

## CHAPTER 9

# The effects of napping on cognitive functioning

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**Abstract:** Naps (brief sleeps) are a global and highly prevalent phenomenon, thus warranting consideration for their effects on cognitive functioning. Naps can reduce sleepiness and improve cognitive performance. The benefits of brief (5–15 min) naps are almost immediate after the nap and last a limited period (1–3 h). Longer naps (>30 min) can produce impairment from sleep inertia for a short period after waking but then produce improved cognitive performance for a longer period (up to many hours). Other factors that affect the benefits from the nap are the circadian timing of the nap with early afternoon being the most favourable time. Longer periods of prior wakefulness favour longer naps over brief naps. Those who regularly nap seem to show greater benefits than those who rarely nap. These conclusions, however, need to be accepted cautiously until more comprehensive research programmes are conducted in which all these parameters are varied. Research is also needed to test the benefits of brief naps taken more naturalistically at the time when sleepiness becomes intrusive. The significant benefits of a brief nap, containing virtually no slow wave EEG activity, are not predicted by the present theory of homeostatic sleep drive (Process S). A new biological process (Process O) suggests that sleep onset followed by only 7–10 min of sleep can result in a substantial increase of alertness because it allows the rapid dissipation of inhibition in the ‘wake-active’ cells associated with the ‘sleep-switch’ mechanism rather than the dissipation of Process S.

**Keywords:** Naps; cognitive performance benefits; nap length; sleep inertia; sleep homeostasis; Process O

### Overview

A nap is commonly referred to as a ‘short sleep’, more specifically a sleep which is distinct from and substantially shorter than an individual’s normal

sleep episode (Dinges, 1989). Dinges et al. (1987) define a nap in more quantitative terms as ‘any sleep period with a duration of less than 50% of the average major sleep period of an individual’ (p. 313). The briefest naps may consist of only a few

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minutes of sleep and the longest up to several hours of sleep. Most commonly nap lengths range from 30 to 90 min (Dinges, 1989). Napping is considered a global phenomenon that occurs during infancy and persists into adulthood for a large proportion of the world's population (Stampi, 1992). Dinges (1989) conducted a comprehensive review of studies which investigated the prevalence of napping among the adult population. The prevalence of regular napping (at least once per week) was reported to vary greatly across countries from 33 to 84%, with the greatest prevalence among countries located close to the equator (Dinges, 1989). More recently, Pilcher et al. (2001) reported similar rates of napping, indicating that approximately 74% of young and middle-aged adults living in the United States reported napping at least once per week.

A multitude of research has investigated the effects of napping and has consistently demonstrated that naps can counteract the effects of sleepiness by enhancing subjective and objective alertness, improving cognition, vigilance and psychomotor ability. This chapter will review the current literature investigating the effects of naps, outline several factors that can affect the recuperative value of a nap, and will discuss potential applications for napping within industry and health care. The chapter will also explain how the recuperative benefits of brief naps cannot be explained by the present conceptualization of homeostatic sleep drive and thus requires a new sleep process (Process O) in addition to the three-process model (Åkerstedt and Folkard, 1997).

For many individuals, napping offers a practical solution to reduce sleepiness. Naps taken for this reason are referred to as replacement or compensatory naps. This type of napping strategy is common among shift workers, individuals suffering from sleep disorders associated with excessive daytime sleepiness and those who have a restricted main sleep episode (Dinges, 1992; Dinges et al., 1981). However, researchers have acknowledged that this is not the only reason individuals may nap. In some circumstances, individuals may choose to

nap in anticipation of sleep loss, or to avoid feelings of sleepiness later on. This type of napping is referred to as prophylactic, and is common among shift workers particularly before beginning extended shifts (Stampi, 1992). Although the majority of experimental research has focused on these types of napping, it has also been reported that some people nap in the absence of sleep loss, due to feelings of boredom or for enjoyment. Åkerstedt et al. (1989) have termed this type of napping as appetitive or recreational.

### Benefits of naps

The high prevalence rates of napping around the globe alone are suggestive that napping is beneficial (Brooks and Lack, 2006; Dinges, 1989). The benefits of naps have been supported by a number of experimental research paradigms (Betrus, 1986; Bonnet, 1991; Brooks and Lack, 2006; Hayashi and Hori, 1997; Hayashi et al., 2003; Lovato et al., 2009; Milner et al., 2006; Takahashi and Arito, 2000; Tietzel and Lack, 2001, 2003; Tucker and Fishbein, 2008). Naps have not only been shown to reduce subjective and objective sleepiness but can also improve cognitive functioning and psychomotor performance and enhance short-term memory and mood (Brooks and Lack, 2006; Hayashi and Hori, 1997; Takahashi and Arito, 2000; Tamaki et al., 2000; Tietzel and Lack, 2003; Tucker and Fishbein, 2008).

Research has also investigated whether the effects of napping are comparable to other countermeasures commonly used to reduce sleepiness and performance impairments, such as caffeine and stimulant medications. Bonnet et al. (1995) showed that a prophylactic nap produced improvements to performance, mood and alertness which were longer lasting and less variable when compared to improvements following caffeine. Mednick et al. (2008) reported that naps significantly improved declarative verbal memory relative to both caffeine and a placebo. In a similar study, Reyner and Horne (1997) assessed the

efficacy of a 15-min nap, caffeine intake or a combination of both on performance using a driver-simulator task. Caffeine taken in conjunction with the nap resulted in a threefold reduction in accidents when compared to caffeine alone.

Limited research has investigated the benefits of naps relative to currently available stimulant medications such as modafinil. [Batejat and Lagarde \(1999\)](#) assessed the effects of naps, modafinil or a combination of both, on cognitive functioning during sleep deprivation. The naps were found to significantly improve psychomotor performance; however, these benefits were strengthened when naps were taken in conjunction with modafinil.

