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CLINICAL REVIEW

Naps, cognition and performance

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SUMMARY

Daytime napping is a frequent habit of many individuals, whether healthy or not, and may occur in a wide variety of contexts. There are several reasons for napping in the human adult, including prophylactic strategies or recuperative need, respectively before or after sleep loss, or even pure appetitive drive. Thus, it is of great theoretical and clinical interest to assess the impact of naps on individuals' performance, especially on cognitive functioning. As the outgrowth of a symposium held by the authors at the 5th Congress of the World Federation of Sleep Research and Sleep Medicine Societies in Cairns, Australia, September 2007, this review will specifically explore: a) the newly developed experimental daytime split-sleep schedules and their effects on recovery, compared with those deriving from a single consolidated sleep episode of equal duration; b) whether naps may be beneficial to wakefulness performance in the working context, through accurate review of "on field" studies; c) the impact of naps on cognition, in light of the very recent advances in the study of naps and memory processes; d) the main features of napping behavior in older individuals and its impact on their health and general functioning, since it is widely recognized that napping may change as a result of the aging process.

Introduction

Daytime napping is a frequent habit in many individuals, whether healthy or not, and may occur in a wide variety of contexts. Seminal research on naps, extensively reviewed in a volume by Stampi,[1] has tried to address the regulatory mechanisms sustaining polyphasic sleep structure, as well as to identify the determinants of napping, on both the psychobiological and the psychosocial level. These studies have focused on several different reasons for napping including: recuperative need, due to prolonged wakefulness or increased sleep pressure; prophylactic strategies, aimed to counteract an expected sleep deprivation and to maintain performance in particular contexts such as shift work or sustained operations; and pure appetitive drive, linked to sociocultural and individual characteristics. Thus the causes of napping are likely to be multifaceted, a picture made even more complex by the continuous interactions of each of these factors with the others. However, the question of what impact napping might have on the general functioning of individuals, with special regard to wakefulness performance and memory processes, has so far received little attention.

This review seeks to raise interest in these theoretically and clinically fundamental aspects of napping. It is the outgrowth of a symposium, "The Effect of Naps on Health and Cognition", held by the authors at the 5th Congress of the World Federation of Sleep Research and Sleep Medicine Societies in Cairns, Australia, September 2007, specifically conceived to pay thorough attention to the relationships between daytime napping and cognitive processes, in light of the very recent advances in the study of naps, memory and performance. Here we will examine the interrelationships of napping, cognition and performance in four specific contexts.

First, the hypothesis that a split-sleep schedule provides more recovery than a single consolidated sleep period of the same total duration is examined. We will start with this particular approach since it represents the most recent experimental contribution, after the classical 80s studies on daytime sleep regulatory mechanisms,[1] to set the basis for the understanding of nap effects in "real life" situations. Second, the advantages and disadvantages of napping in the work environment are examined. Third, the purported benefits of napping for the learning of new material, either declarative (e.g., lists of words) or procedural (e.g., perceptual or motor tasks) are explored, including a discussion of why daytime naps, due to their peculiar sleep infrastructure, might represent a useful model of memory consolidation mechanisms during sleep. Finally, the prevalence of regular napping in the elderly and its association with

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sleep complaints, excessive daytime sleepiness, and mental and physical health problems are examined, with a focus on whether regular napping among older adults, particularly those in good health, may be beneficial to daytime wakefulness or detrimental to night-time sleep propensity.

Effects of split-sleep schedules on sleep stage architecture and neurobehavioral performance

Can split-sleep enhance recuperative benefits to performance?

The idea of splitting a sleep period up into two parts of the same total duration to provide enhanced recuperative benefits was first posed in 1897 and came from observations about the exponential time-course of sleep depth from measured auditory arousal threshold.[2] The idea was that exponential functions are steepest in the first half of the function (i.e., provide more recovery per unit time invested in sleep), thus breaking sleep into two parts would exploit this property advantageously yielding more recovery than a single sleep period of the same total duration. In recent decades, others have reported that alertness and performance are restored as a saturating exponential function of total sleep,[3,4] however only a small number of studies have directly compared split-sleep and monophasic sleep to determine if in fact there are neurobehavioral benefits of splitting sleep into parts. We begin with a review of the factors related to split-sleep schedules that impact sleep architecture and neurobehavioral performance including circadian timing of sleep, duration of prior wakefulness, and cumulative sleep loss.

