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a0005 # Napping

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s0005 ## Introduction

p0005 To answer the question of what the function of napping may be, we must first define 'function.' Though this article concentrates mostly on the function of napping for behavior, it would be possible also to write about the function of napping across cultures and history. For example, there is a long history of napping in Southern regions of the globe, in which it is practiced in the form of a siesta. By the first century BC, the Romans had coined a word for the afternoon break, *meridiari*, derived from the Latin word for 'midday.' Later, the church divided the day into periods designated for specific activities, such as meals, prayer, and rest. Midday became known as *sexta*, as in the sixth hour (noon, by their way of counting), a time when everyone would take rest and pray. The word has survived as the familiar term, 'siesta.' This postprandial sleep custom disappeared in northern Europe with the industrial revolution, but remained a strong tradition in southern Europe and many Latin American cultures, where people would shutter their businesses for a few hours to return home, eat a meal, sleep, and then return to work from 4 p.m. until 9 p.m. While the 'siesta' culture continues today in these regions, enthusiasm for the siesta has cooled substantially.

p0010 Presently, napping is most popular in highly industrious cultures such as Japan and Germany, whereas countries such as Spain or Italy have begun phasing out the practice. Current beliefs about midday rest are being reassessed from an empirical perspective, as evidenced by the fact that this topic is enjoying the spotlight of an entire entry in an encyclopedia of neuroscience for the first time. One reason for this resurgence of interest in the function of naps is due to the changing needs of modern culture. An increase in 24-h work cycles, the regularity of international travel and communication with global markets, and long work days and longer commutes have brought on a host of secondary problems that require attention – reports show continual decreases in nocturnal sleep, increases in sleep disorders, and increases in sleepiness-related accidents. The nap is thus being increasingly investigated as an inexpensive, noninvasive, short period of sleep strategically implemented for sleepiness and fatigue management, sustained productivity and alertness, and optimal cognitive processing.

This emerging body of research is summarized in the following sections, with emphasis on the possible biological basis of effects of napping, implementation during night shift and sleep deprivation studies, and promising new directions investigating the dose- and sleep stage-dependent benefits possible through targeted napping schedules designed to improve performance on a wide variety of behavioral measures. p0015

Definitions and Demographics of Napping s0010

What Is a Nap? s0015

Naps, at least as discussed herein, are defined as intended periods of sleep that can last anywhere from 3 min to 3 h and can be taken anytime during the day or night. Meta-analysis of surveys and diary studies of American populations show that naps usually range between 0.5 and 1.6 h. Naps should be distinguished from microsleep, which is a brief, involuntary period of sleep lasting from seconds to minutes. In addition, naps should be distinguished from 'major' sleep periods that typically occur overnight and typically last at least 5 h or more (of course, in night shift workers, these major sleep periods occur during the day). p0020

Changes in Napping Behaviors across the Life Span s0020

Napping patterns shift throughout life. In infancy, two basic types of sleep emerge: quiet sleep and active sleep. These are the infant equivalent, respectively, of nonrapid eye movement (NREM) and rapid eye movement (REM) sleep seen in adults. Over 50% of neonate sleep is active (though premature babies can achieve levels as high as 80%), but that number will drop to 30% by the end of the first year. Infants have shorter sleep cycles than adults do, with the typical cycle lasting 50–60 min as opposed to 80–100 min in adults. Interestingly, infants also commonly show sleep-onset active sleep especially after feeding, a sleep pattern considered pathological in adults. By the age of 2 years of age, REM occupies 20% of total sleep, a figure that remains relatively common throughout the rest of life. Napping emerges a little before the first birthday, when sleep coalesces into a nocturnal sleep period, a shorter nap (30 min to 1 h) in the morning around 10 a.m., and a longer nap (1–3 h) in the afternoon. Eventually napping consolidates into one long afternoon nap and then the nap disappears in most children around age p0025 four, reappearing in teenage years and into college years, when up to 60% of students report regular napping habits.

