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Do night naps impact driving performance and daytime recovery sleep?

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ABSTRACT

Short, nighttime naps are used as a fatigue countermeasure in night shift work, and may offer protective benefits on the morning commute. However, there is a concern that nighttime napping may impact upon the quality of daytime sleep. The aim of the current project was to investigate the influence of short nighttime naps (<30 min) on simulated driving performance and subsequent daytime recovery sleep. Thirty-one healthy subjects (aged 21–35 y; 18 females) participated in a 3-day laboratory study. After a 9-h baseline sleep opportunity (22:00 h–07:00 h), subjects were kept awake the following night with random assignment to: a 10-min nap ending at 04:00 h plus a 10-min nap at 07:00 h; a 30-min nap ending at 04:00 h; or a no-nap control. A 40-min driving simulator task was administered at 07:00 h and 18:30 h post-recovery sleep. All conditions had a 6-h daytime recovery sleep opportunity (10:00 h–16:00 h) the next day. All sleep periods were recorded polysomnographically. Compared to control, the napping conditions did not significantly impact upon simulated driving lane variability, percentage of time in a safe zone, or time to first crash on morning or evening drives ($p > 0.05$). Short nighttime naps did not significantly affect daytime recovery total sleep time ($p > 0.05$). Slow wave sleep (SWS) obtained during the 30-min nighttime nap resulted in a significant reduction in SWS during subsequent daytime recovery sleep ($p < 0.05$), such that the total amount of SWS in 24-h was preserved. Therefore, short naps did not protect against performance decrements during a simulated morning commute, but they also did not adversely affect daytime recovery sleep following a night shift. Further investigation is needed to examine the optimal timing, length or combination of naps for reducing performance decrements on the morning commute, whilst still preserving daytime sleep quality.

1. Introduction

Two factors of concern to shift workers are increased accident risk on the morning commute, and poor daytime sleep quality following night shifts. Afternoon naps as short as 10-min in length have been found to be effective for improving cognitive performance for up to 2.5-h whilst minimising sleep inertia (Brooks and Lack, 2006). However, it is unknown if a short nighttime nap during the circadian low offers recovery benefits that would extend to the morning commute. In addition to a short nighttime nap, a 10-min morning top-up nap may be a simple strategy for mitigating fatigue-related performance decrements on the morning commute. Short naps on night shift may also have the advantage of preserving daytime sleep quality. Few studies to date have examined the effects of short nighttime naps (<30-min) on driving performance and daytime sleep quality.

Sleep loss following a single night awake is associated with impaired reaction time, accuracy and grammatical reasoning the next morning at levels comparable to subjects with a blood alcohol concentration of twice the legal Australian limit (Lamond and Dawson, 1999; Williamson and Feyer, 2000). It is therefore unsurprising that shift workers demonstrate not only impaired performance during night shifts, but also reports of extreme drowsiness or near accidents while travelling home (Hildebrandt and Stratmann, 1979; Dorrian et al., 2008; Fallis et al., 2011; Armstrong et al., 2013). Laboratory studies demonstrate that simulated commuting post-night shift causes incidents, decreased time to accidents, increased variability in lateral position, and increased eye closure durations (Khaleque, 1999). Subjective reports of sleepiness also suggest that shift workers struggle to stay awake driving home (Hildebrandt and Stratmann, 1979; Hillman et al., 2006; Dorrian et al., 2008; Fallis et al., 2011). Increased risks posed by commuting post-night shift are due to a combination of factors including extended time awake and the circadian low often

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coinciding with the early morning drive (Dijk and Czeisler, 1995). It has been suggested that shift workers should take particular care driving after a night shift and consider taking a short nap (<15-min) before driving home from their shift (Gronczewski, 2001; Scott et al., 2007). Despite these recommendations, there is insufficient evidence to support the effectiveness of short naps before the morning commute.

Naps taken during a night shift rather than immediately before the morning drive may also reduce performance decrements on the morning commute. For example, a 30-min nap opportunity at 04:00 h on an actual night shift has been found to improve lane position, but not speed variability on a 30-min driving task at 06:45 h compared to no nap (Howard et al., 2010). However, large variability in lane position was also observed during baseline testing, and the sample was small ($N = 8$).

Despite potential advantages of nighttime naps, concern exists that they may disrupt the subsequent main sleep period. This is undesirable given that night shift workers already experience daytime sleep of shorter duration and poorer quality compared to nighttime sleep (Costa, 1997). Furthermore, if daytime recovery sleep is diminished by napping on night shift and total sleep time (over the 24-h period) is reduced, then subsequent performance-such as on the evening drive to night shift may be impaired (Banks et al., 2010). Certain sleep parameters appear to be affected by nighttime napping, depending on the timing and duration of naps and subsequent day sleep (Rogers et al., 1989; Tepas et al., 1990; Takeyama et al., 2005). Most research has investigated the impact of longer naps on daytime recovery sleep, rather than short naps. Rogers et al. (1989) found that following a 1-h nap taken at 02:00 h, daytime sleep was shorter in length and contained less slow wave sleep (SWS). Similar results have also been replicated for nighttime naps of one to 2 h in length (Matsumoto and Harada, 1994; Sallinen et al., 1998; Bonnefond et al., 2001).