The restorative effects of naps have been well established across a variety of alertness and performance domains, with improvements evident across a wide range of objective and subjective sleepiness measures and cognitive performance measures. Naps are found to have alerting benefits that are comparable, and often superior, to other countermeasures against sleepiness and performance decrements ([Batejat and Lagarde, 1999](#); [Bonnet et al., 1995](#); [Mednick et al., 2008](#); [Reyner and Horne, 1997](#)). However, there are a number of factors to consider when aiming to optimize the

beneficial effects of a nap, including the duration of the nap and circadian timing of the nap.

### Duration of the nap and sleep inertia

Research has demonstrated that the length of a nap can determine its effect on alertness and cognition ([Bonnet, 1991](#); [Kubo et al., 2007](#); [Tietzel and Lack, 2001](#)). Naps of all durations (from 5 min to 2 h) have been shown to have some benefits to cognition ([Brooks and Lack, 2005](#)). However, it is the way in which these benefits emerge over the period following the nap that produces the most evident differences between different length naps. The benefits of a brief nap (e.g. 10 min of sleep) emerge almost immediately following the nap and can last up to 3 h ([Brooks and Lack, 2006](#)). However, immediately following long naps (e.g. 2 h) performance can actually decline for a period with eventual improvements that can last up to 24 h ([Achermann et al., 1995](#); [Jewett et al., 1999](#); [Lumley et al., 1986](#)). Figure 1 illustrates the tentative conclusions we can draw about the general time course of negative and positive effects on cognition for brief (e.g. 10 min), short (e.g. 30 min)

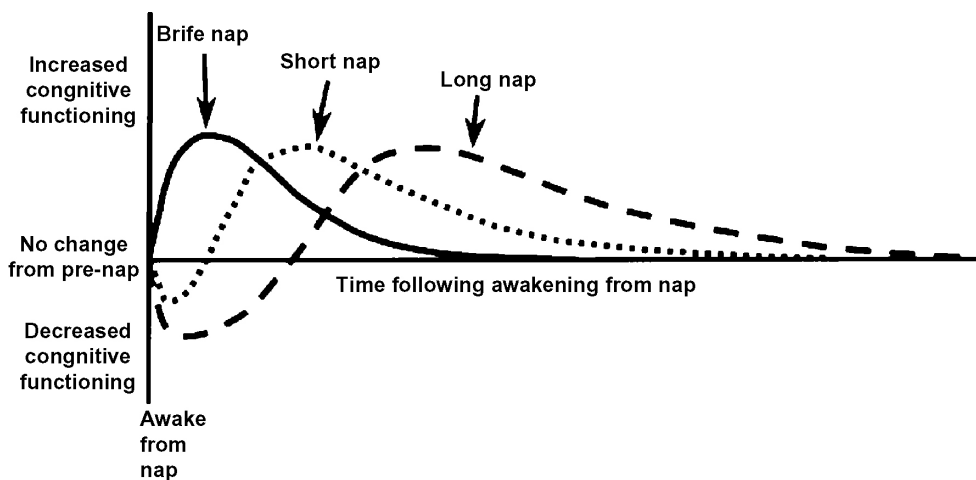


Fig. 1. Relative changes in detrimental and beneficial effects of brief, short and long naps following awakening from the nap.

and long (e.g. 2 h) naps. Still needed is a systematic parametric programme of research in which length of nap, time of nap and amount of prior sleep restriction are all varied while using a comprehensive set of outcome measures of alertness and cognitive performance administered over at least a 3-h period following the nap.

The temporary deterioration of performance immediately following long naps has been attributed to sleep inertia. [Naitoh and Angus \(1989\)](#) describe sleep inertia as 'inferior task performance and/or disorientation occurring immediately after awakening' (p. 226). Sleep inertia reflects a transition from a sleep state to a wake state and is characterized by electroencephalography patterns, which resemble Stage 1 sleep patterns ([Naitoh and Angus, 1989](#)) rather than wake ([Naitoh et al., 1993](#)).

The magnitude of sleep inertia is dependent on several factors the most important of which is the quantity of slow-wave sleep (SWS) contained within the napping episode ([Åkerstedt and Folkard, 1991](#)). Although the quantity of SWS is positively correlated with the recuperative value of a nap, particularly when considering improvements to short-term memory performance ([Schmidt et al., 2006; Tucker et al., 2006](#)), it is also positively correlated with the intensity and duration of sleep inertia ([Åkerstedt and Folkard, 1991](#)). Since SWS normally develops gradually over time asleep, longer naps, at least up to the point of maximum slow-wave activity (SWA) in a sleep cycle, are expected to result in longer and more intense periods of sleep inertia.

The magnitude of sleep inertia is also influenced by prior sleep debt, circadian time and sleep stage at awakening ([Tassi and Muzet, 2000](#)). Sleep inertia is the most persistent from sleep episodes taken during the circadian nadir, under conditions of high sleep debt and waking from SWS ([Tassi and Muzet, 2000](#)). The substantial sleep inertia arising from these longer naps can be ameliorated to some extent by consuming caffeine on awakening ([Bonnet and Arand, 1994; Schweitzer et al., 2006; Van Dongen et al., 2001](#)).

Brief naps (less than 20 min) have been shown to ameliorate sleepiness and improve performance after both a restricted nocturnal sleep and a nocturnal sleep of normal duration ([Hayashi et al., 2005; Tamaki et al., 2000; Tietzel and Lack, 2002, 2003](#)). A number of researchers have demonstrated that naps as brief as 10 min in duration can improve subjective and objective alertness, increase feelings of vigour and decrease fatigue, in addition to improving accuracy and speed on a number of cognitive tasks ([Brooks and Lack, 2006; Horne and Reyner, 1996; Takahashi and Arito, 2000; Tietzel and Lack, 2002](#)). One study has found that a nap as brief as 7 min is beneficial for restoring alertness ([Takahashi et al., 1998](#)). Unlike long naps, the beneficial effects of brief naps are evident almost immediately after waking ([Tietzel and Lack, 2002](#)). Brief naps are associated with shorter periods of sleep inertia, and in some instances, no sleep inertia ([Tietzel and Lack, 2002](#)).

