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# The Effects of the Level of Alertness During the Rest Period on Subsequent Performance

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The aim of this study was to examine how to take an effective rest to prevent a decline in alertness at work. The relationship between alertness during the rest period and subsequent task performance were investigated. The electroencephalogram (EEG) during the rest period was classified into 3 types, and these types had a significant effect on performance after the rest period. Type 1 (increasing in theta, alpha 2, and beta 1 power) was the best one for carrying out the task, whereas performance gradually declined in Type 3 (no change in EEG activity). In the case of Type 1, the method that would relieve sleep inertia had a more positive impact on performance after the rest period.

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alertness rest EEG sleep stages sleep inertia

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## 1. INTRODUCTION

Alertness is one of the most important factors to affect human performance and many variables (e.g., the environment, the time of day, the characteristics of the tasks, one's psychological and physiological state) change the level of alertness. Impaired alertness has a negative effect on human performance: Sometimes it causes human errors or accidents. However, continuous monotonous operations in a control room and long-haul driving easily reduce

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operators' alertness (Bonnet & Arand, 2000; Electric Power Research Institute, 1990; Moore-Ede, 1993; Wright & McGown, 2001).

To prevent a decline in alertness, some countermeasures have been studied, such as exposure to bright light (Baker 1995), exposure to sound (Landström, Englund, Nordström, & Åström, 1999), caffeine intake (Bonnet & Arand, 2000), and so forth. Although these methods can help to maintain alertness, there is concern about their negative effects on health because these methods activate one's brain and raise alertness (Monk & Folkard, 1992).

Another countermeasure to prevent a decline in alertness, a short-term rest, which gives one's brain a rest, can be recommended. Nagasaka and Hirose (2000) conducted an experimental study to investigate the effects of a short-term rest using four methods of resting, that is, resting without closing one's eyes, closing one's eyes, listening to music, and sitting in a massage chair with a massage. As a result, the following conditions of an effective rest were established: (a) alertness should be reduced, (b) sleeping during a rest period is especially recommended, (c) sleep should not be deep, (d) to prevent sleep inertia, it is important to use a method that can immediately restore alertness to a proper level after the rest period. As some previous studies proposed that a short nap has positive effects on alertness (Gillberg, Kecklund, Axelsson, & Åkerstedt, 1996; Hayashi, Ito, & Hori, 1999), the aforementioned suggestions are considered to be important conditions for an effective rest. However, the aforementioned previous work did not specify what a suitable level of alertness during the rest period is, whereas few studies refer to the effects of methods that can restore alertness and can also minimize the impact of sleep inertia after the rest.

Then, the objective of the present study is to find a suitable level of alertness. Based on the aforementioned conditions, the relationship between the differences in the change in alertness during the rest period and task performance after the rest period is examined. This study also investigates the effects of the methods that restore alertness on subsequent performance.

## 2. METHODS

### 2.1. Participants

Eight healthy men participated in this study (aged 19–24 years,  $M = 21.4$ ). All of them regularly slept for 6 or 7 hrs.

## 2.2. Procedure

Three visual display unit (VDU) tasks—an addition task, a search task, and a tracking task—were assigned to every participant for 100 min. Two rests—with closed eyes and listening to participants' favorite music with closed eyes—were introduced for 15 min in the middle of the task. The participants were moved to a comfortable chair during the rest period. In half of the experimental conditions, a method that was expected to relieve sleep inertia was introduced immediately after the rest. The method consisted in the participants wiping their faces with cold wet towels and getting a breeze from an electric fan. The duration of this was left to the participants, with most of them spending a minute or two on the method. Every participant was tested in all 12 experimental conditions.

To assess alertness, an electroencephalogram (EEG) was measured from the 12 channels with 10–20 international methods. For psychological measurement, 11 indices of mood (e.g., sleepiness, tension) were inquired about (see Figure 1). Also, subjective introspection was noted after every experiment.

