

The recuperative value of brief and ultra-brief naps on alertness and cognitive performance

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SUMMARY The aim of the study was to investigate the recuperative value of brief and ultra-brief naps following nocturnal sleep restriction. Sixteen young adult healthy sleepers participated in a repeated measures design comprising four experimental conditions: no nap, 30-s nap, 90-s nap and 10-min nap. On the evening preceding each laboratory session, participants limited their nocturnal sleep to between 24:00 and 05:00 h. Measures of subjective alertness, objective alertness, fatigue, vigour and cognitive performance were taken before the nap and at several intervals postnap. Consistent with our previous study (Tietzel and Lack 2001), the 10-min nap resulted in significantly improved alertness and cognitive performance relative to a no-nap control. There were no measurable improvements for the 30- and 90-s nap conditions relative to no nap, which suggests that the mechanism underlying the benefits of brief naps does not appear to be the onset of stage 1 sleep. Further research is required to investigate whether the benefits of brief naps are because of the onset of stage 2 or delta wave sleep, or a specific duration of sleep between 90 s and 10 min.

KEYWORDS brief naps, multiple sleep latency test, napping, sleep homeostasis

INTRODUCTION

Initiatives that maximize alertness are particularly pertinent in industrialized societies in which people continue to compromise their nocturnal sleep for work-related, domestic or social pursuits. A brief nap (or 'power nap') is one alertness management strategy that has recently received attention and has been shown to ameliorate the negative effects of sleep restriction. However, despite the considerable industrial and scientific interest in brief naps, the minimum duration of nap sleep required for restoring alertness following restricted nocturnal sleep is yet to be elucidated.

Research has shown that naps of mean durations as short as 19.8 (Gillberg *et al.* 1996), 10.8 (Horne and Reyner 1996), 10.2 (Takahashi and Arito 2000) and 10 min (Tietzel and Lack 2001) improve alertness and/or performance following restricted nocturnal sleep. Additionally, researchers have shown that brief naps of 20 min are also recuperative following normal nocturnal sleep, in terms of improved performance

(Hayashi *et al.* 1999a), electroencephalograph (EEG) indicators of alertness and self-ratings of task performance (Hayashi *et al.* 1999b).

Brief naps have also been shown to be at least as effective as longer naps in improving alertness and performance following normal nocturnal sleep (Takahashi *et al.* 1998) and mildly restricted nocturnal sleep (Tietzel and Lack 2001). Specifically, Takahashi *et al.* (1998) compared a 15-min nap opportunity (mean sleep duration 7.3 min) with a 45-min nap opportunity (mean sleep duration 30.1 min) and observed significantly improved alertness 30 min after the 15-min nap opportunity and comparable improvements for the 15- and 45-min nap conditions 3 h after napping. More recently, Tietzel and Lack (2001) revealed that a brief afternoon nap of precisely 10 min was at least as recuperative as a 30-min nap in terms of improved alertness and performance in the hour following napping.

The converging lines of evidence indicate that brief naps provide an effective solution for ameliorating the adverse effects of nocturnal sleep restriction, and appear to be at least as recuperative as longer naps. These findings present a major challenge to the homeostatic model of sleep (Process S) which posits reduced sleep propensity as a function of delta wave

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activity accrued during the sleep episode (Borbély 1982). Process S would therefore predict greater alertness following longer naps as longer naps comprise more delta wave activity.

The incongruity between existing scientific evidence and Process S warrants consideration of an alternative explanation. Perhaps the operative mechanism determining nap benefits is the onset of stage 1 sleep (Process O) rather than sleep duration and delta wave activity (Process S). The present study aims to test this assertion by comparing naps of 30 s, 90 s and 10 min sleep with a no-nap condition. In accordance with Process O, one would predict an improvement in alertness following the 30-s, 90-s and 10-min naps, compared with no nap (Lack and Tietzel 2000).