Although research suggests that both brief and long naps are beneficial for improving alertness, few studies have used the same protocol and outcome measures to directly compare the benefits of brief and long naps. This remains an important research programme to be pursued. Nevertheless, it is suggested that for sleep restricted individuals and individuals who have experienced normal nocturnal sleep duration, brief naps and long naps produce comparable benefits to alertness ([Brooks and Lack, 2006; Takahashi et al., 1998; Taub et al., 1976; Tietzel and Lack, 2001](#)). It is only in the case of total sleep deprivation that naps of a longer duration (1–2 h) have been demonstrated to elicit greater alerting benefits than brief naps ([Helmus et al., 1997; Lumley et al., 1986](#)).

### Circadian placement of the nap

The recuperative value of a nap is also dependent on when the nap is taken with respect to the 24-h circadian rhythm (e.g. as reflected in core body temperature). The three-process model of alertness ([Åkerstedt and Folkard, 1991](#)) proposes that

the maximum period of circadian sleepiness occurs in the early hours of the morning (0300–0600 h). A secondary period of sleepiness occurs in the mid-afternoon (1300–1600 h), referred to as the post-lunch dip period (Åkerstedt and Folkard, 1991). Experimental studies using both continuous wakefulness and sleep/wake ultradian routines across the 24-h day, have also reported peaks in sleepiness and napping at these times (Broughton, 1989; Lack and Lushington, 1996; Lack et al., 2009; Lavie, 1989). Since most individuals take their main sleep nocturnally across the maximum period of circadian sleepiness, the preferred time to nap is usually reported to be during the post-lunch dip period between 1300 and 1600 h (Broughton, 1989).

Research has indicated that naps taken during the post-lunch dip period have a greater recuperative value than when naps are taken in the early morning, late morning or evening (Naitoh and Angus, 1989; Taub et al., 1978). Researchers have further established the optimum time to nap during the 3-h post-lunch dip period. Hayashi et al. (1999a, 1999b) compared a 20-min nap taken at noon or 1400 h relative to a no-nap control condition. The 20-min nap scheduled at 1400 h produced both greater and longer lasting benefits to mood, fatigue, objective performance, self-rated performance and objective alertness, when compared to the 20-min nap scheduled at noon.

Naps taken during the circadian nadir (approximately 0400 h) produce less recuperative value when compared to naps taken during the day or in the early hours of the morning. Sallinen et al. (1998) found that 30- and 50-min naps taken by shift workers at 0100 h improved objective alertness; however, when the same naps were taken closer to the circadian nadir at 0400 h, no alerting benefits were observed. Purnell et al. (2002) reported benefits in performance after a 20-min nap when taken at either 0100 or 0300 h, while Saito and Sasaki (1996) found that 1-h naps ending at either 0400 or 0500 h had no alerting benefits for subjective fatigue. It is still difficult at present to come to confident conclusions about the effect of

circadian phase on napping effects from the sparse evidence available from a few studies using different measures and methodologies. This strengthens the earlier point about the need for a comprehensive research programme testing a variety of circadian times with a variety of nap lengths.

### **Other factors: prior wake time and experience with napping**

Research has also suggested that other factors such as prior wake time and experience with napping can contribute to the duration and magnitude of alerting benefits (Dinges, 1995; Dinges et al., 1987; Rosa et al., 1983). Several researchers have demonstrated that naps taken after long periods of wakefulness (e.g. 18 h) are less effective and have shorter-lasting benefits than naps taken after shorter periods of wakefulness (Dinges, 1995; Dinges et al., 1987). Additionally, research has concluded that the longer an individual has been awake, the longer a nap needs to be to improve alertness (Dinges, 1995; Dinges et al., 1987).

A limited amount of research has been conducted on the impact experience with napping can have on the recuperative effects of a nap. Taub and colleagues (Taub, 1979; Taub and Berger, 1973; Taub et al., 1976, 1977, 1978) conducted several studies investigating the alerting benefits of naps for individuals who habitually nap (one or more times per week for at least 2 years). Taub and Berger (1973) reported that an afternoon nap improved the mood and performance of habitual nappers. Evans et al. (1977) extended Taub and Berger's (1973) work to compare the benefits of a nap for habitual nappers and non-nappers. In this study, participants who regularly napped reported feeling more satisfied and less sleepy and tired following an afternoon nap when compared to participants who did not nap on a regular basis. Recently, Milner et al. (2006) reported that a short nap improved motor learning performance for individuals who regularly napped, but was detrimental for those who were not

habitual nappers. Contrary to these findings, other studies have demonstrated no significant differences in performance for habitual and non-habitual nappers following an afternoon nap (Daiss et al., 1986; Keyes, 1989). Further research is required to clarify the differential effects of naps for habitual and non-habitual nappers (Milner and Cote, 2008). Perhaps habitual nappers choose to nap on a regular basis because they experience a greater benefit from the nap. Habitual nappers may be chronically sleep restricted and require naps to achieve acceptable alertness levels during the day. Differences between regular nappers and non-nappers could thus be compared after several nights of unlimited sleep opportunity in order to eliminate any residual effects of sleep restriction.