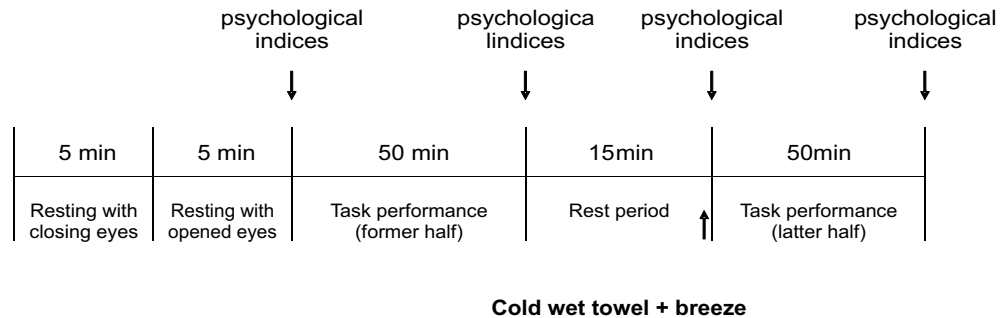


Figure 1. Time schedule of the experiment.

## 2.3. Tasks

In the addition task, the participants calculated the sum of two single figures. They were instructed to calculate precisely and quickly. In the search task, they counted the target number from a 4-line 4-column table within a given time period (2.4 s). In the tracking task, they were required to keep a dot ( $r = 2$  mm) in a circle ( $r = 11.7$  mm) that moved randomly (58.6 mm/s) on a number line.

## 2.4. Data Analysis

As the index of performance, the number of correct answers in the addition task, the correct response rate in the search task, and the success rate in the tracking task were calculated for every minute in the latter half of task performance. Then, these calculated scores were divided by the average of the former half of task performance, and they were averaged at every 10 min.

EEG during the rest period was subjected to a spectral analysis (Fast Fourier Transform on 8-s epochs), yielding the averages of the power in the following frequency bands at every minute: theta (4–7 Hz), alpha 1 (8–10 Hz), alpha 2 (11–13 Hz), beta 1 (14–20 Hz), and beta 2 (21 Hz and over). For analyses, the average of the first minute in each band was used as the baseline.

## 3. RESULTS

### 3.1. Sleep During the Rest Period

In every experimental case, EEG (C3, C4) during the rest period was scored for sleep stages in 30-s epochs using standard criteria (Rechtschaffen & Kales, 1968). Sleep was observed in over 90% of all cases. Although different conditions or participants were involved, no significant differences in sleep parameters were observed.

### 3.2. Classification of EEG During the Rest Period

To classify the transition of alertness during the rest period, cluster analysis was performed at every EEG frequency band during the rest period. Fz was used for the following statistical analyses. All experimental conditions of all participants (95 cases) were analyzed together, because there were no significant differences in any sleep parameter or EEG during the rest period regardless of the kinds of tasks or rests.

Each frequency band could be divided into 2 clusters, and the feature of each 2 clusters was the same at every band: (a) increasing in the power and (b) no EEG activity changed in the power. Then, the relationship between the clusters and the latter half of performance was analyzed by a repeated measure analysis of variance (ANOVA) with repetitions on the average of every 10-min performance. Table 1 shows significant interactions between the clusters and performance in theta, alpha 2, and beta 1 band.

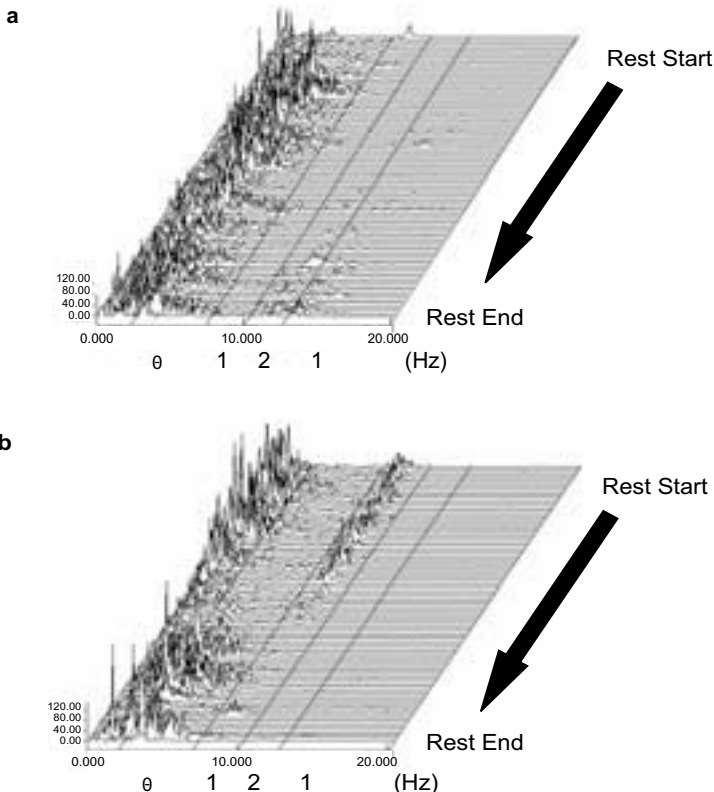
**TABLE 1. Effect of electroencephalogram (EEG) Clusters During the Rest Period on Subsequent Task Performance in Every Frequency Band**