In addition to the theoretical implications of the present study, the findings may have methodological implications for sleep research and clinical practice. The multiple sleep latency test (MSLT) is considered the 'gold standard' objective measure of sleepiness in research and diagnostic clinical practice. At the onset of an MSLT trial, an EEG alpha wave baseline level is established. The criterion for sleep onset is commonly taken as three consecutive 30-s epochs below the 50% of baseline level. Thus, it essentially takes 90 s (an 'ultra-brief' nap) to determine whether a person is asleep. If 90 s of stage 1 sleep improves subsequent alertness then subjective alertness ratings, performance and sleep latency trials occurring after the first trial may be confounded. Alternatively, if 90 s of stage 1 sleep does not affect subsequent alertness, then the MSLT may therefore be considered free of this potentially confounding effect.

The practical implications of the present research findings are also potentially enormous. If a nap as short as 30 or 90 s improves alertness and performance following restricted nocturnal sleep, these ultra-brief naps may offer an extremely efficient practical solution for mitigating the adverse effects of sleep loss.

In summary, research has demonstrated that brief naps improve alertness and performance following restricted nocturnal sleep. Nevertheless, the minimum duration of nap sleep required to restore alertness and performance following nocturnal sleep restriction has not been investigated. The present study addresses this deficiency and, in doing so, addresses issues of theoretical, methodological and applied significance.

METHODS

Participants

The sample comprised eight male and eight female university students (mean age = 22.50 years, SD = 3.86) either recruited from the Flinders University Employment Service (each receiving monetary payment of AU \$144.00) or enrolled in a third year psychology practical topic at Flinders University (each receiving topic credit for their voluntary participation). Participants were not regular nappers, were self-reported good sleepers with no history of sleep complaints, and were not

taking drugs affecting sleep architecture. The study received approval from the Flinders University Social and Behavioural Research Ethics Committee. All participants gave informed consent.

Design

Each subject participated in four separate afternoon laboratory sessions, each of which comprised one of four experimental conditions. These were (a) a no-nap control, (b) a 30-s nap, (c) a 90-s nap and (d) a 10-min nap. The order of conditions was balanced to prevent order effects.

Prior to the laboratory session

Participants were instructed to maintain regular bed times and wake-up times for the week prior to the first laboratory session and for the remainder of their participation in the study, except for the evenings immediately preceding the four laboratory sessions. On these evenings, participants limited their nocturnal sleep to between 24:00 and 05:00 h. This sleep restriction was scheduled following at least two nights of normal nocturnal sleep to avoid an accumulation of sleep debt. Compliance to these instructions was monitored with sleep-wake diaries and activity monitors throughout the experimental period. Additionally, on the night before each laboratory session, compliance to sleep restriction instructions was monitored with check-in telephone calls at 24:00 and 05:00 h.

Participants were asked to refrain from consuming alcohol and caffeine for 3 days prior to and including the laboratory sessions, consume a normal size lunch during the hour prior to their arrival at the sleep laboratory, and refrain from vigorous mental or physical activity and smoking for at least 30 min prior to the session.

The laboratory session

Upon arriving at the sleep laboratory at 13:00 h, EEG electrodes were applied for standard bipolar recording from Cz to Oz (with a ground electrode positioned at Fpz). Electrooculograph (EOG) electrodes were applied to the nasion and the outer canthus of the right eye for eye movement recording. Participants were then confined to bed for the duration of the laboratory session. With the exception of nap periods, the bedroom environment was consistently illuminated by a 75-W light globe 1.5 m above the participants' head, producing 50 lux illumination. External time cues were eliminated.

Each laboratory session comprised three periods of testing and two sleep onset latency (SOL) trials. The first testing period was scheduled prior to napping, the second 5 min after awakening (to assess the immediate changes resulting from the nap), and the third testing period was scheduled 35 min after awakening. The prenap SOL measure was the latency to the nap, and the postnap SOL trial was conducted 65 min after awakening. Immediately prior to the postnap SOL trial, the

Stanford Sleepiness Scale (SSS) was administered to participants. Periods of quiet activity (i.e. reading magazines or novels) were interspersed through the laboratory schedule to combat the arousing effects of electrode attachment and testing. In order for the awakening from naps and subsequent testing periods to occur at essentially the same clock time, the time at which participants attempted to initiate sleep was staggered for the different nap conditions. Lights were turned out at 15:00 h for the no-nap, 30-s nap and 90-s nap conditions and at 14:50 h for the 10-min nap condition. The mean time of arousal from all naps occurred at 15:03 h. Fig. 1 illustrates the scheduling of napping and testing during the laboratory session.

