Changes in Cognition and Mood Due to Sleep Inertia After 30-hour Sleep Deprivation

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Citation

Abstract
Objective: To discuss the changes in objective cognition and subjective mood due to sleep inertia (SI) during a siesta after 30-hour sleep deprivation (SD).

Methods: This study was designed to investigate in eight healthy young males: 1) sleep structure during sleep periods using polysomnographic (PSG) monitoring and 2) self-ratings of alertness and reaction scores in cognitive tasks repeatedly assessed after sleep episodes. The battery of tests included a verbal working memory test, spatial working memory test, logical thinking test, and visual analog scale (VAS) tests. Four tests were randomized and administered at an interval of 30 minutes between two test batteries. There were repeated measures under nap and nonnap conditions at noon after 30-hour SD.

Results: Sleep electroencephalography (EEG) showed characteristics of slow-wave sleep (SWS) when participants were awakened from a one-hour nap after 30-hour SD and deep sleep waves (especially stage III) were the main components. Results by analysis of variance (ANOVA) with repeated measures indicated that dissipation of SI had influences on cognition and subjective mood. Cognitive performance and positive mood increased under the nap condition while they decreased or remained unchanged under the nonnap condition.

Conclusions: This study suggests that a nap improves positive moods factors but it does not improve objective cognition.

INTRODUCTION
Sleep inertia (SI) is defined as “a period of transitory hypovigilance, confusion, disorientation of behavior, and impaired cognitive and sensory-motor performance that immediately follows awakening” (1). Researchers believe that the transition from sleep to wakefulness is such a complex process that it takes some time to adjust from one state of consciousness to another.

SI is regarded as an important component in several models of alertness and performance (2, 3, 4, 5, 6). It integrates the influence of two other major components (7): a 24-hour circadian component with a sinusoidal shape; and a homeostatic component which increases exponentially during wakefulness and becomes reversed during sleep. There is also a wakeup component, Process W (8), which accounts for the fact that people take some time to wake up properly. The magnitude and/or the time constant of dissipation of SI might increase as a consequence of sleep deprivation (SD).

Sleep structure plays a crucial role in SI. Sleep and awakening balance are interrupted when SD increases. The quality of sleep depth is based on slow wave sleep (SWS) quantity and the physiological state when the individual is awakened. When SD increases sleep depth, cognitive ability can be degraded after the participant’s awakening. Also, there are differential effects of rapid eye movement (REM) and non-REM (NREM) sleep stages on performance upon awakening (9). Abrupt awakening during a SWS episode produces more SI than awakening in Stage I or II, with REM sleep having intermediate effects on SI (10, 11). Therefore prior SD usually enhances SI since it increases SWS. To study this, a variety of methods have been adopted in research studies including simple motor tasks (12), sensory-motor tasks (13, 14, 15), and cognitive tasks (16).
While SI has been incorporated in several models of sleep and vigilance regulation, only some attempts have been made to experimentally quantify its time course. SI has been generally reported to be short-lasting, ranging from 1-20 minutes (1). Achermann and colleagues (1a) have studies SI topics for many years. When measuring alertness and operation ability during SI, they found that SI lasts about one hour and it starts to abate by the exponential function form after forty-five minutes for alertness and thirty minutes for performance. However, a study by Jewett and colleagues (17) measuring subjective alertness and cognitive throughput, found that SI dissipated in an asymptotic manner and took two to four hours to approach the asymptote. Most awakenings occurred at the REM stage.