p0030 Recent evidence suggests that men take more naps than women do, even though nocturnal sleep hours average about the same for both sexes. On average, men's nocturnal sleep appears to be less efficient, so men may simply need a nap more than women do. Specifically, studies of young adults show that males not only spend more time in bed awake compared to females, but also enjoy less short-wave sleep (SWS) and REM compared to females. Troubled sleep occurs in women as well, of course, but typically begins later in life, resulting in part from hormone fluctuations that occur across a woman's lifetime.

p0035 Napping behavior also changes as a function of aging. Older adults nap more frequently and later in the day compared with younger adults. There may be multiple underlying causes for these differences, including nocturnal sleep deterioration, weaker circadian rhythm and circadian phase advance, or simply that the elderly have more time to practice elective napping. Some studies have shown that napping in older adults is related to decreases in slow-wave activity and reduced sleep efficiency, whereas napping is not related to nocturnal sleep parameters in normal adults or insomniacs.

p0040 A number of studies have investigated how napping interferes with nocturnal sleep parameters; effects are likely due to the relieving of sleep pressure, the biological drive to go to sleep that increases as a function of time awake. In general, naps are reported to not interfere with nocturnal sleep. Exceptions to this are that (1) naps can decrease slow-wave activity in subsequent sleep episodes when naps are taken within a 2- to 3-h window from nocturnal sleep (bedtime) and that (2) when naps are taken during a night shift, the subsequent daytime sleep can show decreased slow-wave activity.

s0025 Is Napping a Natural Part of Our Circadian Rhythm?