Test instruments

The test battery consisted of the SSS (Hoddes *et al.* 1973), fatigue and vigour subscales of the Profile of Mood States (McNair *et al.* 1971), Symbol–Digit Substitution Task (SDST) and Letter Cancellation Task (LCT). The SDST involved showing participants a series of nine novel shapes paired with numbers between 1 and 9. They were then given a random sequence of shapes and were required to substitute the corresponding numbers as quickly and accurately as possible within a 90-s period. The LCT required participants to search for and cross out two target letters in a matrix of alphanumeric stimuli for a 4-min period. The performance measure in both the SDST and LCT was the number of correct responses. Twelve parallel forms of both performance tasks were constructed to provide novel forms for each testing occasion.

Assessment of objective alertness

Sleep onset latency was used to assess objective alertness. An initial SOL measure (the latency to the nap) was compared with a second SOL measure taken 65 min after the nap.

The LabVIEW 5 computer program (National Instruments, Austin, TX, USA) was used to determine SOL and sleep duration. The program calculated EEG power on the alpha (8–12 Hz), theta (4–7 Hz) and delta wave (0.5–4 Hz) bands for each 30-s epoch, with sleep onset determination derived from the alpha band. Following the cessation of delta wave movement artefact, a 50% alpha baseline level was determined for each sleep trial by averaging the amount of alpha for the two epochs with the highest amount of alpha power (generally occurring in the early part of an SOL trial) then dividing by two. This

procedure has been validated with the conventional Rechtschaffen and Kales (1968) sleep scoring criteria for raw EEG and EOG activity (Patrick 1997). From a random sample of 93 SOL trials, Patrick observed a high correlation [$r(91) = 0.93$] between the power spectral analysis criterion and SOL data scored independently by an experienced polysomnography (PSG) technician using the conventional criteria.

Participants in the no-nap condition were aroused before alpha dropped below the 50% alpha baseline level. In the 30-s nap condition, participants were awoken immediately after one 30-s epoch below the 50% baseline alpha level. In the 90-s nap condition, participants were awoken following three consecutive 30-s epochs below the 50% alpha baseline. Finally, in the 10-min nap condition, participants were awoken when they had slept for precisely 10 min (i.e. 20 epochs below the 50% alpha baseline), with SOL determined using a three-epoch criterion. All SOL measures taken 65 min after the respective naps were also determined according to a three-epoch criterion.

RESULTS

Overview of statistical analyses

Data analyses generally comprised a two-way repeated measures analysis of variance (ANOVA) with factors ‘nap condition’ (no-nap, 30-s nap, 90-s nap, 10-min nap) and ‘time’ (prenap, 5 min postnap, 35 min postnap). With regard to subjective alertness, the ‘time’ factor had four levels (prenap, 5 min postnap, 35 min postnap, 65 min postnap). A two-way repeated measures ANOVA was not performed on objective alertness SOL data because there was no prenap data point for the no-nap condition (subjects did not initiate sleep).

To clarify the nature of a significant interaction term, three two-way repeated measures ANOVA were performed comparing the no-nap condition with each of the other nap conditions.

As previous research has shown that a 10-min nap has recuperative benefits following sleep restriction (Tietzel and Lack 2001), specific post hoc exploratory analyses were also conducted to examine the relative effectiveness of the 10-min nap compared with the other three nap conditions.