Some researchers used physiological instruments to provide further neurophysiological understanding. Takahashi and Arito (1a) also performed some studies on SI. Their results showed that SI prolongs the P300 latency immediately after naps, and that the parasympathetic predominance during naps might improve subsequent alertness which can be assessed by shortened P300 latency three hours after a nap. Ferrara et al. (1b) assessed auditory evoked potentials (AEPs) before sleep and upon three awakenings during an undisturbed baseline night and compared them to AEPs during a night characterized by a recuperative increase in the amount of SWS as a consequence of two consecutive nights of selective SWS deprivation. They found that the N1-P2 amplitude and to a lesser extent, the N1 latency, were sensitive in showing a state of brain deactivation during the sleep-wake transition. The decrease of N1-P2 amplitude at the parieto-occipital locations during recovery was consistent with the hypothesis of a functional link between the SWS amount and cortical hypopausal upon awakening. However, further research is necessary before drawing an unanimous conclusion due to different sensitivity of measurements, different testing times, and lack of additional research in this area. The deterioration of various task performances during sleep inertia have been studied and catalogued (2a), but few studies have focused on whether SI is influenced by circadian rhythms.

As reported in the above-mentioned studies, the difference in SI duration and time-course might be due to some relevant methodological differences between them, such as a different awake time. Van Dongen and Dinges considered that these differences might result from placing sleep at different circadian phases or varying the duration of sleep and/or wakefulness and could have important implications for design and interpretation of experiments (20, 21, 22). Differences in reported results could also be due to possible differential sensitivity of the performance tasks used to assess SI.

In emergencies or military crisis, SD is a common phenomenon and can result in fatigue, loss of battle effectiveness, and depletion of manpower. A nap is an effective countermeasure against SD. Napping may facilitate work that requires extended wakefulness, such as night and shift work, emergency operations, or space flights. Naps can also improve subsequent performance or prevent decreases in performance (e.g. (21, 24, 25, 26)). However, if one is required to perform complex tasks immediately after sudden awakening at an unpredictable time, the negative effects of SD during sustained operations must be compared with the negative effects of SI on abrupt awakening from sleep due to a possible emergency.

In the present study, we evaluate effects of nonnap or one-hour nap at noon after 30-hour SD on cognitive performance and subjective mood. We investigate SI using both objective measures of performance and subjective assessment of sleepiness and mood. These objective and subjective measures were administered at a high frequency during the hour after the sleep opportunity period. It is generally assumed that changes in cognitive performance and subjective mood occurring in the time period after awakening reflect recovery from SI.

**METHODS**

**PARTICIPANTS**

Eight healthy male volunteers (mean age ±SD: 23.4 ± 1.6 yr) were involved in the study. They were recruited through advertisements. All participants were paid for their services. Participants were informed and consented to the study. None of them had a history of neurological disease, sleep disorder, or other psychiatric disorders. They had regular work and rest. Within the past six months, none had experienced any special events, and their physical condition was normal.

**MATERIALS**

**POLYSOMNOGRAPHY**

Sleep architecture during sleep periods was examined with polysomnography (PSG) monitoring. Electroencephalography (EEG) signals were high-pass filtered with a time constant of 0.3 seconds and low-pass filtered at 30 Hz. EEG was recorded from Fz, Cz, Pz, and Oz sites, with the left mastoid (A1) as the reference area.
Submental electromyography (EMG) was recorded with a time constant of 0.03 seconds. Bipolar horizontal and vertical eye movements were recorded. Much of the analysis of sleep recordings was based on a good segmentation of the recordings and a classification into different sleep stages (27).

Two channels of referential electrooculogram (EOG) and two-lead electrocardiogram (EKG) were also recorded. Bipolar horizontal EOG was recorded from electrodes placed about 1 cm from the medial and lateral acanthi of the dominant eye, and bipolar vertical EOG from electrodes located about 3 centimeters above and below the right eye pupil. Electrode impedance was kept below 5 k.

