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The impact of short night-time naps on performance, sleepiness and mood during a simulated night shift

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Abstract

Short naps on night shift are recommended in some industries. There is a paucity of evidence to verify the sustained recovery benefits of short naps in the last few hours of the night shift. Therefore, the current study aimed to investigate the sustained recovery benefits of 30min and 10min nap opportunities during a simulated night shift. Thirty-one healthy participants (18F, 21-35y) completed a 3-day, between-groups laboratory study with one baseline night (22:00h-07:00h time in bed), followed by one night awake (time awake from 07:00h on day two through 10:00h day three) with random allocation to: a 10min nap opportunity ending at 04:00h, a 30min nap opportunity ending at 04:00h, or no-nap (control). A neurobehavioral test bout was administered approximately every 2h during wake periods. There were no significant differences between nap conditions for post-nap psychomotor vigilance performance after controlling for pre-nap scores ($p>0.05$). The 30min nap significantly improved subjective sleepiness compared to the 10min nap and no-nap control ($p<0.05$). The 10min nap significantly worsened negative mood compared to the 30min nap and no-nap control ($p<0.01$). Contrary to some evidence suggesting 'power naps' can help to alleviate performance decrements, a 30min nap opportunity at approximately 04:00h was found to improve subjective, but not objective sleepiness. A 10min nap may lead to increased negative mood in the hours following the nap due to a 'short nap aversion' effect.

1 Introduction

Shift work is increasingly recognised as an occupational health and safety issue. The most widely documented consequence of shift work is sleep disturbance, resulting in fatigue and performance impairments including slower reaction time, poor decision-making abilities, and reduced concentration, memory and mood (Belenky et al., 2003; Dinges et al., 1997; Van Dongen, Maislin, Mullington, & Dinges, 2003; Wyatt, Ritz-De Cecco, Czeisler, & Dijk, 1999). These decrements are attributed to staying awake during the night when sleep propensity is at its highest, and possible sleep restriction due to the decreased sleep duration and reduced consolidation associated with daytime sleep opportunities (Åkerstedt, 1995; Tilley, Wilkinson, Warren, Watson, & Drud, 1982). Planned naps on night shift are already recommended in some industries such as health care (Joint Commission, 2011) and aviation (Caldwell et al., 2009) to help alleviate sleepiness and performance decrements.

Although some work places allow napping, many shift workers avoid taking naps. Perceived barriers to napping on night shift include being too busy and understaffed, an absence of comfortable napping spaces, lack of management support for napping, and fear of sleep inertia (Fallis, McMillan, & Edwards, 2011). Sleep inertia is a period of degradation in performance and alertness upon awakening, which can vary in severity and duration. Short naps could be a solution for shift workers who prefer not to nap due to the above issues. Short naps of less than 30min appear to be favourable for obtaining the restorative benefits of sleep in the afternoon (Brooks & Lack, 2006; Takahashi, Fukuda, & Arito, 1998; Tietzel & Lack, 2001, 2002), and have the added benefit of being more feasible to implement during a night shift, taking less time away from duties.

Short naps on night shift may be operationally viable, but there is a lack of research investigating their benefits. Some studies have investigated brief naps in the afternoon, with naps of 10-30min (total sleep time) shown to reduce sleepiness and improve performance (Hayashi, Ito, & Hori, 1999; Takahashi et al., 1998). Tietzel and Lack (2001; 2002) found that following one night with sleep restricted to 5h time in bed (TIB; 00:00-05:00h), a 10min nap ending at 15:15h immediately improved cognitive performance and alertness for at least an hour following the nap. A 30min

nap ending at 15:15h resulted in an immediate decrease in cognitive performance and alertness, but then improved to levels similar to the 10min nap condition an hour post-nap.

Later research by Brooks and Lack (2006) using a similar methodology extended testing to three hours post-nap. They concluded that of a 5, 10, 20, or 30min nap ending at 15:00h, following night-time sleep restriction to 5h, the 5min nap was the least effective for improving sleepiness and performance. In order to produce significant performance improvement, the nap length needed to be at least 10min. However as in Tietzel and Lack's (2001) study, the 30min nap produced a period of impaired cognitive performance and alertness for up to 35min immediately after the nap. They therefore concluded that a 10min nap was more beneficial than the 30min nap for improving alertness and performance in the afternoon. Hayashi, Motoyoshi, and Hori (2005), also found that brief naps of up to 5min duration offered limited recovery value. Therefore, the optimal duration for a brief nap in the afternoon appears to be longer than 5min but shorter than 30min.