Preliminary analyses

The mean total sleep times for the evenings of enforced sleep restriction, as indicated by wrist actigraphic data, were

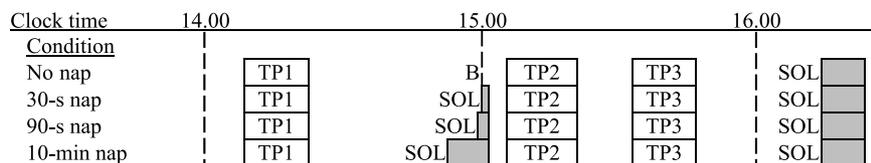


Figure 1. Summary of the experimental protocol. The timing of test periods (TP) and sleep onset latency trials (SOL) are indicated by clock time. The shaded horizontal bars represent sleep. In the no-nap control, the sleep onset trial terminated before sleep onset as indicated as a B for bedtime. TP1, 2 and 3 included testing of subjective alertness, fatigue, vigour and objective performance measures. Subjective alertness was also measured just before the final SOL trial at approximately 16:05 h.

analysed using a one-way repeated measures ANOVA. There was no significant main effect of nap condition, $F_{1,45} = 1.71$, $P > 0.10$, hence the same degree of sleep restriction applied to the no-nap ($M = 4.75$ h, $SD = 0.04$), 30-s nap ($M = 4.64$ h, $SD = 0.06$), 90-s nap ($M = 4.74$ h, $SD = 0.04$) and 10-min nap conditions ($M = 4.69$ h, $SD = 0.06$).

Baseline prenap scores of the six dependent variables were examined for the four conditions using one-way repeated measures ANOVA. Pre-nap values showed no differences between conditions.

Post-hoc analyses were also conducted to examine possible order effects in the SDST and LCT measures. One-way repeated measures ANOVAs applied to prenap scores between the first, second, third and fourth order of administration revealed no significant variation for both the SDST ($F_{3,45} = 0.94$, $P > 0.05$) and LCT measures ($F_{3,45} = 0.23$, $P > 0.05$).

Objective alertness

Fig. 2 shows the change in SOL resulting from the 30-s, 90-s and 10-min naps in comparison with that following no nap.

The one-way repeated measures ANOVA, applied to SOL values of 65 min postnap, showed a significant effect of nap condition, $F(2.01, 30.11) = 6.65$, $P < 0.01$. As there were no differences between no-nap, 30-s and 90-s naps, $F_{2,28} = 0.28$, $P > 0.05$, these three variables were combined and the overall mean compared with the 10-min condition. A paired sample *t*-test indicated that the mean postnap SOL for the 10-min nap condition ($M = 7.47$ min, $SD = 6.63$) was significantly greater than the mean SOL for the other three conditions combined ($M = 3.09$ min, $SD = 2.48$), $t(15) = 3.61$, $P < 0.01$, indicating that the 10-min nap improved objective alertness.

In summary, analyses of SOL data suggest that the 10-min nap improved objective alertness while the 30- and 90-s naps did not.

Subjective alertness

Fig. 3 represents the change in subjective alertness, as indicated by the SSS, for the four napping conditions across

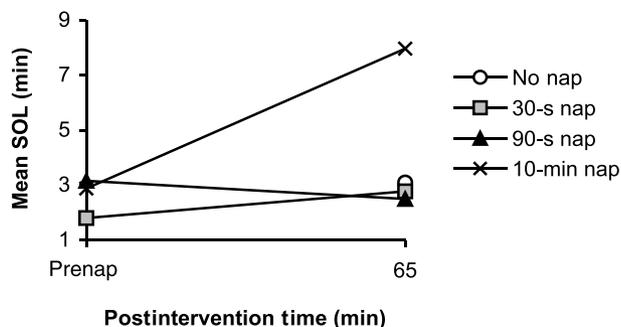


Figure 2. Change in objective alertness (SOL) produced by the 30-s, 90-s and 10-min naps compared with no nap.