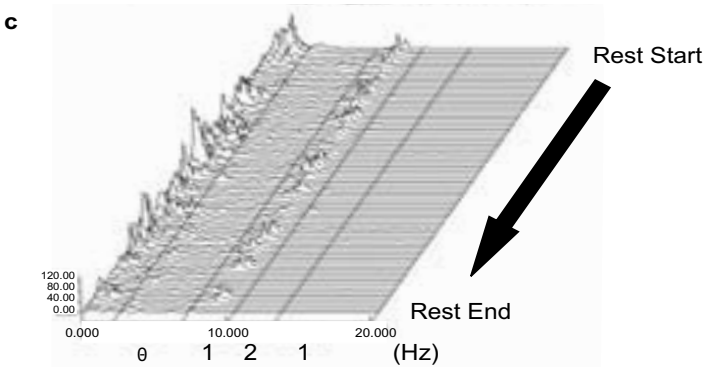
Effect	df	Theta	Alpha 1	Alpha 2	Beta 1	Beta 2
		F	F	F	F	F
Clusters	(1, 93)	5.532 <sup>*</sup>	0.497	9.109 <sup>**</sup>	3.538 <sup>+</sup>	0.174
Performance	(4, 372)	13.640 <sup>***</sup>	11.391 <sup>***</sup>	8.760 <sup>***</sup>	8.140 <sup>***</sup>	10.732 <sup>***</sup>
Cluster × performance	(4, 372)	5.250 <sup>***</sup>	0.701	3.779 <sup>**</sup>	6.112 <sup>***</sup>	0.566

Notes. \*\*\* $p < .001$ , \*\* $p < .01$ , \* $p < .05$ , + $.05 < p < .10$ .

Taking into account those three bands, EEG during the rest period was reclassified into the following 3 types (Figure 2). The cases that did not fit these types were excluded (14 cases):

1. Type 1: Theta power increased rapidly in the first 4 min of the rest, and alpha 2 and beta 1 power gradually increased from the middle of the rest period (27 cases).
2. Type 2: Although theta power was the same as in Type 1, the other bands did not change during the rest period (17 cases).
3. Type 3: No EEG activity changed (37 cases).

**Figure 2.**



**Figure 2. Types of electroencephalogram (EEG) change during the rest period (these figures were obtained from the same participant).** Notes. a—Type 1, b—Type 2, c—Type 3.