SUBJECTIVE MOOD AND COGNITIVE MEASUREMENTS

The measurements involved subjective mood tests and cognitive performance tests. Subjective mood tests included visual analog scale (VAS) tests. Cognitive tests included both working memory and logical thinking tests. There were different testing formats: VAS, verbal and spatial working memory tests were computerized tests, while the logical thinking test was a pencil-paper test. For the cognitive tests, the dependent variables (DVs) recorded for each task mainly included reaction times (RTs) and accuracy (i.e., the percentage of correct responses). The tasks in the battery were as follows:

WORKING MEMORY TEST

Working memory tests (19, 20) were administered on a Legend personal computer (Intel® Pentium/256M/40G/ATI 9600SE 128M /15’LCD China). Equipment used included a keyboard and mouse. Participants were positioned about seventy centimeters away from the computer screen and their eyes were at the same height as the center of the screen. The computer screen had a black background during the testing process. The twelve English capital letters from A to L were used as stimuli to test working memory. At the beginning, a white “×” was shown at the center of the screen as a cue. This white “×” lasted about 200 milliseconds. After 1.1 seconds, the cue disappeared and the true stimulus (a capital letter) was shown and remained for 200 milliseconds on the screen. The location of the capital letter was one of the twelve points in two conformal hexagons with one heart. The radiuses of two hexagons were 1 centimeter and 3.5 centimeters respectively (see Figure 1).

LOGICAL THINKING TEST

The logical thinking test is a pencil-paper test. In this test, the order of ten numbers was arranged randomly from 0 to 9. Participants were asked to count the numbers in turn as quickly and accurately as possible. Two neighboring numbers were added quickly, and only the last digit of the results had to be remembered and added to the next neighbouring number and so on. In this process, if the next number was smaller than the last digit of the results, it was skipped until a bigger one appeared. When all the numbers were counted, the results were recorded on the paper. In this test there were twenty trials. The participants were asked to complete the task within 3 minutes.
VISUAL ANALOG SCALE (VAS)

The VAS was part of the SI computerized test battery. The eight items were based upon Smith's research (28) and included: 1) alert/able to concentrate, 2) anxious, 3) energetic, 4) feel confident, 5) irritable, 6) jittery/nervous, 7) sleep, and 8) talkative. Each item of subjective alertness was measured using a 100 millimeters VAS (29), with one end labeled ‘not at all’ and the other end labeled ‘extremely’. Using a mouse or trackball, participants made a mark at the point in which they felt their level of the item was best described. The VAS was then scored as mm from the ‘extremely’ end of the scale.

PROCEDURE

The experiments were conducted in temperature-controlled and soundproof rooms of the sleep laboratory at the Xijin Hospital of the Fourth Military Medical University. To ensure that participants were well acquainted with the tests and to reduce practice effects, the participants practiced each performance test twenty times the day before the study. On the day of the study, participants completed a baseline session with all the five sleep inertia measures.

Participants were required to be familiar with the experiment environment and to practice a little in order to eliminate the practice effects before formal testing. The participants were asked to nap at 13:00-14:00 and their EEG was recorded. The length of the nap was set at 1 hour, according to the Chinese siesta habit. The nap after 30-hour SD in our study was arranged from 13:00 to 14:00, which is the normal sleep habit of most Chinese. These conditions were considered to be beneficial and have a significant effect on SI. In our cognitive experiment, the participants practiced at least twenty times in the day before the formal test until their accuracy rate remained continuously at 80% for three times. In our study, the baseline results were the averages of five tests and the test results were measured every two hours in the first formal test day. The testing times started at 08:00, 10:00, 12:00, 14:00 and 16:00 during the daily routine. (Table 1)

Figure 2

Table 1: Arrangement of Testing Time

<table>
<thead>
<tr>
<th>Session Condition</th>
<th>Start Time</th>
<th>Sleep Time</th>
<th>End Time</th>
<th>Nap</th>
<th>Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nap condition</td>
<td>07:00</td>
<td>10h</td>
<td>13:00</td>
<td>13:00-14:00</td>
<td>14:00-16:00</td>
</tr>
<tr>
<td>Nonnap condition</td>
<td>08:00</td>
<td>10h</td>
<td>14:00</td>
<td></td>
<td>14:00-16:00</td>
</tr>
</tbody>
</table>

We had a self-contrast and repeated measures experimental design. There were eight participants. All participants were required to finish two tests under different conditions. The different conditions included: 1) 30-hour SD and without a nap (nonnap condition); 2) one-hour nap after 30-hour SD (nap condition). They participated in the experiment twice with an interval of 1 week, under two conditions at random (once each). In the nap condition, the participant took a nap at 13:00, and in the nonnap condition, the participant rested without sleeping by sitting on a semi-reclining chair at 13:00.