### **Can experiments capture the naturalistic use of napping?**

There is considerable experimental support for the ability of brief naps to increase alertness as evidenced in measures of subjective feelings, objective sleep latency and objective measures of cognitive performance. All of these studies administered nap opportunities at scheduled times in fixed experimental protocols. They were not self-selected times that, in a more naturalistic situation, would usually determine the timing of a nap. In practice, an individual is likely to take a nap when sleepiness becomes so intense that it interferes with ongoing activity and when opportunity or conditions (physical and social) allow. Most of us in our mildly sleep-restricted lives have experienced occasional drowsiness and the struggle to remain awake whether it is during an uninteresting lecture or meeting, some quiet reading or study in the early afternoon, or in front of the television in the evening (Johns, 1991). A common anecdotal report is that a brief nap at that time can remarkably remove the drowsiness feeling and restore cognitive functioning. The experimental evidence supports these reports. We predict that an experiment that allowed a self-selected nap time at the point of

heightened drowsiness would show even more impressive improvements in subjective alertness as well as objective cognitive performance.

### **Theoretical implications of brief nap benefits**

The research confirming the benefits of brief naps not only has applied importance but it can also contribute to theoretical biological models of sleep propensity. The apparent rapid reversal of sleepiness following a brief nap suggests the need for a biological mechanism additional to the presently accepted three-process model that includes sleep homeostasis (Process S), circadian phase (Process C) and sleep inertia (Process W) (Åkerstedt and Folkard, 1997). The three-process model would suggest that if the circadian factor was kept relatively constant and any sleep inertia were allowed to dissipate, any benefits of a brief sleep would be entirely dependent on the decrease of homeostatic sleep drive (Process S) following sleep onset. The original simplified conceptualization of the dissipation of Process S was represented by an exponential decaying function in which the rate of decay was maximal following sleep onset (Daan et al., 1984). However, the model was then revised to indicate that the decrease of homeostatic sleep drive during sleep is entirely dependent of the amount of SWA that varies across sleep with an ultradian rhythm of an approximately 90-min period length (Achermann and Borbély, 1990). Thus, Process S would dissipate most rapidly when SWA is at a maximum, but this would not occur immediately at sleep onset. It would increase gradually over 20–70 min with the gradual increase in SWA. The ultradian rhythm of SWA during sleep and the predicted decrease of Process S is illustrated in Fig. 2.

This dissipation function of Process S during sleep would suggest that the longer the sleep or the nap, especially the more SWA included in the sleep, the greater the benefit for alertness or decrease of sleepiness. However, the data suggest considerable benefits to alertness from very brief



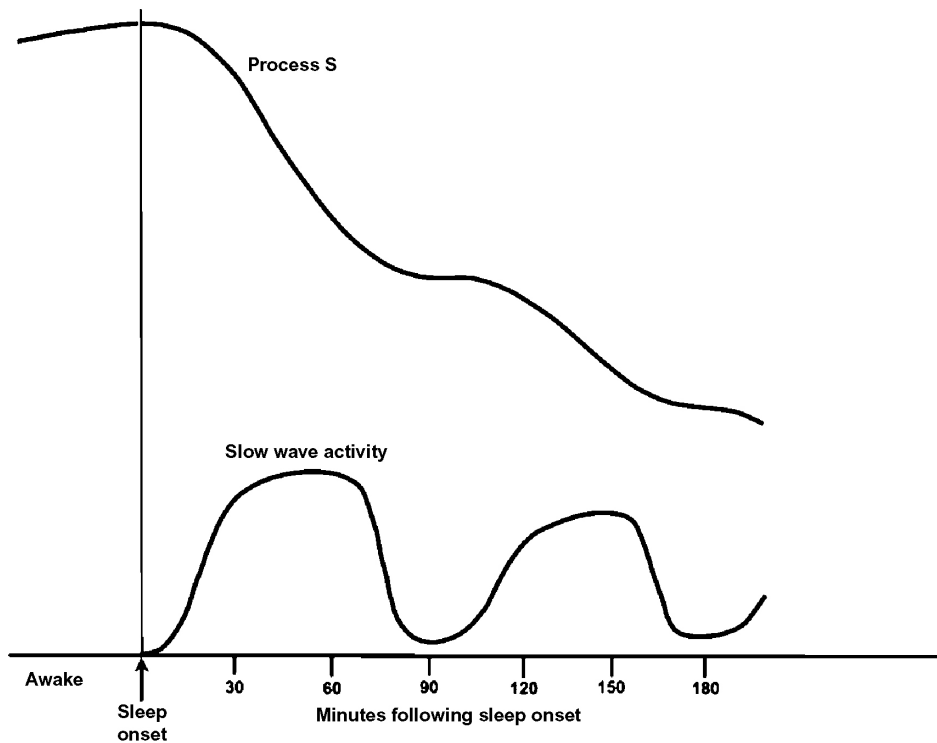


Fig. 2. Revised dissipation of homeostatic sleep drive (Process S) as a function solely of slow-wave activity during the sleep period illustrating very little decrease of Process S for brief (<15 min of sleep) naps.

(7–10 min of sleep) naps. Yet, in terms of satisfying accumulated homeostatic sleep drive, such a brief and light sleep with virtually no SWA should result in virtually no decrease in Process S and thus provide almost no benefit. For example, Fig. 2 shows very little decrease of Process S in the first 15 min of sleep. However, in comparison with longer naps (20–60 min of sleep) containing much more SWA, the benefits following brief naps are surprisingly comparable. These benefits are maintained even after allowing for the dissipation of the negative effects of sleep inertia immediately following a longer sleep. This suggests some other mechanism, apart from homeostatic sleep drive, determines the improvement of alertness and performance following brief naps.

