclusion that the MWT may measure somewhat different abilities from the MSLT.20,21 It has always been presumed that the longer sleep latencies common in the MWT were based on the specific methodological difference (the instruction to remain awake as opposed to fall asleep) between the tests. This assumption was directly tested and supported in a study22 in which all participants were required to lie in bed in a dark room with their eyes closed and to try to either fall asleep or stay awake. Under baseline sleep conditions, the command to stay awake was associated with significantly longer sleep latencies (17 versus 12.5 minutes). Since this early study, the MWT has evolved as an independent test that is currently performed under different circumstances. It has been suggested that lying in bed in a dark room and trying to stay awake is an unrealistic measure of typical situations requiring sustained alertness, so several differ-

Study Objectives: The purpose of this study was to determine the relative contribution of the instruction to maintain wakefulness versus posture change as major components determining sleep latency in the MWT as compared to the MSLT.

Design and Setting: After adaptation, subjects spent 3 nights and the following days in the laboratory. On each day, Ss had eight sleep latency measurements including four sleep latency tests from two of the following conditions: Lay down and Sleep (MSLT); Lay down and Stay Awake; Sit up and Sleep; Sit up and Stay Awake (MWT); and sit in a chair in front of a Computer and stay awake.

Participants: Participants were 14 young adult normal sleepers.

Interventions: NA

Measurement and Results: Significant differences in sleep latency were found for each condition with respect to all of the others except that the Computer condition did not differ from the Sit-Awake condition. Means for conditions were: Lay-Sleep - 11.1 minutes; Sit-Sleep - 17.7 minutes; Lay-Awake - 21.7 minutes; Sit-Awake - 29.0 minutes; Computer - 30.1 minutes. Correlations between conditions declined as subjects sat up.

Conclusions: The MWT differs from the MSLT by taking advantage of the arousal system (motivation and posture) to maintain alertness (i.e., increase sleep latency). These arousal effects are additive. MSLT results may not always correlate well with MWT results because the MWT measures the combined effects of the sleep and arousal systems while the MSLT, in ideal situations, measures only sleepiness.

Key words: Sleep; arousal; MSLT; MWT; heart rate; sleep disorders; sleepiness
ent variants of the MWT have been proposed. The current MWT is performed with participants sitting in a dimly lit room trying to stay awake, usually with eyes open. The evolution of the MWT to represent a more normal waking environment has therefore added several additional arousal components to the test. Recent work with the MSLT\(^{19,15}\) has shown that measured sleep tendency itself is not a pure measure of sleepiness. Studies have shown that several sources of arousal ranging from background music to sitting up to a five-minute walk prior to the test significantly increases sleep latencies\(^{8,19,14}\). At another level, ground music to sitting up to a five-minute walk prior to the test sleep tendency itself is not a pure measure of sleepiness. Studies of these studies is that the MSLT demonstrates a combination of the level of underlying sleepiness plus the level of state and trait arousal. As ideally administered, major sources of external environmental stimulation are minimized in the MSLT by performing the test in a quiet, dark, comfortable bedroom. In comparison, the MWT, as currently administered, reflects a situation that essentially incorporates sources of external stimulation which should independently increase sleep latencies. Unfortunately, the exact impact of these sources of external stimulation has not been systematically investigated. It is known that typical values reported from the MWT in normal individuals are in the range of 30 minutes.\(^{23}\) However, Harte et al.\(^{22}\) reported latencies of 17 minutes when only asking Subjects to try to stay awake during an otherwise typical MSLT procedure. It is possible that the sympathetic activation associated with the upright posture and light adds an additional 13 minutes to the sleep latencies.

The intent of the current study was to determine the impact of instruction and posture on measured sleep tendency, to determine whether these arousal components are additive in their effect, and to determine whether heart rate, an independent measure of arousal, also varies systematically with the conditions.

**METHODS**

**Subjects**

Subjects (Ss) were required to be healthy, 18—50 year-old males and females. Potential Ss were solicited from research referrals and from ads in the local papers for participants in sleep research. Individuals considered further completed a screening questionnaire that indicated that they had normal sleep with rare daytime naps and no current history of night work. Selected Ss did not consume excessive caffeine (more than 250 mg of caffeine per day) and had not used psychoactive medications within the previous year. Potential Ss who had histories strongly suggestive of circadian desynchrony (e.g. shift workers), sleep apnea, or periodic leg movements were excluded.