During the 30-hour SD, participants actions and behaviors were limited to the laboratory. They were allowed light-exertion activities such as reading magazines and watching television. However, they were not allowed to eat or drink any stimulant food or drink (e.g., coffee). The formal tests started at 07:00 in the given nap condition or at 08:00 in the nonnap condition. Tests were arranged every two hours, and in order to avoid the sequence effect, five tests in each battery were randomly arranged.

Standard polysomnography (SW2000 Mingsi Company, China) recorded the sleep EEG of the eight participants for 2 one-hour naps (1 normal, NOR; 1 recovery, REC). During 30 hours of continuous wakefulness, participants were tested every two hours. After one-hour nap from 13:00 to 14:00, participants were tested at 14:00, 14:30, 15:00, 15:30 and 16:00 at a standard illumination condition.

There were a series of tests: 1) cognitive tests that involved the test of successive calculation and working memory tests; and 2) subjective mood tests (VAS). The series of tests were administered five times repeatedly. The series of tests had a randomized immediate order. Each series lasted about ten minutes with an interval of twenty minutes between the two series. Participants were required to remain sober and to avoid any outside stimulation. Except for the one-hour nap, the nonnap condition had the same testing process as the nap condition.

DATA ANALYSIS

For all SI assessments, data in the sessions after the experimental phase were calculated as a deviation from the individual baseline (referred to as relative speed or accuracy). The data were submitted to repeated measures analysis of variance (ANOVA) with the Huynh–Feldt correction for sphericity violation. The ANOVAs used the factors of experiment time (early or late), condition (nap or nonnap), and session (1–5). Because initial analyses showed no significant main effect or interactions involving the factor experiment time, we performed the analyses with the factors...
condition and session. In the case of significant interactions, ANOVAs with the factor session were performed separately for each condition. Planned comparisons with paired or unpaired t-tests were used to test for differences between sessions or conditions when the ANOVAs revealed significant effects. The reported values are means and standard errors.

Because the testing scores were influenced not only by reaction time but also by validity, this study adopted “the number of correct answers / time” as the statistical value for each trial of cognitive tests. The average values of all test results in the first day were taken as the baseline.

SPSS 10.0 was used for the statistical analyses. ANOVA with repeated measures was used to analyze and contrast each trial index. Alpha level for statistical significance was p<0.05. Microsoft Excel of Office 2000 was used to draw the plots for the average value of each trial.

RESULTS

SLEEP VARIABLES

The sleep EEG showed SWS when the participants were awakened from a one-hour nap after 30-hour SD, in which deep sleep waves (especially Stage III) were main components. REM sleep almost disappeared. (Table 2)

Figure 2: EEG of Normal 1-hour Nap Compared with that After 30-hour SD

COGNITIVE TEST PRACTICE EFFECT

Participants were required to be familiar with the experiment environment and practiced the tests to eliminate the practice effect before the formal test. According to the results of Cao’s experiment, in order to eliminate a practice effect, the practice times before formal testing should be more than eighteen (30). There were no significant differences between the best practice results and the baseline results (p>0.05 Table 3), although two of the tests approached significance. This indicates that we reduced possible practice effects for this measure. The data in the complete experiment did not ascend with time but showed a wave trend consistent with the human biorhythm. However, strictly speaking, the practice effect cannot be avoided absolutely. In the study, two participants had an improvement in their test scores. We considered that it might result from further information processing or the change of testing strategy during the later stages.