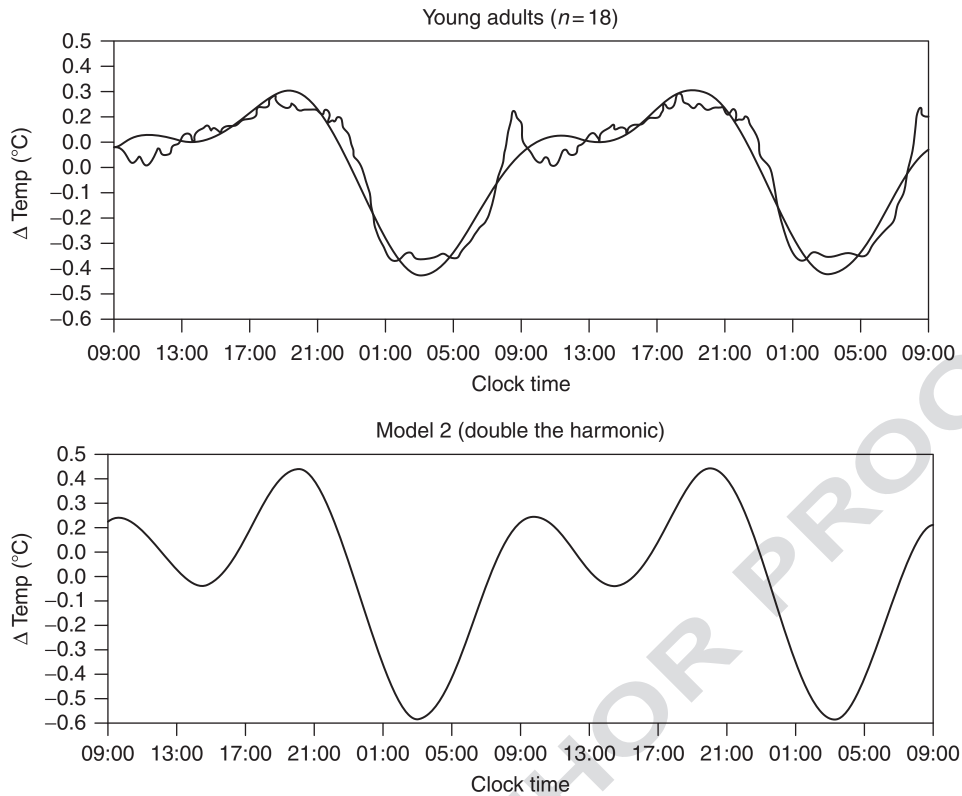
s0030 Timing of Naps

p0045 When napping is examined in the laboratory, the consistent finding is that daytime sleepiness is a regularly occurring phenomenon. The afternoon 'nap zone,' first proposed by Broughton, is a period between 14:00 and 16:00, when daytime sleep propensity is highest. Such a propensity for diurnal sleep has been demonstrated in a variety of different experimental milieus, including with removal of all temporal constraints or 'free-running' conditions during ultrashort routines, in which sleep–wake schedules occur over a 90-min period, and as evidenced in the classic 'M-shaped' time-of-day function in studies of sleep propensity using the Multiple Sleep Latency Test (MSLT), a test in which the time it takes to fall asleep, sleep onset latency, is measured at regular intervals across the day. Even in studies when individuals are specifically asked not to nap, resistance to daytime sleep has been most weak during these afternoon hours. Due to the time of day increased sleep propensity occurs as well as the historical develop of napping behaviors, it has been (perhaps misleadingly) termed 'the postprandial dip.' Studies have shown, however, that the energy slump occurs even in the absence of lunch and/or without knowledge of the time of day.

Physiological Evidence for 'Nap Zone' s0035

A fluctuation in core body temperature (CBT), a fundamental measure of circadian rhythms, represents the best physiological marker to correlate with increased afternoon sleep propensity. Generally speaking, there is a rise in temperature across the daytime and a decrease during the night. The falling temperature traditionally has been considered one important trigger for onset and method of sustainment for nocturnal sleep. CBT starts to fall prior to habitual bedtime and reaches its lowest point approximately two hours prior to habitual wake time (typically between 03:00 – 05:00 in most adults). Though circadian fluctuation of CBT can be fit with a simple sinusoid function spread across the 24-h period, further investigations have found that CBT is better described by adding a 12-h bicircadian component to the model, which corresponds to a robust finding of a dip in temperature in the afternoon (**Figure 1**). p0050

The afternoon dip in temperature corresponds to the time when individuals show a greater sleep propensity. Although decreases in CBT are temporally correlated with increases in sleepiness, a direct mechanistic link has yet to be discovered. Sedative-hypnotics such as melatonin and benzodiazpines decrease CBT and increase peripheral heat loss, which has been directly related to sleep onset latency. In contrast, agents such as caffeine, amphetamines, nicotine, and cocaine decrease sleep propensity and increase core body temperature. Further, studies have shown that the best predictor of sleep onset (better than melatonin) was the distal–proximal skin gradient, an index of peripheral heat loss. Thus, it is likely that a decrease in temperature (CBT and peripheral heat) is a trigger for sleep in general, and possibly also for afternoon naps. The duration of a sleep episode may also be related to the direction of change in CBT – that is, long nocturnal sleep occurs during an extended period of decreased temperature while short sleep occurs p0055



f0005 **Figure 1** (Top) Double-plotted 24-h rectal temperature rhythms from 18 young adults on a nycthemeral routine, together with best fitting composite 24- and 12-h sinusoids (see text). (Bottom) The same fitted model, but with the 12-h amplitude raised from 0.152 °C to 0.304 °C.

when CBT increases. Studies have found that increases in CBT are related to more frequent awakenings. Further research is needed to disentangle the causal relationship between changes in CBT and daytime sleep onset.