The recovery benefit of naps differs depending not only on the duration of the nap, but also the temporal placement of the nap. Around the circadian nadir at approximately 04:00h, sleep propensity is elevated due to extended prior wakefulness and circadian pressure, and diurnal impairments in performance are at their peak (Banks & Dinges, 2007). Given these conditions, the sleep and performance benefits of a nap around this time may be quite different to afternoon naps. Whilst some studies show no difference in benefits regardless of temporal placement of night-time naps (Purnell, Feyer, & Herbison, 2002; Sallinen, Härmä, Åkerstedt, Rosa, & Lillqvist, 1998), there is some evidence to suggest that increased duration of wakefulness prior to a nap results in better quality sleep during the nap (Signal, Gander, Anderson, & Brash, 2009). Other research suggests that the benefits of naps are shorter lasting when taken after long periods of wakefulness (e.g. 18h) compared to after short periods of wakefulness (Dinges, Orne, Whitehouse, & Orne, 1987). It is important to establish the sustained recovery benefits of short, night-time naps, in the early morning hours towards the end of a night shift, when shift workers are at

greatest risk of errors and accidents (Mollicone, Van Dongen, Rogers, Banks, & Dinges, 2010).

Based on data from the afternoon, shorter nap lengths (less than 30min) might still provide some extended recovery benefits. However, research on short, night-time naps is limited. A 30min nap at 02:30h following a 2h prophylactic napping opportunity at 15:00h has been shown to improve performance and subjective alertness for up to three hours compared to not napping (Lovato, Lack, Ferguson, & Tremaine, 2009). Few studies have investigated naps with less than 30min total sleep time (TST), commonly referred to as 'power naps'. One field study found that a 30min nap opportunity (13.44±8.9min TST) taken between 02:00h and 03:00h improved subjective sleepiness and psychomotor vigilance task (PVT) response speed for up to three hours post-nap compared to a no-nap control (Smith, Kilby, Jorgensen, & Douglas, 2007). However, findings are based on *N*=9, with only *N*=6 for objective sleep data. Another study found that a 30min nap opportunity (23.50±5.48min TST) slightly later in the night, at 04:00h, did not improve PVT performance or subjective sleepiness for the following three hours (Howard, Radford, Jackson, Swann, & Kennedy, 2010). Participants' sleep on the night prior to the night shift was not objectively measured, which may have influenced findings. Differences in results could also be due to variation in the timing of the naps and amount of sleep obtained in the 30min nap opportunities.

One study investigating extended performance benefits of a slightly shorter sleep length, in a 20min nap opportunity at 01:40h, found that in comparison to a no-nap condition, a 20min nap opportunity did not improve performance 1.5-6h post-nap (Mulrine, Signal, van den Berg, & Gander, 2012). This is in contrast to a field study (Purnell et al., 2002), which found that a 20min nap opportunity between 01:00-03:00h improved response speed on a vigilance task at the end of the first, but not the second night shift compared with a no-nap control condition. However, an objective measure of sleep was not obtained, and therefore actual sleep duration during the naps is not known. Taken together these studies show that naps of less than 30min in duration may offer some recovery benefits in the hours following the nap.

Short naps on night shift are potentially a useful countermeasure for sleepiness and performance decrements. However, the existing evidence is based mainly on naps taken in the afternoon, and methodological issues in the existing night-time nap studies mean that firm conclusions cannot yet be drawn to provide an evidence-base for napping recommendations. The degree to which naps offer recovery benefits may differ depending on the temporal placement and length of the nap. Thirty-minute nap opportunities during the night seem to offer similar benefits to 30min naps in the afternoon, but no research to date has investigated whether 10min night-time nap opportunities are as effective. Therefore the current laboratory study assessed whether there are sustained recovery benefits of a 30min night-time nap opportunity compared to a 10min night-time nap opportunity during the 3h post-nap, once sleep inertia had dissipated.

2 Methods

2.1 Ethics Statement

The study was approved by the University of South Australia Human Research Ethics Committee. Participants provided written informed consent and were paid an honorarium for their time.

2.2 Participants

Thirty-two healthy adult participants (19F, aged 21-35y, mean body mass index 22.2 ±SD 3.0) participated in the study. Participants were required to be of sound physical and mental health, with no reports of habitual napping, insomnia, daytime sleepiness, or other sleep disturbances (confirmed by self-report measures). Participants were non-smokers and did not engage in shift work, trans-meridian travel, excessive caffeine or alcohol consumption (>2 caffeinated beverages and >2 standard drinks of alcohol per day) for the two months prior to the study. A screening questionnaire battery including the Composite Scale of Morningness-Eveningness (only intermediate types included) (Smith, Reilly, & Midkiff, 1989) and the Pittsburgh Sleep Quality Index (scores ≤5 included) (Buysse et al., 1989) was used to confirm sleep health. Current medication use (except for oral contraception) and illicit drug use were not allowed. Participants undertook urine tests to screen for illicit substance use and blood tests to screen for health abnormalities.