Figure 3: PSG Scored EEG Parameters During 1-hour Nap After 30-hour SD

Table 2: Comparison of Best Practice Result and Baseline Test Result of Cognitive Tests (n=8)

CHANGES IN COGNITIVE FUNCTION DUE TO SI AFTER 30-HOUR SD

To clarify the nature of a significant interaction term, three two-way repeated measures ANOVA (two-factor analysis of variance for repeated measures) were performed comparing the nonnap condition, the nap conditions and baseline. We found that there were statistically significant differences only for the logical thinking tests. After conducting post-hoc
tests, the results of the logical thinking tests showed that there were significant differences between baseline and the nap condition or nonnap condition, but no statistical differences between the nap condition and the nonnap condition (Table 4). Also, there were significant differences within “session” factors and there were interactions between “trials” (time or session) and “condition” (nap vs. nonnap). In addition, time trend lines were protracted according to the averages of four trials with their baselines as reference. The aim was to observe how participants returned to normal or general states from SI.

**Figure 6**
Table 4: Cognitive Tests Results by Repeated Measure ANOVA

<table>
<thead>
<tr>
<th>Repeated measure</th>
<th>Logical Thinking</th>
<th>Verbal Working Memory</th>
<th>Spatial Working Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>SESSION</td>
<td>4</td>
<td>8.275</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SESSION x CONDITION</td>
<td>8</td>
<td>4.504</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CONDITION</td>
<td>2</td>
<td>4.688</td>
<td>0.032</td>
</tr>
</tbody>
</table>

We protracted plots with the average values of the repeated trial results. On whole, in all cognitive tests, the scores of the nonnap condition had a downturn trend while the nap condition had an uptrend. Both lines in each plot intersected with each other, and the point of intersection was a turn in the course of SI dissipation. From the turning point, the line of the nap condition approached the baseline line but the line of the nonnap condition moved away from the baseline line with time. In the verbal working memory plot, the point of intersection was shown after the third trial, that is over one-hour after being awakened, and almost two hours were spent to arrive at the baseline. In the plot of spatial working memory, the point appeared at 30 minutes. In the successive calculation plot, the point appeared at one hour.

The SI after 30-hour SD had a significant effect on logical thinking and working memory. The negative effect on the spatial working memory test was less significant because it took about thirty minutes to reach the baseline nap levels, while the logical thinking and the verbal working memory test took more than one hour to reach baseline nap levels. (Figures 3-5)

**Figure 7**
Figure 3: Logical Thinking Test

For logical thinking, the performance of participants in the nap condition increased with time. However, that of participants in the nonnap condition did not change much. The results of the nap and nonnap conditions were all significantly different from baseline levels (five test points p<0.01). On the other hand, there were no significant difference between the two conditions.

**Figure 8**
Figure 4: Verbal Working Memory Test

For verbal working memory, the performance of participants in the nap condition increased with time. However, participants in the nonnap condition did not have much change. The average performance of participants did not significantly differ between the two conditions on the five test time points. Compared with baseline levels, the results did not significantly differ at the 15:30 and 16:00 test points in the nap condition, but did significantly differ only at the 14:30 test point under the nonnap condition.
For spatial working memory, the performance of participants in the nap condition increased with time. There were significant differences between the nap and nonnap conditions, but not at the 14:30 and 15:00 test points. The results for the nap condition were higher than that in the nonnap condition after 15:00. Compared with baseline levels, significant difference (p<0.05) was only detected at the 15:30 test point under the nonnap condition.

**CHANGES IN MOOD DUE TO SI AFTER 30-HOUR SD**

There were statistically significant differences in the nap condition, nonnap condition, and baseline for the mood test items measured by the VAS of “alert,” “energetic,” and “sleep.” There were significant differences within “session” factors only for the “anxious” items of the VAS (Table 5).