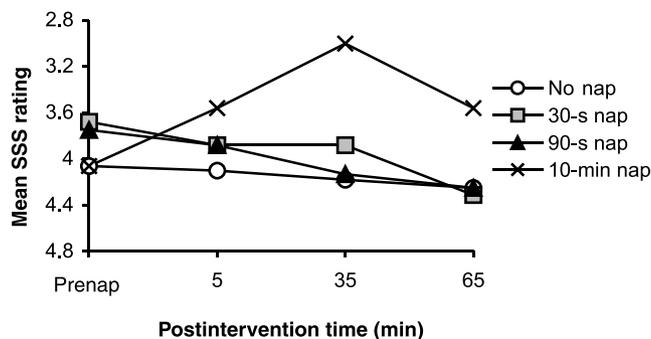


Figure 3. Change in subjective alertness produced by the 30-s, 90-s and 10-min naps relative to no nap, as indexed by mean Stanford Sleepiness Scale (SSS) ratings (1 = most alert).

four measurement time points. The SSS scale is inverted such that reduced sleepiness (i.e. improved alertness) is in the positive direction.

A two-way repeated measures ANOVA indicated a significant main effect of nap condition ($F_{3,45} = 3.13$, $P < 0.05$), a non-significant main effect of time ($F_{1,32, 19.82} = 0.62$, $P > 0.05$), and a significant interaction ($F_{9,135} = 2.89$, $P < 0.01$).

To clarify the nature of the significant interaction term, a series of two-way repeated measures ANOVAs were conducted to compare the no-nap control with each of the other nap conditions. There were two levels on the factor 'nap condition' (e.g. no-nap, 30-s nap) and four levels on the factor 'time' (prenap, 5 min postnap, 35 min postnap, 65 min postnap). There were no significant interactions between the no-nap and the 30-s ($F_{3,45} = 0.82$, $P > 0.05$) and 90-s ($F_{3,45} = 0.62$, $P > 0.05$) conditions. A significant interaction was observed between the no-nap and 10-min conditions ($F_{3,45} = 3.58$, $P < 0.05$).

Post-hoc exploratory analyses were performed to examine the relative contributions of the 10-min nap compared with the other nap conditions. As there were no differences between the no-nap and the 30- and 90-s nap conditions, these three conditions were combined into one variable. Three two-way repeated measures ANOVAs were then conducted to examine the relationship between the 10-min nap and combined nap condition. These analyses revealed a non-significant interaction between the 10-min and combined condition between prenap and 5 min postnap, $F_{1,15} = 3.94$, $P > 0.05$ ($P = 0.07$), and significant interactions between prenap and 35 min postnap, $F_{1,15} = 17.52$, $P < 0.01$, and prenap and 65 min postnap, $F_{1,15} = 7.96$, $P < 0.05$.

It is therefore suggested that the 10-min nap significantly improved subjective alertness relative to the other nap conditions combined, with significant benefits emerging 35 min after the nap, which were maintained 65 min postnap.

Fatigue

Fig. 4 shows the mean fatigue scores for the four nap conditions at the three measurement times (prenap, 5 min

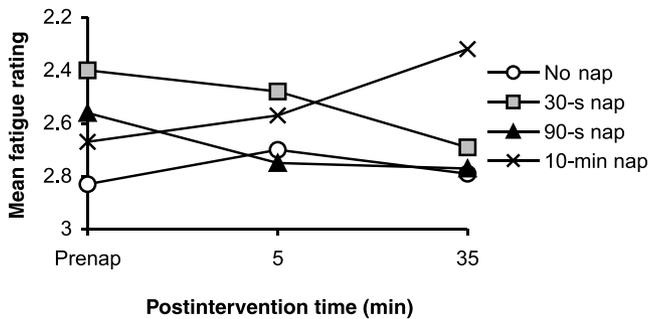


Figure 4. Change in fatigue produced by the 30-s, 90-s and 10-min naps compared with no nap, as indexed by mean fatigue ratings on the Profile of Mood States (1 = least fatigued).

postnap and 35 min postnap). The fatigue scale is inverted such that reduced fatigue is in the positive direction.

Two-way repeated measures ANOVA analyses of fatigue, showed a non-significant main effect of nap condition ($F_{3,45} = 1.20$, $P > 0.05$), a non-significant main effect of time ($F_{2,30} = 0.01$, $P > 0.05$) and a non-significant interaction ($F_{6,90} = 1.64$, $P > 0.05$).