In the week prior to the study, participants were required to have a bedtime before midnight and rise time before 09:00h. They were not allowed to nap, or consume alcohol or caffeine. Sleep diaries and actigraphy were used to ensure proper sleep times were adhered to, and all participants reported obtaining at least 7h sleep per night. With the exception of one female subject who withdrew partway through the study due to illness, all participants completed the 3-day laboratory study. The remaining 31 participants were randomly assigned to one of three conditions: A 30min nap condition (*N*=10, 24.7y ± 2.7); a 10min nap condition (*N*=10, 23.6y ± 4.2); or a no-nap control condition (*N*=11, 24.5y ± 3.3).

2.3 Experimental Protocol

Participants were studied in groups of four at the Centre for Sleep Research at the University of South Australia for three consecutive days (Figure 1). The first day was used for adaptation and training before a baseline sleep opportunity (22:00h-07:00h). Participants undertook neurobehavioural testing throughout the baseline day, before commencing a simulated night shift (one night awake) with random allocation to: a 30min nap opportunity ending at 04:00h; a 10min nap opportunity ending at 04:00h; or no-nap (control). All conditions were followed by a 6h daytime recovery sleep period (10:00h-16:00h).

These nap opportunities were chosen as it was expected that participants would achieve enough sleep (more than 5min, but less than 30min) to potentially offer a recovery benefit, whilst avoiding the sleep inertia associated with sleep durations of 30min or more. Additionally, a nap opportunity was chosen instead of total nap time, as most individuals allow themselves a set sleep opportunity rather than expecting to achieve a set amount of sleep time. In order to minimise influences on post-nap performance, the objectives of the study and nap lengths were not made explicit to the participants until the end of the study.

The laboratory was temperature (22±1°C) and sound controlled. The laboratory environment was free of natural light, and artificial lighting was set at <50 lux during wake periods and <0.03 lux during sleep periods. Showers and calorie-controlled meals were provided at set times. When not engaged in testing, participants were

permitted to read, watch movies or socialise in a communal living area. They were not permitted to use backlit devices, or engage in physical activity. Participants had access to their mobile phones for 10min on the baseline morning, at the start of a free-time period.

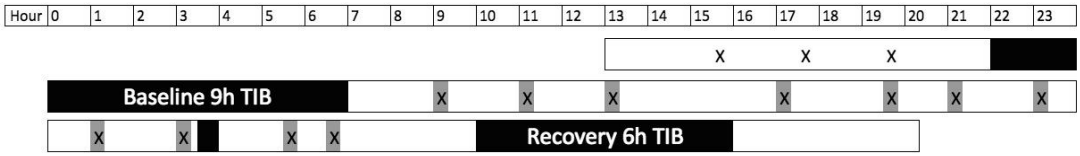

Figure 1. Protocol schematic of the 3-day laboratory study. Unshaded crosses represent practice neurobehavioural test bouts (NTB). Shaded crosses represent NTBs included in analyses. Black boxes represent time in bed (TIB) opportunities: 9h baseline sleep opportunity, 10min or 30min nap opportunity ending at 04:00h, and 6h recovery sleep opportunity.

One-hour prior to allocated sleep periods, participants were prepared for polysomnographic recording of sleep. During the timeframe that was used for napping in the 30min and 10min nap conditions, participants in the no-nap control condition engaged in quiet activities such as reading, watching movies, or conversing with other participants and researchers.

Participants completed a computer-based neurobehavioural test bout (NTB), which included a 10min psychomotor vigilance task, the Karolinska Sleepiness Scale (KSS), and the Positive and Negative Affect Schedule (PANAS) approximately every 2h starting from 09:00h after the baseline sleep (Figure 1). The NTB commenced approximately 1.5h after sleep periods concluded (at 09:00h after the baseline sleep and at 05:30h after the nap) to allow for a period of sleep inertia tests. These tests indicated that the 30min nap was associated with sleep inertia, as indicated by PVT impairment, lasting for up to 47min post-nap (Hilditch, Centofanti, Dorrian, & Banks, In press). NTBs were conducted in participants' individual bedrooms, and took approximately 15-20min to complete.

2.4 Measures

2.4.1 Performance

A 10min PVT was used to measure sustained attention and response speed. The PVT is a simple reaction time task which is commonly used in similar studies (Dorrian, Rogers, & Dinges, 2005). The task requires participants to attend to a small square on a computer screen and to respond to a stimulus, a number in milliseconds, as quickly as possible by pressing a button with their dominant thumb when the stimulus appears. Interstimulus intervals varied from 2-10s. PVT lapses and fastest 10% of reaction times (Fastest10%) were used to measure sustained attention and response speed. Number of lapses were defined as the reaction times greater than 500ms.

2.4.2 Subjective Sleepiness

The KSS was used as a measure of subjective sleepiness (Åkerstedt & Gillberg, 1990). The KSS consists of the question, 'How do you feel at the moment?' and nine response options ranging from 1- 'Extremely alert' to 9- 'Very sleepy, great effort to stay awake, fighting sleep'. This scale has been found to significantly correlate with polysomnographic, behavioural and subjective indicators of sleepiness (Kaida et al., 2006).