**Table 5: ANOVA Repeated Measure for the VAS Tests**

<table>
<thead>
<tr>
<th>Session</th>
<th>Alert</th>
<th>Anxious</th>
<th>Energetic</th>
<th>Feeling Confident</th>
<th>Irritable</th>
<th>Flirty</th>
<th>Sleep</th>
<th>Talkative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>df</strong></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>1.285</td>
<td>5.345</td>
<td>0.015</td>
<td>2.167</td>
<td>0.597</td>
<td>0.759</td>
<td>0.504</td>
<td>0.950</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>0.694</td>
<td>0.001</td>
<td>0.495</td>
<td>0.077</td>
<td>0.730</td>
<td>0.555</td>
<td>0.733</td>
<td>0.439</td>
</tr>
</tbody>
</table>

As shown in Table 6, for alert, compared with baseline, there were significant differences on all 5 test points, not only for the nap condition but also for the nonnap condition. For anxious, compared with baseline, there were significant differences only on the first test point after arousal in the nap condition. For energetic, there were significant differences on all 5 test points between the two conditions and baseline. For feeling confident, compared with baseline there were not any significant differences on all 5 test points in the nap condition and at baseline, but there were significant differences at the 14:00 and 15:30 test points in the nonnap conditions. For irritable, compared with baseline, there were significant difference between the two conditions except for the first test time in the nap condition and the first test point and the last test point in the nonnap condition. For jittery, compared with baseline, there were not any significant differences on all 5 test points in the nap condition and at baseline, but there were significant differences at the 14:00 and 15:30 test points in the nonnap conditions. For sleep, there were significant differences on all 5 test points between the two conditions and at baseline. For talkative, compared with baseline there were not any significant differences on all 5 test points in the two conditions and at baseline.

Time-trend plots regarding subjective mood values were drawn. For the nap condition, the measures demonstrated that alertness and positive moods including “talking” and “feeling confident” gradually improved during the testing period. There was no significant improvement for the nonnap condition.

**Figure 11**

Table 6: T-Test For Nap and Nonnap Compared With Baseline For The VAS Tests

<table>
<thead>
<tr>
<th>Alert</th>
<th>Anxious</th>
<th>Energetic</th>
<th>Feeling Confident</th>
<th>Irritable</th>
<th>Flirty</th>
<th>Sleep</th>
<th>Talkative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.6175</td>
<td>0.5505</td>
<td>0.3392</td>
<td>0.0038</td>
<td>0.6274</td>
<td>0.5518</td>
<td>0.5568</td>
</tr>
<tr>
<td>Nap</td>
<td>0.1629</td>
<td>0.0125</td>
<td>0.4952</td>
<td>0.0386</td>
<td>0.6250</td>
<td>0.5512</td>
<td>0.5568</td>
</tr>
<tr>
<td>Nonnap</td>
<td>0.1629</td>
<td>0.0125</td>
<td>0.4952</td>
<td>0.0386</td>
<td>0.6250</td>
<td>0.5512</td>
<td>0.5568</td>
</tr>
</tbody>
</table>

DISCUSSION

The objective of the present experiment was to evaluate the effects of SI after 30-hour SD by analyzing the differences of subjective mood and objective cognitive ability of the participants between nap and nonnap conditions. Furthermore, our main goal was to shed some light on the psychophysiological mechanisms underlying SI and likely to generate the lowered performance usually observed during
Changes in Cognition and Mood Due to Sleep Inertia After 30-hour Sleep Deprivation

During the period of SI, the decline of work performance is to a greater extent than the negative effects of SD. Some researchers (31, 33) suggest that people cannot perform complex tasks in an urgent military operation or industrial condition because of SI. The results of this study show that a one-hour nap after 30-hour SD can impact sleep structure. SWS was the main component in the sleep structure. However, in the first one-hour of nap at noon without SD, the sleep structures were at Stages I and II (34). The mean sleep latency of approximately 14 minutes was in the expected range for healthy participants at this time of day (35). In our research, sleep latency was shortened too, but all for less than ten minutes. These results support the recent research of Tassi (36).