This additional process may incorporate what [Saper et al. \(2001\)](#) have termed as a ‘sleep-switch’ mechanism. This is a bi-stable, ‘flip-flop’ circuit that spends little time in transition and promotes stability of either sleep or wake. Evidence suggests the sleep-switch mechanism involves nuclei of sleep-active neurons and opposing nuclei of wake-active neurons with mutual inhibitory connections. When the balance is tipped in favour of sleep, as a result of accumulated homeostatic sleep drive, high circadian sleep propensity or sleep-conducive circumstances, the sleep-active nuclei increase their activity and thus increase their inhibition of the wake-active neurons. With the decreased activation of the wake-active neurons there would be less inhibitory feedback to the

sleep-active neurons and the switch to sleep would occur quickly and then tend to be maintained by strong inhibition of the wake-active neurons. The process is analogous to the switches that occurs when breathing (from inspiration to expiration and the opposite change), these also being controlled by groups of mutually inhibitory neurons.

### **An additional sleep process (Process 'O')**

We suggest that alertness can be increased a constant amount simply through the process of sleep onset (or Process O) ([Lack and Tietzel, 2000](#)). What exactly constitutes sleep onset in this sense and how brief the period of sleep needs to be and still satisfy this process has already been explored to some extent. It appears to require more than the onset of Stage 1 sleep since ultra-brief naps of 30–90 s of sleep produce no measurable benefit ([Tietzel and Lack, 2002](#)). [Hayashi et al. \(2005\)](#) have suggested that it is not the onset of Stage 2 but the presence of at least 3 min of Stage 2 sleep following 4–5 min of Stage 1 sleep that provides the benefits of a brief nap. More recently, [Brooks and Lack \(2006\)](#), by comparing different nap lengths (5, 10, 20 and 30 min sleep), obtained data that suggested an elapsed amount of sleep (about 10 min) or the onset of some SWA are potential candidates for the benefits of Process O.

This proposed mechanism may be intrinsic to the sleep switch itself rather than an 'external' factor (elsewhere in the brain) playing upon it such as Process S or C. As [Saper et al. \(2001\)](#) describe, when the switch 'flips' to the sleep state, the sleep nuclei become active and the wake-active nuclei are inhibited and, as a result, become inactive. The mechanism we suggest would incorporate a fatigue or adaptation process that builds up slowly over the period of activation with a time constant in the order of hours. This would gradually decrease the excitability of the active neural centre. However, with a flip or flop of the sleep switch, the previously active centre is turned off during which the accumulated fatigue or satiation

(lowered excitability) dissipates relatively rapidly with a time constant more in the order of minutes. Thus, during a brief (e.g. 10 min) sleep, excitability returns almost entirely to the now inactive wake centre. If an awakening then occurs, the wake-active nuclei have regained most of their maximal excitability and provide a significant increase of alertness or decrease of the prior sleepiness. This would account for the relatively rapid improvement in alertness following a brief nap and its benefits lasting in the order of 2–3 h as fatigue slowly builds again in the wake-active nuclei.

This return of excitability to the wake-active centre during a brief nap does not flip the switch back to awake on its own, since it is still being inhibited by the still active sleep centre. Therefore, if one desires to limit the length of a nap to a brief 10–15 min it would be advisable, particularly for inexperienced nappers, to use a timed alarm. Interestingly, there are anecdotal reports from experienced brief nappers that they are usually able to awake spontaneously to ensure a brief nap only. This is an interesting question that deserves some research to explore its applied utility.

The existence of differential time constants between reduction of excitability during activation and return of excitability at the cessation of activity is not a novel mechanism in physiology and behaviour. There are other analogues of this process such as sensory adaptation, habituation and reactive inhibition ([Hull, 1951](#)). These processes have similarities with a relatively slow build up of inhibition during activation and a relatively rapid dissipation of this inhibition or return of excitability following cessation of activity ([Duncan, 1956](#)). As a further example, the time-constants are very different between activation and de-activation of sodium and potassium voltage-gated channels during the generation of an action potential in excitable tissues.

The anecdotal scenario described above, in which strong drowsiness is alleviated following a brief nap, could be explained in terms of Process O which is intrinsic to the 'sleep-switch' mechanism of [Saper et al. \(2001\)](#). The strong drowsiness



feeling would be an indication that the input to the sleep switch from situational and behavioural variables was moving the switch closer to the threshold of sleep or tipping the position of the switch very close to a 'flop' into sleep. Then allowing sleep to occur for the few minutes to maximally satisfy Process O would return excitability to the 'wake-active' nuclei and result in noticeably increased alertness upon awakening.

We are not suggesting that this dissipation of 'fatigue' or recovery of excitability of the wake-active nuclei is enough on its own to overcome Process S, which has decreased very little during this brief sleep. The maximum effect of this intrinsic mechanism, Process O, in comparison with Process S needs to be investigated by considerably more research. However, our guess is that it is significantly weaker than the effect of accumulated Process S during 16 h of wakefulness in a normal day. We suggest that this Process O is similar in operation to Process S but with a much shorter time scale and smaller maximum intensity. Thus, although it accumulates fatigue much more slowly than it dissipates it, the time scale to maximum fatigue would be in the order of 2–3 h and dissipation complete in 8–15 min. In contrast, Process S can accumulate sleep pressure over days of total sleep deprivation and require over 10–12 h of sleep to dissipate entirely.

Paraphrasing, the most parsimonious assumption of the operation of this process on the sleep switch is that it operates symmetrically for brief awakenings during the major sleep period as it would for brief sleeps during the major wake period. That is a brief (5–10 min) awakening from the major sleep period should rapidly dissipate fatigue from the sleep-active nuclei thus facilitating the re-establishment of sleep when it recurs. Such a re-establishment of sleep, in conjunction with Process W, sleep inertia (still potent only after 5–10 min of wakefulness) and maximal sleepiness from Process C towards the end of the normal sleep period, should all help to maintain the continuity of the major sleep period (Dijk and Czeisler, 1994).