s0040 **Behavioral Markers for the 'Nap' Zone**

p0060 Anecdotal evidence for behavioral measures of the 'nap' zone can be easily found in any typical workplace, with decreased productivity and increased caffeine consumption during the afternoon, as well as an increase in traffic accidents during this time of day (even after taking into account the increased number of cars on the road). On the other hand, it has been more difficult to find consistent laboratory evidence for behavioral markers. Two factors are most likely the cause. First, there may be specific cognitive processes that are vulnerable to circadian peaks and troughs, while others are not. For example, tasks that rely on continuous performance show dips in the afternoon, such as card sorting, serial search, a variety of signal detection tasks, and physical exertion such as sprinting. Memory tasks and perceptual tasks, on the other hand, have not shown a strong circadian component. Second, individual differences are likely to produce a large source of variation. Intriguing findings of individual differences in vulnerability to a midafternoon performance deficit on a monotonous visual vigilance task demonstrate that only half of the individuals show the 14:00 performance dip. Monk and colleagues compared the CBT of the 'dippers' to the 'nondippers' and showed that performance decreases coincided with a flattening of the CBT in the dippers, whereas CBT in the nondippers continued to increase in a linear manner during this period. Monk proposed that an individual's propensity for midday decreases in performance may be predicted by a combination of the individual's endogenous circadian pacemaker and the length of time the individual has been awake (i.e., magnitude of sleep pressure). Specifically, Monk stated that "the size (or timing) of the 12-h temperature rhythm component might be predictive of the size (or presence) of a post-lunch dip in performance." Further research investigating other biological and genetic determinants of midday dip vulnerability, such as morningness and eveningness measures proposed by Horne, will be extremely interesting pieces of information for answering these questions.

s0045 ## What is the Function of Naps?

p0065 Now that we have provided evidence in favor of naps being a natural part of sleep–wake cycles, at least in some individuals, we turn our attention to the possible function of naps. As already stated, the concept of 'function' can take many forms. For example, one can ask whether the function of a nap is the same as the function of sleep in general, or if it serves a purpose separate from that of the major sleep period. While we do not yet fully understand why we sleep, we do know that a variety of molecular, genetic, and physiological processes occur exclusively, or primarily, during sleep. For the most part, research has not examined whether these same changes occur during naps. What has been examined, though, are the behavioral and cognitive benefits of a nap under a variety of conditions. In other words, research has examined how naps help individuals function better. Thus, it is this more operational definition of function that we discuss here.

s0050 ### Sleepiness versus Fatigue Countermeasures

p0070 In the broadest sense, naps are used operationally as either sleepiness countermeasures or fatigue countermeasures. The distinction between sleepiness and fatigue is one that is, unfortunately, often blurred or confused, but is an important distinction to keep in mind. Sleepiness is the physiological propensity to fall asleep, either intentionally or unintentionally. As discussed earlier, the circadian rhythm of the CBT is one traditional biomarker of sleepiness. When naps are used as a sleepiness countermeasure, the intended function is to increase arousal and alertness. This increased alertness level may, in turn, produce better performance. In contrast, fatigue refers to a decrease in physical or cognitive efficiency related to time-on-task and workload, independent of whether someone has a propensity to fall asleep. When naps are used as a fatigue countermeasure, the intended function is to directly boost performance. Most often, the term 'fatigue countermeasure' is incorrectly used to cover both functions (of not only naps, but also interventions such as caffeine) when used in operational settings.

s0055 ### Napping in Sleep-Deprived Conditions

p0075 Until recently, napping research has focused primarily on treating sleepiness during extended work periods, such as long-haul truck driving, transatlantic airplane routes, and NASA space flight, as well as during nontraditional work schedules such as night shifts. In both of these circumstances sleepiness due to sleep deprivation is a common danger and has been implicated as contributing to accidents during work and transit from work to home, as well as to increased health problems in these workers.

Night shift work is particularly vulnerable to extreme performance decrements due to unintentional sleep, increased sleepiness, and decreased performance for most skills, including vigilance, reaction time, serial addition/subtraction, spatial orientation, and flight simulator operation. Critical hours for increased errors and slowness are between 03:00 and 05:00 (coinciding with CBT nadir). The two main sources of reduced alertness and performance during night work are (1) the circadian rhythm of sleepiness and alertness (as discussed earlier) and (2) increased homeostatic sleep pressure. Contributing to this difficulty with night shift work is the poor adaptability of circadian regulated processes such as endocrine, sleep, CBT, adrenaline, alertness, and other physiological rhythms to even long-term (2–3 months) reversal of sleep–wake cycles. Even workers on permanent night shift schedules do not show a change in the timing of the circadian system and continue to show reduced performance and increased mistakes after years on the night shift. Thus, the need to find sleepiness and fatigue management solutions for this population is an imperative. p0080