**COGNITIVE TESTS**

**LOGICAL THINKING**

The results are consistent with the research of Jewett and colleagues (37), which highlighted an addition task that showed a sharp rise in the first hour after awakening and began to level off about two hours after awakening. Our results suggest that although SI existed, the nap still had a recuperation function to make up the deficit of calculation ability due to the 30-hour SD. Our study found that there is no significant difference between the nap and nonnap conditions. The possible reasons were: 1) SI is a gradual restoring process over time, and 2) small sample size.

**WORKING MEMORY**

Verbal working memory did not improve until about two hours after a one-hour nap. The same reasons discussed above for logical thinking can apply too. However, for spatial working memory, the test scores had a great recuperation after a nap. Only scores at the first trial (tested immediately after awakening) and at the thirty minutes post-nap were lower than the baseline. The results of this study are different from those of Achermann's study (38), in which they found that SI persisted for slightly less than one hour by assessing reaction times in a memory test. However, our study showed that verbal memory needs more time to restore than the spatial working memory. According to the Level of Processing theory by Craik and Lockhart (39), a has more feature structure than location. We considered that in the cognitive process, that matching letters needs more mental resource than matching locations. This suggests that the verbal working memory test needs more time to restore to baseline than the spatial working memory test. This finding is consistent with Courtney's study (40) that object and spatial visual working memory activate separate neural systems in the human cortex.

In summary, the results of the cognitive function tests showed that cognitive ability including logical thinking and working memory decreased after 30-hour SD. However, the tendency of working memory to change was different at baseline, the nap condition, and the nonnap condition.

**MOOD**

Although many researchers have discussed SI's effects on performance, we still know very little about the effect of mood and the relationship between subjective mood estimates and objective cognitive performance. Our results suggest that the subjective value of “alert,” “energetic,” and “sleep” can be impacted powerfully by SD and is not improved by a nap, whereas that of “talkative,” “feeling confident,” “irritable,” and “jittery” cannot be impacted by SD or SI. The subjective value of “anxious” increases when participants are instantly aroused from a nap.

Under the condition of SD, the results are consistent with those of previous research (41). That study shows that mood changes after a nap differed from those with SD during the same test session. In our study, there was also no significant difference between the two conditions. The nap after 30-hour SD improved the individual mood to some extent, but the scores did not attain to those of baseline. Two possible reasons are 1) with regard to 30-hour SD, a one-hour nap was not strong enough to improve the personal mood affected by 30-hour SD, and 2) an individual's mood needs a restorative process during SI. It also can be suggested that SI delayed the effects of a nap. Our results are supported by the study of Reilly and Piercy (42).

In 2005, Hofer-Tinguely et al. (43) showed that the slowest reaction times showed a significant recovery after 20 minutes. The groups reported similar increases in subjective sleepiness after the experimental period. These findings provide evidence for performance slowing and recovery during the hour following a nap opportunity. They highlight the importance of employing multiple control groups and various objective and subjective measures to assess SI.

**CONCLUSION**

SI is a major factor accounting for changes in human alertness and performance after a period of sleep, but surprisingly little is known about its mechanisms. For example, the physiological underpinnings of SI (44) and the
pharmacological treatment of SI are new exploratory areas (e.g. Ref. (12)). Few studies have investigated SI after daytime sleep. SI after daytime naps is of practical and clinical relevance. For example, daytime napping may help to counteract sleepiness in patients with sleep disorders. This has relevant applications to disciplines including the military, industry, medicine, and any occupation that has a shift work system. Previous researchers paid more attention to cognitive functions and actual working skills. It is important to establish a comprehensive research system of SI. We suggest that the adverse effects of SD on SI magnitude should be avoided by any personnel who may have to perform critical tasks immediately after awakening. Also, although the positive mood factors improved, it does not indicate that a nap can improve the ability to physically function as immediately as one’s feelings improve. We recommend to avoid performing complicated tasks for a short time after individuals are awakened from a nap or sleep.

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