What remains unknown is whether naps that are <30-min in length and are placed closer to the morning commute may offer protective benefits on the morning drive without impacting upon daytime sleep. Therefore, the present study aims to investigate the effect of a 30-min nighttime nap, and a 10-min nighttime nap with a 10-min morning top-up nap on (i) driving performance during the morning simulated commute (ii) sleep architecture during a daytime recovery sleep opportunity, and (iii) driving performance post-recovery sleep.

2. Methods

2.1. Ethics statement

The study was approved by the University of South Australia Human Research Ethics Committee. All subjects provided written informed consent prior to entering the laboratory and were paid an honorarium for their time.

2.2. Subjects

Thirty-two healthy adult subjects (20F, aged 21-35y, mean body mass index [BMI] 22.2 ± SD 3.0) participated in the study. Subjects were required to be of sound physical and mental health. Subjects reported no habitual napping, insomnia, daytime sleepiness, or other sleep disturbances including sleep disorders (confirmed using a general health questionnaire, a morningness/eveningness questionnaire and the Pittsburgh Sleep Quality Index (Buysse et al., 1989), and sleep diaries and actigraphy the week prior to the study). Subjects were non-smokers and did not engage in shift work, transmeridian travel, excessive caffeine consumption, or unusual sleep routines for the two months prior to the study. Subjects were excluded from participation if their BMI was outside of the normal range given the association between high BMI and obstructive sleep apnoea (Young et al., 2004). A trained sleep technician who scored all sleep records verified absence of arousals. Subjects undertook urine and blood tests to screen for illicit substance use and health abnormalities.

All subjects completed the 3-day laboratory study with the exception of one female subject who withdrew due to illness. The remaining 31 subjects were randomly assigned to one of three conditions: A 30-min nap condition ($N = 10$, 24.7 y ± 2.7); a "10-10-nap" condition ($N = 10$, 23.6 y ± 4.2); or a no-nap control condition ($N = 11$, 24.5 y ± 3.3).

2.3. Experimental protocol

Subjects were studied in groups of four, for three consecutive days at the Centre for Sleep Research at the University of South Australia. The first day was used for adaptation and training. Subjects underwent one night of baseline sleep (22:00 h–07:00 h). Subjects were then assigned to one night of sleep deprivation with either: A 30-min nap opportunity ending at 04:00 h; a 10-10-nap condition, with one 10-min nap opportunity ending at 04:00 h, and another 10-min nap opportunity at 07:00 h; or no-nap (control). All conditions were followed by a 6-h daytime recovery sleep period (10:00 h–16:00 h). The objectives of the study and nap lengths were not made explicit to the subjects to minimise influences on post-nap performance.

The laboratory environment was free of natural light, and artificial lighting was set at <50 lux during wake periods. The laboratory was temperature (22 ± 1 °C) and sound controlled. Showers and calorie-controlled meals were provided at set times. When not engaged in testing, subjects were permitted to read, watch movies or socialise in a communal living area. They were not permitted to use mobile phones or backlit devices, or engage in physical activity.

Approximately 1-h prior to bedtime, subjects were prepared for polysomnographic recording of sleep. On the baseline day, subjects in all conditions undertook a 40-min driving simulator task at: 18:30 h to simulate the commute to a night shift; at 07:10 h to simulate the commute home following the simulated night shift; and again at 18:30 h following a daytime recovery sleep.

2.4. Measures

2.4.1. Driving simulator task

The 40-min computer-based driving simulator task was custom designed by York Computer Technologies. A Logitech steering wheel and pedals were installed on driving computers located in each subject's bedroom. The task was designed to mimic a monotonous country drive, with no road lights or cars to overtake. A five-min circuit consisted of straight roads and four gentle corners, and was repeated approximately eight times for the 40-min duration of the task. Subjects were instructed to adhere to the speed limit of 100 km per hour on straights and 80 km per hour on corners as closely as possible, and to stay in the centre of the left lane at all times. Derived driving variables were risk of a first crash, lane variability, and percentage of time spent in a safe zone (Fig. 1). Although the York simulator is yet to be validated against real-world driving, speed and lane variability within this task have been found to be sensitive measures of fatigue (Baulk et al., 2006). The York simulator has also shown to be sensitive to the effects of naps (De Valck et al., 2003).

2.4.2. Sleep

Sleep was measured using polysomnography (PSG). PSG recordings were made using the Compumedics Grael Sleep System, and Compumedics Profusion PSG 3 Software (Melbourne, Australia).

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