The degree to which fatigue improved following the 10-min nap (see Fig. 4) was examined using post-hoc exploratory analyses. As there were no differences between the no-nap and the 30- ($F_{2,30} = 0.43$, $P > 0.05$) and 90-s naps ($F_{2,30} = 0.80$, $P > 0.05$), these three variables were combined and compared with the 10-min condition. Two-way repeated measures ANOVA, examining the relationship between the 10-min nap and other nap conditions combined, revealed a non-significant interaction between prenap and 5 min postnap, $F_{1,15} = 0.55$, $P > 0.05$, but a significant interaction between prenap and 35 min postnap, $F_{1,15} = 8.49$, $P < 0.05$. These findings suggest reduced fatigue 35 min after the 10-min nap relative to the other conditions combined.

Vigour

Changes in vigour were similar to changes in fatigue; however, none of the analyses showed significant effects.

Symbol-digit substitution task

Fig. 5 shows the change in SDST performance across three measurement time points.

The SDST yielded non-significant main effects of nap condition ($F_{3,45} = 1.51$, $P > 0.05$) and time ($F_{2,30} = 1.74$, $P > 0.05$) and a non-significant interaction ($F_{6,90} = 1.63$, $P > 0.05$).

The relative improvement in SDST performance following the 10-min nap (see Fig. 5) was examined further using post-hoc exploratory analyses. As no differences were evidenced between the no-nap and the 30- ($F_{2,30} = 1.66$, $P > 0.05$) and 90-s naps ($F_{2,30} = 0.66$, $P > 0.05$), these variables were combined. Two-way repeated measures ANOVAs, examining the relationship between the 10-min nap and other nap

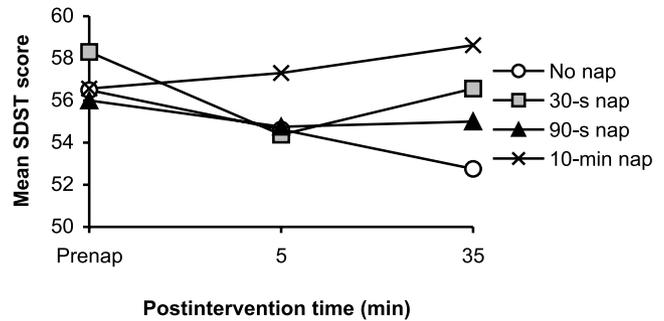


Figure 5. Change in Symbol-Digit Substitution Task (SDST) performance produced by the 30-s, 90-s and 10-min naps relative to no nap. Points represent the mean number of correct responses on the SDST.

conditions combined, revealed a non-significant interaction between prenap and 5 min postnap, $F_{1,15} = 3.60$, $P > 0.05$ (although approaching significance $P < 0.10$), and a significant interaction between prenap and 35 min postnap, $F_{1,15} = 6.00$, $P < 0.05$. These findings suggest that the 10-min nap improved SDST performance relative to the other napping conditions, with statistically significant improvements demonstrable 35 min postnap.

Letter cancellation task

Although the LCT showed similar trends to the SDST (i.e. decline over time for the no-nap, 30- and 90-s nap conditions but increase over time for the 10-min nap), none of the statistical analyses were significant.

DISCUSSION

The findings from this study showed that following mild nocturnal sleep restriction, a 10-min afternoon nap significantly improved subjective alertness, fatigue and SDST performance 35 min postnap, and objective and subjective alertness 65 min postnap. The beneficial effects of the 10-min nap were generally consistent with earlier studies examining the recuperative value of brief naps following nocturnal sleep restriction (Gillberg *et al.* 1996; Horne and Reyner 1996; Takahashi and Arito 2000; Tietzel and Lack 2001). In the context of our previous study (Tietzel and Lack 2001), which examined the effectiveness of a 10-min nap using identical research methodology, improvements in alertness and cognitive performance 35 and 65 min postnap were replicated, although immediate postnap benefits were not significant in the present study.