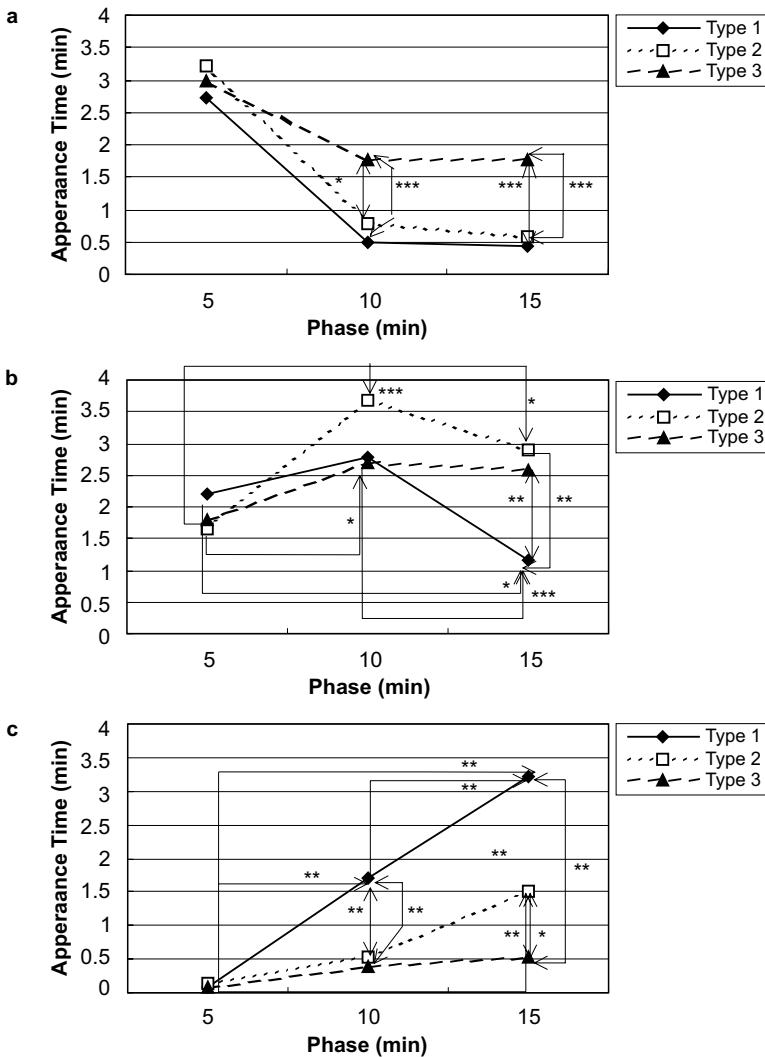
### 3.3. Relationship Between the Types of EEG and Sleep Stages

The difference in the aforementioned types depended on whether or not the participants could sleep during the rest period. Then, using the scored EEG data for sleep stages (see section 3.1), the following analysis was carried out. First, the rest period was divided into 3 phases (every 5 min), and the total time of each sleep stage was calculated in each experimental case. Then, a two-way 3 (types of EEG)  $\times$  3 (rest phases) ANOVA with repeated measures was conducted in each sleep stage (Awake, Stage 1 sleep, and Stage 2 sleep). Both main effects and the interaction of the types and rest phases were significant in all sleep stages (Figure 3). Also, sleep interruption time was significantly different among the types of EEG,  $F(2, 71) = 12.955$ ,  $p < .001$ , one-way ANOVA. Type 3 had longer sleep interruption time than the others.

As a result, the following features were suggested about the relationship between the types of EEG and sleep stages.

1. Type 1: It reached Stage 2 sleep by the middle of the rest period and remained in the Stage until the end.
2. Type 2: It barely reached Stage 2 sleep at the end of the rest period.
3. Type 3: It fluctuated between Stage 1 sleep and Awake (i.e., only drowsy).

Combined with the above classification of EEG, it was suggested that the gradual increase in alpha 2 and beta 1 in Type 1 meant the appearance of sleep spindle that was often observed in Stage 2 sleep.



**Figure 3. Types of electroencephalogram (EEG) change and the stages of sleep (asterisks indicate the results of multiple comparisons). Notes. \*\*\* $p < .001$ , \*\* $p < .01$ , \* $p < .05$ ; a—awake, b—Stage 1 sleep, c—Stage 2 sleep.**

### 3.4. Relationship Between the Types of EEG and Task Performance

To investigate the relationship between these types of EEG and the latter half of performance, a two-way 3 (types of EEG)  $\times$  5 (every 10-min performance) ANOVA with repeated measures was applied. As a result, there was a significant interaction between the types and performance,  $F(8, 312) = 4.394$ ,  $p < .001$ . Multiple comparison (Tukey's HSD method) revealed that a decline



of performance was only seen in Type 3, whereas Type 1 was best for maintaining subsequent performance (Figure 4). No significant differences were obtained among the kind soft tasks.

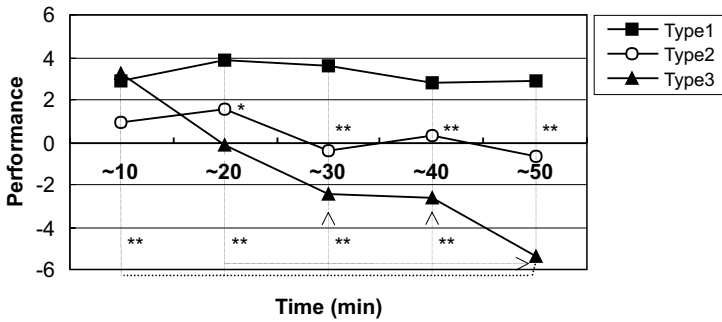


Figure 4. Effect of the types of electroencephalogram (EEG) on subsequent performance (asterisks indicate the results of multiple comparison). Notes. \*\* $p < .01$ , \* $p < .05$ .