Subjects meeting the above criteria were invited to participate in the study after completing an informed consent and practice on computer tests and questionnaires to be used in the study.

**Design**

After completing the consent, subjects were scheduled for an adaptation night. On this night, a standard clinical polysomnogram, including two eye channels, central and occipital EEG channels, chin and leg EMG channels, EKG, airflow, chest movement (two channels), and SaO\(_2\) was performed.\(^{24,25}\) To qualify for the study, subjects were required to have a sleep efficiency of more than 85%. Subjects with an apnea/hypopnea index greater than 10 or a periodic leg movement arousal index greater than 10 were disqualified.

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 IIGS computer. Subjects participated in the study in groups of one to two individuals. Subjects completed tests and questionnaires at their individual computer workstation in their room under technician observation via video monitors. Meals and breaks were scheduled in another area of the laboratory, which was also within technician observation. Ss performed computer tests, completed an MMPI and a sleep history, and were fed the same daily menu of food prepared at the lab during the day. Caffeinated beverages were not available. Ss usually did not leave the lab during this day and did not engage in vigorous activity.

**Table 1—Daytime schedule**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>07:00 - 07:10</td>
<td>Practice tests</td>
</tr>
<tr>
<td>07:10 - 07:40</td>
<td>Breakfast</td>
</tr>
<tr>
<td>07:40 – 07:50</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>07:50 – 08:00</td>
<td>Computer Tests*</td>
</tr>
<tr>
<td>08:10 – 08:55</td>
<td>Sleep Latency Test A</td>
</tr>
<tr>
<td>09:00 – 09:10</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>09:05 – 09:15</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>09:15 – 10:00</td>
<td>Sleep Latency Test B</td>
</tr>
<tr>
<td>10:15 – 10:20</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>10:20 – 10:30</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>10:30 – 11:15</td>
<td>Sleep Latency Test A</td>
</tr>
<tr>
<td>11:30 – 11:35</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>11:35 – 11:45</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>11:45 – 12:30</td>
<td>Sleep Latency Test B</td>
</tr>
<tr>
<td>12:30 - 12:50</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:50 – 12:55</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>12:55 – 13:05</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>13:05 – 13:50</td>
<td>Sleep Latency Test A</td>
</tr>
<tr>
<td>14:05 – 14:10</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>14:10 – 14:20</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>14:20 – 15:05</td>
<td>Sleep Latency Test B</td>
</tr>
<tr>
<td>15:20 – 15:25</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>15:25 – 15:35</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>15:35 – 16:20</td>
<td>Sleep Latency Test A</td>
</tr>
<tr>
<td>16:35 – 16:40</td>
<td>Electrode check/replace</td>
</tr>
<tr>
<td>16:40 – 16:50</td>
<td>Computer Tests</td>
</tr>
<tr>
<td>16:50 – 17:35</td>
<td>Sleep Latency Test B</td>
</tr>
<tr>
<td>17:35</td>
<td>Dinner</td>
</tr>
</tbody>
</table>
All protocol and nap times cited in this paper were specified for a S who normally went to bed at 23:00 and arose at 07:00. For Ss who normally went to bed somewhat later (or earlier), bed time and wake up time were adjusted to approximate normal weekday times. Testing and sleep latency tests were correspondingly moved to maintain similar circadian timing for all Ss on all nights.

Ss spent three consecutive nights and the following days in the laboratory. The Ss had normal sleep at their habitual times on all nights. During each day, all Ss remained at the laboratory where they took a series of eight naps and performed brief computer tests. The daytime schedule is summarized in Table 1. During each day, Ss were fed standard meals. The daytime protocol was divided into eight blocks (see table). Each block started with electrode checks followed by 10 min. of computer tests including subjective sleepiness (10-point visual analog scale), Profile of Mood States (POMS), and oral temperature. The computer tests were used to assure that all Ss had the same level of physical inactivity and surround prior to the sleep latency tests because it has been shown that preceding activity can influence sleep latency. Consequently, these mood and temperature data were not analyzed. The computer tests were followed by a sleep latency test (see below).

Sleep recordings (LE - A2, RE - A2, C3 - A2, OZ - A1, V5 - right clavicle, 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 polysomnograms and sleep latency tests.