The present study also showed that ultra-brief naps of precisely 30 and 90 s produced no significant postnap benefits. One may therefore conclude that the mechanism underlying the benefits of brief naps does not appear to be the onset of stage 1 sleep. It may, however, be useful to retain the notion of a Process O (sleep onset), albeit with some modification dependent on what specific aspect of sleep produces the benefit. Perhaps the recuperative nature of brief naps can be

attributed to the onset of stage 2 sleep, the initiation of delta wave activity during the sleep episode, or perhaps some fixed period of sleep between 90 s and 10 min. Further research is therefore required to explore the relative benefits of a greater range of nap lengths.

Finally, as a matter of interest to sleep researchers and clinicians employing the MSLT procedure with either a one- or three-epoch sleep onset criterion, the findings from the current investigation suggest that the MSLT does not improve subsequent alertness within 65 min of napping. Of note, recent evidence has shown that a three-epoch (i.e. 90 s) sleep onset criterion may lead to increased sleepiness (i.e. reduced alertness) (Plenzler 1999). This was not demonstrated in the present study. There were no significant differences between the no nap and the 30 and 90-s naps for any of the dependent variables.

In summary, the findings of this investigation further attest to the benefits of brief afternoon naps in the order of 10 min duration following mild nocturnal sleep restriction. Future research is required to investigate the mechanism determining the recuperative value of brief naps as well as the minimum duration of nap sleep required for improving daytime alertness following mildly restricted nocturnal sleep. Studies such as this will be of theoretical interest to sleep researchers and will have important practical implications for clinicians, individuals and industry alike.

REFERENCES

- Borbély, A. A. A two process model of sleep regulation. *Hum. Neurobiol.*, 1982, 1: 195–204.
- Gillberg, M., Kecklund, G., Axelsson, J. and Åkerstedt, T. The effects of a short daytime nap after restricted night sleep. *Sleep*, 1996, 19: 570–575.
- Hayashi, M., Watanabe, M. and Hori, T. The effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activity. *Clin. Neurophysiol.*, 1999a, 110: 272–279.
- Hayashi, M., Ito, S. and Hori, T. The effects of a 20-min nap at noon on sleepiness, performance and EEG activity. *Int. J. Psychophysiol.*, 1999b, 32: 173–180.
- Hoddes, E., Zarcone, V., Smythe, H., Phillips, R. and Dement, W. C. Quantification of sleepiness: a new approach. *Psychophysiology*, 1973, 10: 431–436.
- Horne, J. A. and Reyner, L. A. Counteracting driver sleepiness: effects napping, caffeine, placebo. *Psychophysiology*, 1996, 33: 306–309.
- Lack, L. C. and Tietzel, A. J. Do the benefits of brief naps suggest a fourth biological process determining sleepiness? *Sleep*, 2000, 23 (Abstract Suppl.): A56.
- McNair, D. M., Lorr, M. and Droppleman, L. F. *Manual for the POMS*. Educational and Industrial Testing Service, San Diego, CA, 1971.
- Patrick, S. *Afternoon Sleepiness – an Endogenous Component of the Sleep/Wake Cycle?* Unpublished Honour's Thesis. Flinders University, South Australia, Australia, 1997.
- Plenzler, S. C. The sensitivity of a short interval multiple sleep latency procedure to sleep restriction and sleep extension. *Diss. Abst. Int. Section B. Sci. Eng.*, 1999, 59: 6512.
- Rechtschaffen, A. and Kales, A. (Eds) *A. Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*. UCLA Brain Information Services/Brain Research Institute, Los Angeles, 1968.
- Takahashi, M. and Arito, H. Maintenance of alertness and performance by a brief nap after lunch under prior sleep deficit. *Sleep*, 2000, 23: 813–819.
- Takahashi, M., Fukuda, H. and Arito, H. Brief naps during post-lunch rest. effects on alertness, performance, and autonomic balance. *Eur. J. Appl. Physiol.*, 1998, 78: 93–98.
- Tietzel, A. J. and Lack, L. C. The Short-Term Benefits of Brief and Long Naps Following Nocturnal Sleep Restriction. *Sleep*, 2001, 24: 293–300.