### 3.5. A Method That Can Relieve Sleep Inertia

A two-way 2 (with or without towel)  $\times$  5 (every 10-min performance) ANOVA with repeated measures was carried out in each type. As a result, the effect of the method that was expected to restore alertness differed with the types. In Type 1, using the method had a better effect than not using it throughout the latter half of performance: the main effect of the method,  $F(1, 25) = 6.189$ ,  $p < .05$ . Although the effect was just a little time, it was suggested that the method played a role as a countermeasure against sleep inertia in Type 3 ( $p < .05$ , Figure 5).

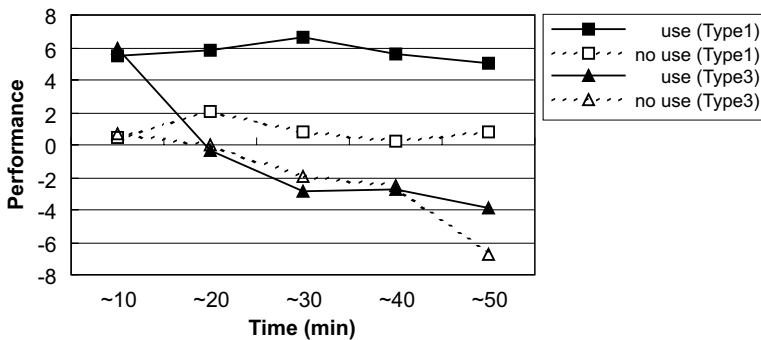


Figure 5. Effects of the method that can restore alertness on subsequent performance by the difference in the types of electroencephalogram (EEG) change.

## 4. DISCUSSION

### 4.1. A Suitable Level of Alertness for an Effective Rest

The results showed that a short-term rest, in the middle of the task, varied by the differences in alertness during the rest period, was more effective in reducing alertness in Stage 2 sleep by the middle of the rest period than no sleep or dozing. The previous study (Nagasaka & Hirose, 2000), which suggested the importance of shallow short sleep during the rest period was supported in this study. The reason why Type 1 is best for a rest depends on whether participants can obtain a sense of sufficient sleep. According to Takahashi (1996), participants whose subsequent performance was significantly improved after a 15-min nap had obtained a sense of sleep during the nap. On the other hand, others who had not napped found their performance could not be improved. Also, it is said that people can obtain a sense of sufficient sleep during a short nap if stable and continuous sleep spindle or slow waves are observed (Hiroshige, 1997). On the basis of the aforementioned, it is suggested that participants can obtain a sense of sleep during the rest period only in the case of Type 1. A sense of sleep could also refresh the body and the mind and increase motivation for subsequent performance. Indeed, there were significant differences among the types of EEG in some psychological indices. The refreshing, the motivated, and the concentrated scores during the latter half of task performance were significantly higher in Type 1 than in Type 3 ( $p < .05$  each). Also, the physical fatigue score during the latter half of task performance was higher in Type 3 than in Type 2 ( $p < .05$ ).

In contrast, it was found that Type 3 was the worst rest for subsequent performance. Not only was there a decline in the performance but it also gave the participants a poor impression. The participants' introspection showed that participants in Type 3 felt sleepiness or a lack of concentration during the latter half of task performance in comparison with the other types of EEG. There was also a weak negative correlation between the latter half of performance and sleep interruption during the rest period ( $r = -.28$ ). Because of the aforementioned reasons, it is suggested that a slight decline of alertness like Type 3 during the rest period is not useful in maintaining subsequent performance or alertness.