Sleep Latency Tests

On each of the three days in the laboratory, the Ss had eight sleep latency tests. Four sleep latency tests from two of the conditions described below alternated across each day. The condition for the sleep latency tests was the independent variable in this experiment. The five conditions were:

1. Lay in bed and fall asleep (traditional MSLT)
2. Lay in bed and stay awake
3. Sit up in bed and fall asleep
4. Sit up in bed and stay awake (traditional MWT)
5. Sit in a high back chair watching a computer screen saver pattern and stay awake

For all conditions, the bedroom door was closed, the overhead room light was turned off, external light was blocked, and a dim light 10 feet to the side and behind the head end of the bed was illuminated (the light intensity was 4 lux measured at the pillow). For the sit up in bed conditions, a commercial bed wedge was placed at the head of the bed with the point toward the ceiling so that Ss could lean back against the wedge (about 30 degrees past perpendicular) with support for their head. The high back chair allowed similar head support but the degree of tilt past perpendicular was less. All sleep latency observations were continued for 45 minutes (to control for any effect of length of test) or until the appearance of sleep spindles, k-complexes, or rapid eye movements.

On each day, Ss were assigned to two of the five conditions described above. The first 12 Ss were assigned to the first four conditions described above in a Latin Square design for the first two days. These Ss were all assigned to condition 1 (traditional MSLT) and condition 5 on the third day. This assignment allowed examination of the effect of repeating the MSLT (to rule out adaptation or sleep satiation effects). The final two Ss had condition 1 (standard MSLT) and condition 5 on the first and a random order of conditions 1—4 on the second and third days. All Ss completed all five of the conditions listed above and repeated the first condition on another day.

**EKG Data Collection**

Throughout the daytime test sessions, EKG data were digitized by a National Instruments NB-MIO-16 AD Board sampling at a rate of 500 samples per second. A time code was digitized by a second channel on the AD board and also printed out on the polygraph paper to allow second by second matching of digitized EKG with sleep stages and events. The EKG and time code data were recorded through a Grass Braintree system running Gamma software.

After collection, the EKG and time data were visualized and checked for artifacts with the Gamma software and output to a separate peak detection program used to construct the tachogram and associated time code. Mean heart interbeat intervals for consecutive five-minute periods of wakefulness during the sleep latency tests will be reported.

**Analyses**

Data were analyzed by repeated measures ANOVA with terms for sleep latency condition (Conditions 1—5 above), time of test (four times of day) and interaction. 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 will refer to statistically significant differences (p < .05) except where noted otherwise.

**Results**

Fourteen Ss—age 29 (sd 6.3), weight 148 pounds (sd 32), and BMI=24 (sd 4)—completed the study. Nine Ss were female. The Ss’ reported weekday bedtimes and wake times were 24:00 (sd 1.3 hours) and 07:54 (sd 1.0 hours) respectively (range of bed times and wake times was 22:30—02:00 and 06:00—10:00). Lab scheduled bed times and wake times were 23:54 (sd 1.1 hours) and 08:00 (sd 0.6 hours) respectively (range of bed times and wake times was 22:30—01:00 and 06:30—09:00). The only Ss taking prescription medication were three females who were using birth control pills.

**Sleep Data**

EEG data from the study were consistent with normal sleep on all nights. No sleep efficiency was below 85% on any study night. Sleep stages were consistent and sleep efficiency was high and constant throughout the study (95.6, 95.9, and 96.1 on the three respective study nights).
Correlations between the averaged MSLT values and the other conditions were: Sit and Sleep = 0.481 (p<.01); Lay and Wake = 0.697 (p<.05); MWT = 0.287 (NS); Sit at Computer = 0.665 (p<.05).

The correlations between the two MSLT days was r=0.622 (p<.05). The correlations between the averaged MSLT values and the other conditions were: Sit and Sleep = 0.481 (p<.1); Lay and Wake = 0.697 (p<.05); MWT = 0.287 (NS); Sit at Computer = 0.665 (p<.05).

The Pearson correlation between the two MSLT days was r=0.622 (p<.05). The correlations between the averaged MSLT values and the other conditions were: Sit and Sleep = 0.481 (p<.01); Lay and Wake = 0.697 (p<.05); MWT = 0.287 (NS); Sit at Computer = 0.665 (p<.05).

**Figure 1—** Multiple Sleep Latency Test means with standard error of the mean for the five sleep latency conditions. The mean sleep latencies for the respective conditions were: MSLT = 11.1 (s.d. 6.9); Sit and Sleep = 17.7 (9.9); Lay and Wake = 21.7 (10.2); Sit and Wake = 29.0 (12.2); and Sit at Computer = 30.1 (13.7). Conditions marked with * differ from all others. Conditions marked with ** differ from all conditions not marked with **.