### **Relative impacts of brief and long naps on subsequent nocturnal sleep and clinical implications**

The substantial SWS contained in longer naps has been demonstrated to disturb the duration and architecture of the subsequent nocturnal sleep period (Åkerstedt et al., 1989; Dinges, 1989). For this reason, behavioural treatments of insomnia, such as stimulus control therapy and bedtime restriction therapy, that rely upon the increase of sleep drive in the early stages of treatment, recommend avoiding daytime naps that would lower the therapeutic benefits of this temporarily raised sleep pressure. On the other hand, brief afternoon naps have not been shown to affect the length or quality of the subsequent night sleep (Purnell et al., 2002). Therefore, brief naps during the day to temporarily reduce daytime sleepiness that may accumulate during the initial stages of insomnia treatment may be permissible. If successful at relieving the sleepiness, the use of brief naps may improve the compliance with these sometimes onerous therapies. In addition, the adoption of this brief nap strategy may provide the insomniac with a tool to counteract the tiredness following a poor night of sleep. Therefore, this new napping skill could reduce the negative daytime consequences of poor sleep and thus help to ameliorate the insomnia.

### **Applications for napping**

The benefits of napping have been well established and can be utilized in many situations to minimize sleepiness and regain alertness. Naps of brief duration are particularly ideal for use within the workplace as they can be taken during the employees' break time (Anthony and Anthony, 2005; Signal and Gander, 2002). The minimal sleep inertia produced by brief naps also allows for maximum productivity to resume almost immediately after waking from the nap. Research has suggested that brief naps can temporarily relieve the excessive levels of daytime sleepiness experienced by narcolepsy

suffers (Mullington and Broughton, 1993; Roehrs et al., 1986; Rogers and Aldrich, 1993; Schulz et al., 1992). Also, sleep apnoea patients with high levels of daytime sleepiness regularly take naps to alleviate bouts of sleepiness.

The use of napping is also recommended for trans-meridian travel to allow the biological clock to adapt en route (Kerkhof, 2009). Kerkhof (2009) has also recently reported the use of multiple 10-min naps by a solo sailor during long legs of a journey when opportunities for longer sleeps were not possible. Therefore, brief naps (power naps) have anecdotal and research support for their effectiveness in relieving sleepiness as well as becoming a prompt for revising our theoretical models of sleep.

## References

- Achermann, P., & Borbély, A. A. (1990). Simulation of human sleep: Ultradian dynamics of electroencephalographic slow-wave activity. *Journal of Biological Rhythms*, 5(2); 141–157.
- Achermann, P., Werth, E., Dijk, D. J., & Borbély, A. (1995). Time course of sleep inertia after nighttime and daytime sleep episodes. *Archives Italiennes de Biologie*, 134, 109–119.
- Åkerstedt, T., & Folkard, S. (1991). A three process model of the regulation of alertness and sleepiness. In: Ogilvie, R., Broughton, R. (Eds.), *Sleep, arousal and performance: Problems and promises*. Birkhäuser, Boston, pp. 11–26.
- Åkerstedt, T., & Folkard, S. (1997). The three-process model of alertness and its extension to performance, sleep latency, and sleep length. *Chronobiology International*, 14, 115–123.
- Åkerstedt, T., Torsvall, L., & Gillberg, M. (1989). Shift work and napping. In: Dinges, D., Broughton, R. (Eds.), *Sleep and alertness: Chronobiological, behavioural and medical aspects of napping*. Raven Press, New York, pp. 205–220.
- Anthony, W., & Anthony, C. (2005). The napping company: Bringing science to the workplace. *Industrial Health*, 43, 209–212.
- Batejat, D. M., & Lagarde, D. P. (1999). Naps and modafinil as countermeasures for the effects of sleep deprivation on cognitive performance. *Aviation, Space, and Environmental Medicine*, 70, 493–498.
- Betrus, P. (1986). Afternoon naps: Immediate and delayed effects on performance and mood. *Dissertation Abstracts International*, 46, 3630–3631.
- Bonnet, M. (1991). The effect of varying prophylactic naps on performance, alertness and mood throughout a 52-hour continuous operation. *Sleep*, 14, 307–315.
- Bonnet, M., & Arand, D. L. (1994). The use of prophylactic naps and caffeine during a continuous operation. *Ergonomics*, 37(6); 1009–1020.
- Bonnet, M., Gomez, S., Wirth, O., & Arand, D. (1995). The use of caffeine versus prophylactic naps in sustained performance. *Sleep*, 18, 97–104.
- Brooks, A., & Lack, L. C. (2005). Naps. In: Kushida, C. A. (Ed.), *Sleep deprivation: Clinical issues, pharmacology, and sleep loss effects*. Marcel Dekker, Inc, New York, pp. 457–474.
- Brooks, A., & Lack, L. (2006). A brief afternoon nap following nocturnal sleep restriction: Which nap duration is most recuperative? *Sleep*, 29, 831–840.
- Broughton, R. J. (1989). Chronobiological aspects and models of sleep and napping. In: Dinges, D. F., Broughton, R. J. (Eds.), *Sleep and alertness: Chronobiological, behavioural and medical aspects of napping*. Raven Press, New York, pp. 71–98.
- Daan, S., Beersma, D. G. M., & Borbély, A. A. (1984). Timing of human sleep: Recovery process gated by a circadian pacemaker. *American Journal of Physiology*, 246, R161–R178.
- Daiss, S., Bertelson, A., & Benjamin, L. (1986). Napping versus resting: Effects on performance and mood. *Psychophysiology*, 23, 82–88.
- Dijk, D., & Czeisler, C. (1994). Paradoxical timing of the circadian rhythms of sleep propensity serves to consolidate sleep and wakefulness in humans. *Neuroscience Letters*, 166, 63–68.
- Dinges, D. F. (1989). Napping patterns and effects in human adults. In: Dinges, D. F., Broughton, R. J. (Eds.), *Sleep and alertness: Chronobiological, behavioural and medical aspects of napping*. Raven Press, New York, pp. 171–204.
- Dinges, D. F. (1992). Adult napping and its effects of ability to function. In: Stampi, C. (Ed.), *Why we nap: Evolution, chronobiology and functions of polyphasic and ultrashort sleep*. Birkhäuser, Boston, pp. 118–132.
- Dinges, D. (1995). An overview of sleepiness and accidents. *Journal of Sleep Research*, 4(Suppl. 2); 4–14.
- Dinges, D., Orne, M., Orne, E., & Evans, F. (1981). Behavioural patterns in habitual nappers. [Abstract only]. *Journal of Sleep Research*, 136
- Dinges, D., Orne, E., Whitehouse, W., & Orne, M. (1987). Temporal placement of a nap for alertness: Contributions of circadian phase and prior wakefulness. *Sleep*, 10, 313–329.
- Duncan, C. P. (1956). On the similarity between reactive inhibition and neural satiation. *American Journal of Psychology*, 69, 227–235.
- Evans, F., Cook, M., Cohen, H., Orne, E., & Orne, M. (1977). Appetitive and replacement naps: EEG and behaviour. *Science*, 197, 687–689.
- Hayashi, M., & Hori, T. (1997). The effects of a 20-minute nap in the early afternoon. [Abstract only]. *Psychiatry and Clinical Neurosciences*, 51, 558.
- Hayashi, M., Fukushima, H., & Hori, T. (2003). The effects of short daytime naps for five consecutive days. *Sleep Research Online*, 5, 13–17.