Work-related napping strategies have categorized three types of naps: prophylactic napping (taken in anticipation of sleep deprivation), compensatory napping (taken after sleep deprivation has begun), and operational napping (napping during working hours). Overall, prophylactic napping taken just before the work night seems to best enhance performance overnight, although a combination of prophylactic napping and caffeine may work even better. With respect to operational napping, it has been found that both pilots and truck drivers unofficially nap during night shifts and long-haul transportation trips. Research has shown that a 20-min operational nap between 01:00 and 03:00 significantly improves speed of response on a vigilance task measured at the end of the shift, compared with a control condition. The potential problem with napping during the night is that there is increased risk for waking with sleep inertia. Sleep inertia is the feeling of slowness, irritability, and poor decision-making ability that can occur during the first 20–30 min after waking from deep sleep, although this period may be shorter with naps than with longer sleep periods. Methods for combating sleep inertia, however, have been proved successful, including exposure to bright light, washing the face, exercise, and, of course, a dose of caffeine. Apart from performance on specific measures, napping has been shown generally to p0085 improve alertness, productivity, and mood, and this may be especially so under sleep-deprived conditions, during night shift work, and during prolonged periods of driving.

s0060 **Cognitive Benefits of Napping Linked to Specific Stages of Sleep**

p0090 It is perhaps unsurprising that napping has been shown to be an effective sleepiness countermeasure, and that improved alertness can, in turn, have a positive impact on performance. What may be even more interesting to explore is whether napping can be a fatigue countermeasure independent of alerting effects, and whether naps can even enhance normal performance when fatigue and/or sleepiness are not an issue. Recent studies investigating the impact of napping on a variety of memory consolidation measurements have in fact provided evidence for both of these functions. Studies on the benefit of napping on performance have demonstrated that short daytime sleep episodes not only can decrease sleepiness but also show selective enhancement of various forms of memory, as well as increase alertness and physical and mental stamina. Furthermore, these studies have related these napping-related improvements to specific sleep stages.

p0095 An important methodological aspect of napping that has been exploited by these studies is that sleep during naps can be titrated to have specific stages of sleep without disturbing the napper's sleep. This is accomplished primarily by manipulating the duration and timing of the nap. Such manipulations have been attempted during nocturnal sleep studies by depriving individuals of sleep during the first or the second half of the night, in order to isolate SWS or REM sleep. Although selective cognitive benefits have been shown, this method does not actually isolate stage two, SWS, or REM. Naps, on the other hand, have shown a high degree of specificity in performance between stage one alone versus stage one and two combined, and naps with SWS alone versus SWS and REM combined.

p0100 Hayashi et al. demonstrated the recuperative power of napping for sleepiness and alertness measurements even with a 5-min nap limited to stage one sleep. They report that performance improvement on a visual detection task and digit symbol task, as well as decreases in slow eye movements during testing, required a nap with stage two. Walker demonstrated that a nap can improve performance on a motor learning task to the same degree as can a full night of sleep, with stage two sleep playing an important role.

p0105 Naps rich in SWS have been shown to improve declarative memory for pictures or word pairs after a nap, as well as prevent deterioration in performance that develops across the day. Mednick and colleagues have reported a series of studies establishing the efficacy of naps in combating performance deterioration. These studies utilized a visual perceptual task in which individuals reliably show significant decreases in performance with repeated testing across the day, even when the test is only given twice. Importantly, they found that a 60-min midday nap rich in slow-wave sleep can reverse perceptual deterioration and restore performance to baseline, with long-lasting benefits to performance (**Figure 2**).