**Sleep Latency Data**

Data from the repeated MSLT days were examined first to determine any significant impact of order in the experiment. The ANOVA comparing the first day of standard MSLT to the last day of Standard MWT had no significant F-values. The main effect F-value for day (first day of MSLT versus second day of MSLT) was F1,13=0.465 (NS). Respective daily means were 11.7 (7.7) and 10.5 (6.5) minutes. The data were therefore averaged to form the MSLT condition for the condition ANOVA reported below.

Sleep latency data for the five conditions are plotted in Figure 1. The time of day by condition interaction was not significant (F12,156=1.21, NS) so data were pooled to test the main effects. Large, consistent main effects were found for both nap condition (F4,220=31.11, p < .001) and time of day (F3,207=9.20, p < .001). Newman-Keuls pairwise comparisons indicated that mean latencies in all of the nap conditions differed significantly from all others with the exception of the difference between the sitting in bed awake condition and the sitting at the computer condition. Pairwise comparisons also indicated that latencies were significantly longer in the final latency test during the day compared to all other times (average latencies across the four tests were 21.2 [sd 10.5], 19.2 [sd 12.3], 20.6 [sd 13.8], and 26.8 [sd 13.3]).

Correlations between the conditions were also calculated to address the issue of independence of the sleep latency measures. The Pearson correlation between the two MSLT days was r=0.622 (p<.05). The correlations between the averaged MSLT values and the other conditions were: Sit and Sleep = 0.481 (p<.1); Lay and Wake = 0.697 (p<.05); MWT = 0.287 (NS); Sit at Computer = 0.665 (p<.05).

It was common for the sleep latency tests in the MWT and Computer conditions to last for the entire 45-minute test period. Twenty-seven of 56 tests (48%) were terminated by time in the Computer Condition, and 23 of 56 tests (41%) showed no sleep in the MWT Condition. Very few tests reached 45 minutes in the other conditions. In the MSLT, only 4 of 112 tests (3.5%) went for 45 minutes without sleep; in the Lay-Wake Condition, 7 of 56 tests went for 45 minutes (12.5%); and, in the Sit and Sleep Condition, 6 of 56 tests went for 45 min (10.7%). Two Ss accounted for 10 of the 17 45-minutes latency tests in these latter three conditions. These two Ss also had 45-minutes tests on 15 of their 16 total MWT and Computer latency tests. One other S had 45-minutes tests on all 8 of his MWT and Computer latency tests. This S also had one 45-minutes test in the other three conditions. This data implies strong within subject consistency in sleep latency across all of the variations of sleep latency examined.

**EKG Data**

The average interbeat intervals from the first and last five-minute segments of wakefulness of each sleep latency test from the three days were entered into a repeated measures ANOVA with terms for First or Last five-minute period of wake (2 levels), Condition (5 levels) and Time of Day (4 levels).

There were no statistically significant interactions in the ANOVA. The main effect for first versus last heart period observation was not statistically significant (F1,13=1.22, NS). The main effects for Condition and Time were both statistically significant. The respective F-values were F4,369=25.67 (p<.0001) and F3,359=39.79 (p<.0001). The mean heart period data were converted to heart rate for easier presentation and are plotted in Figure 2. Heart rate was significantly higher when Ss sat in front of the computer as compared to all other conditions. When Ss sat up in bed and remained awake, heart rate was significantly higher than in all other conditions except the Sit-Computer Condition. Pairwise comparisons also indicated that heart rate at the first latency test was equal to that in the third latency test. Both of these heart rate values were higher than heart rate at the fourth test, which was also significantly greater than heart rate during the second test (average heart rate across the four tests was 70.9 [sd 8.2], 66.8 [sd 7.5], 71.6 [sd 7.6], and 68.9 [sd 7.2]).