- Hayashi, M., Ito, S., & Hori, T. (1999a). The effects of a 20-min nap at noon on sleepiness, performance and EEG activity. *International Journal of Psychophysiology*, 32, 173–180.
- Hayashi, M., Motoyoshi, N., & Hori, T. (2005). Recuperative power of a short daytime nap with or without stage 2 sleep. *Sleep*, 28, 829–836.
- Hayashi, M., Watanabe, M., & Hori, T. (1999b). The effects of a 20 min nap in the mid-afternoon on mood performance and EEG activity. *Clinical Neurophysiology*, 110, 272–279.
- Helmus, T., Rosenthal, L., Bishop, C., Roehrs, T., Syron, M., & Roth, T. (1997). The alerting effects of short and long naps in narcoleptic, sleep-deprived and alert individuals. *Sleep*, 20, 251–257.
- Horne, J., & Reyner, L. (1996). Counteracting driver sleepiness: Effects of napping, caffeine and placebo. *Psychophysiology*, 33, 306–309.
- Hull, C. L. (1951). *Essentials of behavior*. Greenwood, Westport, CT.
- Jewett, M., Wyatt, J., Cecco, A., Khalsa, S., Dijk, D., & Czeisler, C. (1999). Time course of sleep inertia dissipation in human performance and alertness. *Journal of Sleep Research*, 8, 1–8.
- Johns, M. (1991). A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep*, 14, 540–545.
- Kerkhof, G. (2009). Transmeridian sailing. *Mind Open: Insights in Psychology* 4–5
- Keyes, K. (1989). Effects of sleep quality and daytime naps on the mood and functioning of older persons. *Dissertation Abstracts International*, 58, 2350–2351.
- Kubo, T., Takeyama, H., Matsumoto, S., Ebara, T., Murata, K., & Tachi, N., et al., (2007). Impact of nap length, nap timing and sleep quality on sustaining early morning performance. *Industrial Health*, 45, 552–563.
- Lack, L., & Lushington, K. (1996). The rhythms of sleep propensity and core body-temperature. *Journal of Sleep Research*, 5, 1–11.
- Lack, L., & Tietzel, A. (2000). Do the benefits of brief naps suggest a fourth biological process determining sleepiness? *Sleep*, 23(Suppl. 2); A56.
- Lack, L., Bailey, M., Lovato, N., & Wright, H. (2009). Chronotype differences in circadian rhythms of temperature, melatonin, and sleepiness as measured in a modified constant routine protocol. *Nature and Science of Sleep*, 1, 1–8.
- Lavie, P. (1989). To nap, perchance to sleep – Ultradian aspects of napping. In: Dinges, D., Broughton, R. (Eds.), *Sleep and alertness: Chronobiological, behavioural and medical aspects of napping*. Raven Press, New York, pp. 99–120.
- Lovato, N., Lack, L., Ferguson, S., & Tremaine, R. (2009). The effects of a 30-min nap during night shift following a prophylactic sleep in the afternoon. *Sleep and Biological Rhythms*, 7, 34–42.
- Lumley, M., Roehrs, T., Zorick, F., Lamphere, J., & Roth, T. (1986). The alerting effects of naps in sleep-deprived subjects. *Psychophysiology*, 23, 403–408.
- Mednick, S., Cai, D., Kanady, J., & Drummond, S. (2008). Comparing the benefits of caffeine, naps and placebo on verbal, motor and perceptual memory. *Behavioural Brain Research*, 193, 79–86.
- Milner, C., & Cote, K. (2008). Benefits of napping in healthy adults: Impact of nap length, time of day, age, and experience with napping. *Journal of Sleep Research*, 18(2); 272–281.
- Milner, C., Fogel, S., & Cote, K. (2006). Habitual napping moderates motor performance improvements following a short daytime nap. *Biological Psychology*, 73, 141–156.
- Mullington, J., & Broughton, R. (1993). Scheduled naps in the management of daytime sleepiness in narcolepsy-cataplexy. *Sleep*, 16, 444–456.
- Naitoh, P., & Angus, R. (1989). Napping and human functioning during prolonged work. In: Dinges, D., Broughton, R. (Eds.), *Sleep and alertness: Chronobiological, behavioral and medical aspects of napping*. Raven Press, New York, pp. 221–246.
- Naitoh, P., Kelly, T., & Babkoff, H. (1993). Sleep inertia: Best time not to wake up? *Chronobiology International*, 10, 109–118.
- Pilcher, J., Michalowski, K., & Carrigan, R. (2001). The prevalence of daytime napping and its relationship to nighttime sleep. *Behavioral Medicine*, 27, 71–76.
- Purnell, M., Feyer, M., & Herbison, G. (2002). The impact of a nap opportunity during the night shift on performance and alertness of 12-h shift workers. *Journal of Sleep Research*, 11, 219–227.
- Reyner, L., & Horne, J. (1997). Suppression of sleepiness in drivers: Combination of caffeine with a short nap. *Psychophysiology*, 34, 721–725.
- Roehrs, T., Zorick, F., Wittig, R., Paxton, C., Sickelsteel, J., & Roth, T. (1986). Alerting effects of naps in patients with narcolepsy. *Sleep*, 9, 194–199.
- Rogers, A., & Aldrich, M. (1993). The effect of regularly scheduled naps on sleep attacks and excessive daytime sleepiness associated with narcolepsy. *Nursing Research*, 42, 111–117.
- Rosa, R., Bonnet, M., & Warm, J. (1983). Recovery of performance during sleep following sleep deprivation. *Psychophysiology*, 20, 152–159.
- Saito, Y., & Sasaki, T. (1996). The effect of length of a nocturnal nap on fatigue feelings during subsequent early morning hours. *Journal of Science Labour*, 72, 15–23.
- Sallinen, M., Harma, M., Åkerstedt, T., Rosa, R., & Lillqvist, O. (1998). Promoting alertness with a short nap during a night shift. *Journal of Sleep Research*, 7, 240–247.
- Saper, C. B., Chou, T. C., & Scammell, T. E. (2001). The sleep switch: Hypothalamic control of sleep and wakefulness. *Trends in Neurosciences*, 24, 726–731.
- Schmidt, C., Peigneux, P., Muto, V., Schenkel, M., Knoblauch, V., & Munch, M. (2006). Encoding difficulty promotes post-learning changes in sleep spindle activity during napping. *Journal of Neuroscience*, 26, 8976–8982.