Factors related to split-sleep that affect sleep architecture

Circadian timing of sleep has been extensively examined in experiments involving long-term temporal isolation, multi-cyclic sleep wake schedules, and forced desynchrony. These experiments showed that circadian phase as well as the duration of prior wakefulness affects sleep propensity (i.e., sleep onset latencies and sleep duration) and sleep architecture by primarily impacting rapid eye movement (REM) sleep. In fact it has been shown that there are certain circadian "forbidden zones" where nap sleep initiation would be improbable at normal homeostatic levels.[5,6] For an extensive review of these experiments see the review by Dijk and Czeisler.[7] Sleep loss resulting from total sleep deprivation and chronic partial sleep deprivation has also been shown to affect sleep propensity and sleep architecture.[8,9] Experiments about sleep loss effects on sleep architecture are reviewed by Dinges et al.[10]

Factors related to split-sleep that affect neurobehavioral performance

In order to fully characterize the impact of napping on neurobehavioral performance associated with split-sleep performance, factors such as mood, cognitive performance, and motor function must be examined across a range of homeostatic levels resulting from both acute total sleep deprivation and chronic partial sleep deprivation. It is known from controlled laboratory experiments that sleep loss resulting from acute total sleep deprivation negatively affects mood, cognitive performance, and motor function due to an increasing sleep propensity and destabilization of the wake state.[11] Sleep loss resulting from chronic partial sleep deprivation progressively impacts these same factors in a dose-response relationship with TIB across days of sleep restriction.[9,12] The duration of prior wakefulness at the time of testing has been shown to impact performance and to interact with circadian phase.[13] The important theoretical question is whether split-sleep schedules mitigate neurobehavioral deficits resulting from homeostatic pressure associated with sleep restriction when compared to consolidated sleep. Sleep inertia must also be accounted for in the interpretation of experiments designed to measure the impact on neurobehavioral performance of split-sleep schedules. Sleep inertia impacts neurobehavioral performance for 2 or more hours after waking [14] and is most pronounced at adverse circadian phases in the middle of the habitual night.[15] It has been shown to increase in magnitude and duration with total sleep deprivation and can be mitigated by caffeine.[16] Finally, experimental evidence has demonstrated that there are large, stable, trait-like differences among individuals in the amount of daily sleep required to maintain stable levels of performance.[17] In fact, individual differences in the response to sleep loss should be considered when studying any of the above mentioned factors related to split-sleep schedules.[18]

Experiments that directly compare consolidated and split-sleep schedules

We now review experiments that specifically compared consolidated sleep with split sleep. In all of the experiments described in this section cognitive performance was assessed using objective measures such as a digit symbol substitution task, mental arithmetic tasks, or simple and choice reaction times tasks. Mood and sleepiness were assessed with subjective scales. The first experiment considered was a within-subjects design by Nicholson et al. that compared 8 h of continuous nocturnal sleep to a split-sleep schedule that was comprised of two 4 h sleep periods bisected by 10 h of nocturnal wakefulness.[19] No differences in performance were detected in subsequent daytime performance between the consolidated and split-sleep schedules. Other experiments examining split-sleep compared to consolidated sleep of the same total duration found increases in subsequent daytime performance; however these effects were attributed to experimental confounds related to differences in duration of prior wakefulness at the time of testing.[20,21] A recent controlled laboratory experiment by Dinges' group examined performance impairments associated with a range of split-sleep schedules that were comprised of restricted nocturnal sleep augmented with a daytime nap or no nap. In order to minimize confounds related to circadian phase and duration of prior wakefulness, data were analyzed based on daily-average-performance to identify the functional relationship between performance and nocturnal anchor sleep and diurnal nap sleep. Tests that occurred immediately after awakening from a nocturnal sleep or diurnal nap were not included in the daily performance averages to avoid measuring sleep inertia effects. The overall finding was that performance was a function of total daily time in bed independent of whether sleep was consolidated or split into two parts.[22] In terms of total sleep time and neurobehavioral performance, it did not substantively matter whether sleep was consolidated or scheduled in two parts.[22,23] Less is known, however, about any health impacts of any types of split-sleep regimen, even if this strategy of sleep would be favorable for maintaining performance.

Effects of naps on vigilance/performance/subjective well-being as assessed from "on field studies"

With respect to napping in working life, most naps occur in association with night work. Although the majority of naps seem to be compensatory in nature (i.e., a result of sleepiness/sleep pressure), the large number of naps occurring before the first night shift demonstrate that many workers also take prophylactic naps to reduce night-shift sleepiness.[24,25] Some studies report that up to