**Correlations**

To further assess the relationship of level of arousal and sleep latency, three sets of within-subject correlations were computed. To determine the independent relationship of heart period and sleep latency with the conditions of the experiment, the conditions of the study were rank ordered based upon the hypothesized level of arousal during the sleep latency test. The MSLT tests were given a rank of 1 (lowest arousal), and the Computer Condition was given a rank of 5 (highest arousal). The MWT was given a rank of 4. The Lay and Wake and the Sit and Sleep Conditions both had one (different) component of arousal and were therefore both given the tied rank of 2.5. Spearman rank order correlations were then performed between the rank arousal level and a) sleep latency and b) the mean heart period in the first five minutes of each test within each S. All of the 14 correlations (i.e., one for each S) between arousal level and sleep latency were positive (binomial probability p = .0001), and the average corre-
Arousal Components, MWT, and MSLT—Bonnet et al

The current study was designed within a framework that posits

**DISCUSSION**

Historically, the MSLT and MWT have been viewed as measures of sleep tendency. Both tests have been repeatedly shown to be sensitive to sleep deprivation and sleep reduction. More recently, these tests have also been shown sensitive to changes in both state and trait arousal in several experiments.8,19,14 This means, for example, that sleep latencies are longer when Ss have walked prior to a sleep latency test than when they have rested in bed prior to the test.19,15 despite the fact that their prior sleep was the same. These studies have also shown significant correlations between heart rate, used as a measure of arousal level, and sleep tendency.

Sleep latencies measured by the MSLT and the MWT have always been found to be quite different numerically. An understanding that level of arousal has an impact on measured sleep tendency could offer a compelling explanation of the different sleep latencies reported for the MSLT versus the MWT. In the current study, the instruction and position methodological differences between the MWT and MSLT were specifically examined to determine their individual contributions to sleep latency.

The current data indicate, as expected, that Ss placed in a standard MWT design (sitting in a lit room trying to stay awake) will be able to maintain wakefulness for a significant period of time. Doghramji et al,23 in a normative study of the MWT, reported an MWT value of 32.6 (s.d. 9.9) in a group of normals somewhat older than the current group (age 48) with a finding that MWT values increased somewhat with age. Nonetheless, the 32.6 min value does not differ significantly from the 29.0 value from the current study, and this indicates that the MWT methodology from the current study was probably reasonably similar to that in standard use for MWT tests of 40 minutes or longer.

Hartse et al.22 in an early study of the MSLT with the command to either fall asleep or stay awake, found sleep latencies of 12.5 minutes in a traditional MSLT. This value agrees closely with the value of 11.1 minutes in the current study. This comparison is important because the Lay and Sleep Condition in the present study was conducted with a dim light, another possible source of arousal, in the room. Having eyes closed, however, may have minimized this source of arousal. The Hartse et al. data22 are also relevant because they included a condition in which Ss were required to lay in bed in the dark with their eyes closed and stay awake. That manipulation increased sleep latencies by 4.5 minutes. In comparison, in the present study, sleep latencies were increased by 10.6 min when Ss were asked to lay in bed and stay awake. It is probable that the additional stimulation/arousal associated with having open eyes and dim light in the room was sufficient to account for the additional six minutes of sleep latency in the current Lay and Stay awake condition as compared to the Hartse et al. stay awake condition.

Data from the current study along with data from Hartse et al.22 and Doghramji et al.23 are listed in Table 2 to allow assessment of the contribution of various sources of arousal in the determination of sleep latencies. Based entirely upon the Hartse et al. study, the command to stay awake increased sleep latency by 4.5 min. Sitting up (current study) increased latencies by seven minutes regardless of whether Ss were trying to fall asleep or stay awake. Allowing Ss to keep their eyes open with dim light in the room seems to add about five minutes (comparing data from Hartse et al. to the current study). The effect of these various sorts of arousal appear to be additive. For example, the request to Lay and stay Awake increased sleep latency by 11 minutes over the standard MSLT; the request to Sit up adds seven minutes to the standard MSLT; and, therefore, these values imply that the request to Sit and stay Awake should add 11+7=18 minutes to the standard. It was found empirically in the Sit and stay Awake (MWT) Condition that Ss did in fact take exactly 18 minutes longer to fall asleep than in the standard MSLT.