- Schulz, H., Wilde-Frenz, J., Volk, S., & Geisler, P. (1992). Narcolepsy and the pathological aspects of multiple napping. In: Stampi, C. (Ed.), *Why we nap: Evolution, chronobiology and functions of polyphasic and ultrashort sleep*. Birkhauser, Boston, pp. 258–270.
- Schweitzer, P. K., Randazzo, A. C., Stone, K., Erman, M., & Walsh, J. K. (2006). Laboratory and field studies of naps and caffeine as practical countermeasures for sleep-wake problems associated with night work. *Sleep*, 29(1); 39–50.
- Signal, L., & Gander, P. (2002). Psychomotor performance improvements with a short workplace nap on the night shift: Benefits of stage 1 sleep. [Abstract only]. *Sleep*, 25, 116.
- Stampi, C. (1992). Evolution, chronobiology and functions of polyphasic and ultrashort sleep: Main issues. In: Stampi, C. (Ed.), *Why we nap: Evolution, chronobiology and functions of polyphasic and ultrashort sleep*. Birkhauser, Boston, pp. 1–20.
- Takahashi, M., & Arito, H. (2000). Maintenance of alertness and performance by a brief nap after lunch under prior sleep deficit. *Sleep*, 23, 813–819.
- Takahashi, M., Fukuda, H., & Arito, H. (1998). Brief naps during post-lunch rest: Effects on alertness, performance and autonomic balance. *European Journal of Applied Physiology*, 78, 93–98.
- Tamaki, M., Shirota, A., Hayashi, M., & Hori, T. (2000). Restorative effects of a short afternoon nap (<30 min) in the elderly on subjective mood, performance and EEG activity. *Sleep Research Online*, 3, 131–139.
- Tassi, P., & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, 4(4); 341–353.
- Taub, J. (1979). Effects of habitual variations in napping on psychomotor performance, memory and subjective states. *International Journal of Neuroscience*, 9, 97–112.
- Taub, J., & Berger, R. (1973). Performance and mood following variations in the length and timing of sleep. *Psychophysiology*, 10, 559–570.
- Taub, J., Hawkins, D., & Van de Castle, R. (1978). Temporal relationships of napping behaviour to performance, mood states and sleep physiology. *Sleep Research*, 7, 164.
- Taub, J., Tanguay, P., & Clarkson, D. (1976). Effects of daytime naps on performance and mood in a college student population. *The Journal of Abnormal Psychology*, 85, 210–217.
- Taub, J., Tanguay, P., & Rosa, R. (1977). Effects of afternoon naps on physiological variables, performance and self-reported activation. *Biological Psychology*, 5, 191–210.
- Tietzel, A., & Lack, L. (2001). The short-term benefits of brief and long naps following nocturnal sleep restriction. *Sleep*, 24, 293–300.
- Tietzel, A., & Lack, L. (2002). The recuperative value of brief and ultra-brief naps on alertness and cognitive performance. *Journal of Sleep Research*, 11, 213–218.
- Tietzel, A., & Lack, L. (2003). The objective alerting effects of brief naps following eight hours of nocturnal sleep. [Abstract only]. *Sleep*, 26, 431.
- Tucker, M., & Fishbein, W. (2008). Enhancement of declarative memory performance following a daytime nap is contingent on strength of initial task acquisition. *Sleep*, 31, 197–203.
- Tucker, M., Hirota, Y., Wamsley, E., Lau, H., Chaklader, A., & Fishbein, W. (2006). A daytime nap containing solely non-REM sleep enhances declarative but not procedural memory. *Neurobiology of Learning and Memory*, 86, 241–247.
- Van Dongen, H., Price, N. J., Mullington, J. M., Szuba, M. P., Kapoor, S. C., & Dinges, D. (2001). Caffeine eliminates psychomotor vigilance deficits from sleep inertia. *Sleep*, 24(7); 813–819.