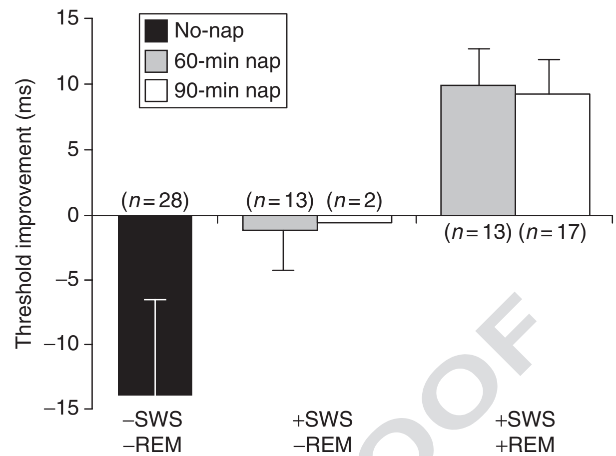
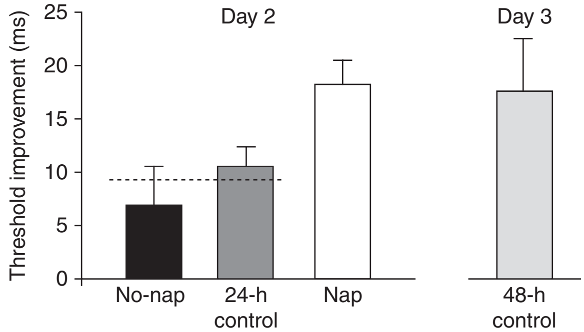


Figure 2 Same-day improvement in no-nap, 60-min nap, and 90-min nap groups, with and without rapid eye movement (REM) and short-wave sleep (SWS). (Left) No-nap group shows deterioration at 19:00 from baseline test at 09:00. (Center) Performance after naps with SWS but without REM shows neither deterioration nor improvement. (Right) Naps with SWS and REM led to significant improvement. Only two individuals in the 90-min nap group showed no REM. f0010

Naps including both SWS and REM actually led to an improvement in perceptual performance equivalent to that following a full night of sleep. Furthermore, when individuals are tested after a nap and a full night of sleep, they demonstrate as much benefit as with two nights of sleep, indicating that sleep-dependent learning is similarly effective whether it is from daytime naps or nocturnal sleep. Also, the benefits from napping and nocturnal sleep are additive (**Figure 3**). It should be emphasized that these sets of studies examined performance after a normal night of sleep, rather than following a period of sleep deprivation. Thus they showed that naps can enhance performance beyond even 'normal' levels. p0110

Summary s0065

In examining the function of naps it appears that modern culture has redefined the functionality to suit the needs of an increasingly 24-h society. The p0115



f0015 **Figure 3** Improvement for nap and no-nap groups. (Left) Improvements 24 h after training for the no-nap group's second retest, the 24-h control group's first retest, and the 90-min nap group's second retest, all at 09:00 on day 2. Dashed line shows nap group's improvement on day 1. (Right) Improvement 48 h posttraining with no nap.

amount of nocturnal sleep continues to decrease as labor demands increase in duration, as well as with the increase in around-the-clock work schedules. Thus the nap serves as both a fatigue and sleepiness countermeasure. Some studies demonstrate that napping in the afternoon may in fact be an inherent part of our natural sleep–wake cycle, as evidenced by physiological and performance decreases during the afternoon that temporally coincide with increased propensity to sleep. Most research on napping has examined either alertness or specific cognitive benefits. An important consideration that has emerged from this body of research is that specific stages of sleep can confer specific benefits to performance. Overall, naps seem to confer a number of possible benefits, but this area of investigation is still young. Present directions of research are investigating the cognitive benefits of napping and the possibility of fitting a nap to an individual's needs by adjusting the duration and time of day of the nap. Important areas for future research concerning the function of naps will include the medical, physiological, and psychological benefits of napping that have been reported to occur with nocturnal sleep.

See also: Immune function during sleep and sleep deprivation (00068); Thermoregulation during sleep and sleep deprivation (00069); Autonomic dysregulation during REM sleep (00070); Sleep-dependent memory processing (00072); Sleep deprivation and brain fu+D46nction (00074).

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