The current study was designed within a framework that posits

**Table 2—** Sleep latency values from selected studies

<table>
<thead>
<tr>
<th>Condition</th>
<th>Latency</th>
<th>Difference from MSLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSLT</td>
<td>11, 12.5*</td>
<td></td>
</tr>
<tr>
<td>Awake, dark, eyes closed</td>
<td>17*</td>
<td>4.5*</td>
</tr>
<tr>
<td>Sit-Sleep</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Lay-Awake</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Sit-Awake</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Sit-Computer</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>MWT Norm</td>
<td>33**</td>
<td></td>
</tr>
</tbody>
</table>

*Hartse et al.22
**Doghramji et al.23

![Figure 2—Heart rate means with standard error of the mean during the Sleep Latency Tests. The mean heart periods, when converted to heart rates were respectively 67.2, 66.8, 67.6, 68.7, and 72.0 beats per minute for the respective conditions MSLT, Lay-Wake, Sit-Sleep, Sit-Wake, and Sit-Computer. Conditions marked with * differ from all others.](image-url)
that the difference between the MSLT and MWT is based upon changes in physiological level of arousal. The current study controlled for prior sleep, time of sleep latency test, length of sleep latency test, and the criterion of sleep onset in the test. Heart period was measured as an independent indicator of level of arousal. The heart period data varied significantly with the conditions of the experiment: heart rate was highest in the condition hypothesized to be most arousing (Computer); heart rate was significantly lower in the second most arousing condition (MWT); and heart rate was significantly lower than these two conditions in the remaining three conditions. In terms of sleep latency differences between conditions, the difference between the MWT and Computer Conditions appeared relatively small (and was not significantly different). However, it is likely that sleep latencies in both the MWT and computer conditions were limited somewhat by the large number of tests in which sleep did not appear (“ceiling” effect). Without this effect, differences in sleep latency between the MWT and Computer Conditions might have been as large as the effect seen in heart rate. In addition, the correlation data showed that 13 of 14 Ss had the predicted relation of shorter heart period (higher heart rate) with more arousing condition. In replication of earlier studies, a significant correlational relationship was also found between heart period and sleep latency.

The relationship between heart period and study condition is significant and meaningful, but it is not as strong as the relationship between sleep latency and study condition. This could indicate that there is “more” to the differences in sleep latency than can be attributed to the effect of arousal. However, the opposite viewpoint—that sleep latency is simply a much more sensitive measure of basal arousal level than heart rate—is more compelling. Heart rate is well-known to respond to many physiological and psychological variables which may be independent or even contrary to basal arousal level. For example, in the current study there was a significant time of day effect for heart rate, but that effect (higher in the first nap than in the second and higher in the third nap than in the fourth) is directly related to metabolism. Heart rate increases in response to the work of digestion. It is increased in the first nap because that nap follows breakfast. Heart rate is increased more in the third nap because of the circadian effect and the fact that the third nap followed lunch (see, which the current finding replicates). When the effect of digestion is taken into account, it can be seen that heart rate is higher in the afternoon, on average, than in the morning as would be expected from a circadian rhythm. However, even demonstrating a circadian rhythm from heart rate might be difficult without knowledge of the other physiological demands on the heart.

It has been concluded in some previous experiments that the MSLT and MWT seem to measure somewhat different abilities. This would be expected if the MSLT were a relatively pure measure of sleep tendency and the MWT measured sleep tendency plus several components of arousal. If the arousal system is independent of the sleep system, tests including substantial arousal components in addition to sleepiness would be expected to differ from tests only measuring the sleep system. Correlations from the current study offer marginal support for this contention. MSLT results were significantly correlated with prior MSLT results, with the Lay-Wake Condition, and with the Sit at Computer Condition. Correlations between the MSLT and the Sit-Sleep Condition and the MWT Condition were not statistically significant. This tends to suggest that arousal associated with the upright posture may decrease the relationship except that the Sit-Computer Condition also included sitting.

The data from this study show that many stimuli make independent contributions to increase arousal and overcome the effects of the sleep system even during sedentary activities. The Maintenance of Wakefulness Test entails much more than just the intention to stay awake. Asking individuals to stay awake accounts for only a small increase in time awake and helps explain why individuals can fall asleep while driving, especially at night. At one level, the data attest to the importance of environmental control during tests of sleepiness or alertness—ever subtle changes in MSLT or MWT environment may provide additional stimuli to prolong wakefulness. At another level, identification of the impact of individual activities and stimuli upon the ability to maintain wakefulness is crucially important in the field of Industrial Psychology. The design of any industrial or educational environment should be based upon empirically identified sources of arousal so that alertness can be maintained at an optimal level in that environment. Arousal must be sufficient to maintain alertness based upon the type of work performed and the work schedule. The identification of specific components of arousal and empirical determination of this impact upon alertness could help maximize performance in many areas especially during sedentary activities like working with computers, monitoring systems, or attending in class, lectures, or meetings.

REFERENCES

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