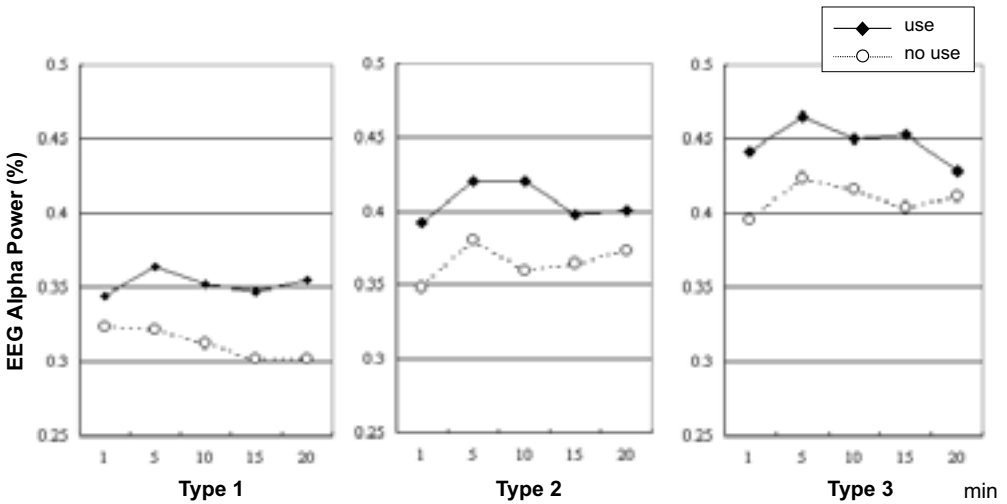
Even though there was no negative effect on the performance, it is supposed that Type 2 is not useful for workers either. As mentioned earlier, it is likely that a sense of sleep was hard to obtain by Type 2 participants because

Stage 2 sleep could not be observed sufficiently in this type. In fact, immediately after the rest period, the “lack of motivation” score was significantly higher in Type 2 than in the other types ( $p < .05$ ).

## 4.2. A Method That Can Restore Alertness After the Rest Period

The results showed that the effect of the method, which was expected to relieve sleep inertia, differed with the types. It was also indicated that cold wet towels and a breeze from an electric fan acted more effectively on the latter half of task performance when the participants could obtain Type 1 rest. To make sure the effects of the aforementioned method, a three-way repeated measure ANOVA was calculated using the first 20-min EEG during the latter half of task performance. As a result, the main effects of the types of EEG during the rest period,  $F(2, 51) = 5.200$ ,  $p < .01$ , and the alpha (alpha 1 + alpha 2) power during task performance,  $F(4, 204) = 3.812$ ,  $p < .01$ , were only significant (Figure 6). With or without the method, the alpha power in Type 1 was significantly smaller than in Type 3 ( $p < .01$ ). Previous studies (Åkerstedt & Gillberg, 1990; Horne & Reyner, 1996) said that an increase in EEG power in the alpha range indicated increasing sleepiness. Then, this result not only indicates the effectiveness of Type 1 rest, but it also means that the transition of alertness during the rest period has a greater effect on subsequent performance than a method that restores alertness. It is well known that slow-wave sleep (SWS) awakenings yield the greatest performance decrements (Ferrara & Gennaro, 2000), however, SWS was not observed in all participants in this study. Judging from that, it is supposed that the method that was expected to raise alertness had little effect on subsequent performance because sleep inertia had little small impact on the participants.

In spite of the aforementioned result, the participants expressed favorable opinions about the cold wet towels. Six out of eight participants chose closing their eyes with using a cold wet towel as the best rest method. Also, the method had a small but positive effect even in the case of Type 3 rest. Those facts indicate that some countermeasures against sleep inertia are needed for workers immediately after the rest period, even if they have no significant effects. Future studies should still look for the most effective method that counteracts sleep inertia regardless of the type of EEG during the rest period.



**Figure 6.** Effects of the method that can restore alertness on the electroencephalogram (EEG) alpha power during the latter half of task performance by the difference in the types of electroencephalogram (EEG) change.

## 5. CONCLUSION

The aim of this study is to propose an effective rest method from the viewpoint of the change of alertness during the rest period. According to the results, in order for a rest to be effective (a) alertness must be reduced to Stage 2 sleep during the rest period as rapidly as possible, and it must remain so until the end of the rest; (b) after taking such a rest, it is more effective to use methods that can restore alertness for promoting subsequent performance. In future, it is planned to seek rest methods that can reduce alertness as soon as possible and that can be applied in all situations and to all workers. Moreover, the best timing for starting a rest, and other methods that will relieve sleep inertia will be taken into consideration.

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