2.4.3 Mood

The PANAS, a 20-item scale, was used to measure subjective mood (Watson, Clark, & Tellegen, 1988). Participants were asked to rate the extent to which they were experiencing each of a list of emotions at that moment, with reference to a 5-point scale, from 1- 'Very slightly or not at all', to- 5 'Very much'. The PANAS provides outcomes for two separate domains- positive affect and negative affect (min score = 10, max score = 50), which have been shown to be independent from one another (Watson, Wiese, Vaidya, & Tellegen, 1999). The PANAS has been found to be a reliable and valid measure of affect in non-clinical samples (Crawford & Henry, 2004; Watson et al., 1988).

2.4.4 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). Placement of electrodes was in line with the 10/20 system of

electrode placement (Carskadon & Rechtschaffen, 1994). The PSG montage included placements C3/A2, C4/A1, F3/A2, F4/A1, O1/A2, bi-lateral electrooculogram (EOG), electromyogram (EMG), and electrocardiogram (ECG). Sleep data were analysed and scored by a trained sleep technician in 30-second epochs in accordance with the criteria of Rechtschaffen and Kales (1968).

Outcome measures derived from PSG were total sleep time (TST; total amount of sleep within a scheduled sleep episode), sleep onset latency (SOL; the time from the beginning of the sleep opportunity to the third consecutive 30-second epoch of Stage 1 or first epoch of any higher stage), wake after sleep onset (WASO; the occurrence of epochs of wakefulness following sleep onset), sleep efficiency % (TST divided by actual TIB) and sleep stages (Stage 1, Stage 2, Stage 3, Stage 4 [combined into slow wave sleep [SWS] in analyses], and rapid eye movement [REM] sleep, expressed in minutes for a scheduled sleep episode).

2.5 Statistical Analyses

Analyses were performed using SPSS Statistics Version 21.0 (IBM Corp., Armonk, NY, USA). A one-way analysis of variance (ANOVA) was used to test differences in sleep stages by condition (30min nap, 10min nap, no-nap) during the baseline sleep and the nap opportunities (N=31).

A series of fully saturated, linear mixed model ANOVAs were conducted to compare performance prior to the naps between conditions (30min nap, 10min nap, no-nap) and trials (all pre-nap trials) for PVT, KSS, and PANAS scores.

Fully saturated, mixed model ANOVAs were also conducted to compare post-nap performance between nap conditions (30min nap, 10min nap, no-nap) and trials (05:30h and 06:30h trials). The grand mean of all pre-nap scores was included in the post-nap models as a covariate in order to control for pre-nap differences. The pre-nap covariate significantly contributed to all models ($p<0.001$). Analysis of covariance using an average of several pre-test trials reduces measurement error and provides an unbiased method for comparing effects pre- and post- an experimental treatment (nap) between conditions (Cronbach & Furby, 1970; Van Breukelen, 2006).

A Satterthwaite correction was applied to the denominator degrees of freedom. Degrees of freedom values have been reported to the nearest whole number, and F values to two decimal points. *N*=1 participant's PVT data from the 10min nap condition was removed from analyses due to non-adherence to the task.

3 Results

3.1 Sleep

During the baseline sleep, TST did not differ between the 30min nap condition, 10min nap condition and no-nap control (M 7.7h SEM±0.15h; $F_{2,28}$=2.18, p=0.131). No significant differences were observed for SOL ($F_{2,28}$=3.31, p=0.051), WASO ($F_{2,28}$=1.08, p=0.353) or sleep efficiency (M 85.68±1.67%; $F_{2,28}$=2.09, p=0.142). There were no significant differences in Stage 1 ($F_{2,28}$=0.01, p=0.986), Stage 2 ($F_{2,28}$=1.84, p=0.177), SWS ($F_{2,28}$=0.21, p=0.809), or REM sleep ($F_{2,28}$=2.13, p=0.138) (Figure 2).

During the nap opportunities, the 30min nap had significantly more TST than the 10min nap ($F_{1,18}$=358.53, p<0.001) (Figure 2). The 30min nap comprised of significantly more Stage 2 sleep ($F_{1,18}$=12.79, p=0.002) and significantly more SWS ($F_{1,18}$=55.22, p<0.001) than the 10min nap. There were no differences in Stage 1 sleep ($F_{1,18}$=0.24, p=0.633), REM sleep ($F_{1,18}$=1.97, p=0.177), sleep efficiency (M 83.9±3.75%; $F_{1,18}$=2.16, p=0.159), SOL ($F_{1,18}$=1.76, p=0.201) or WASO ($F_{1,18}$=1.50, p=0.236).

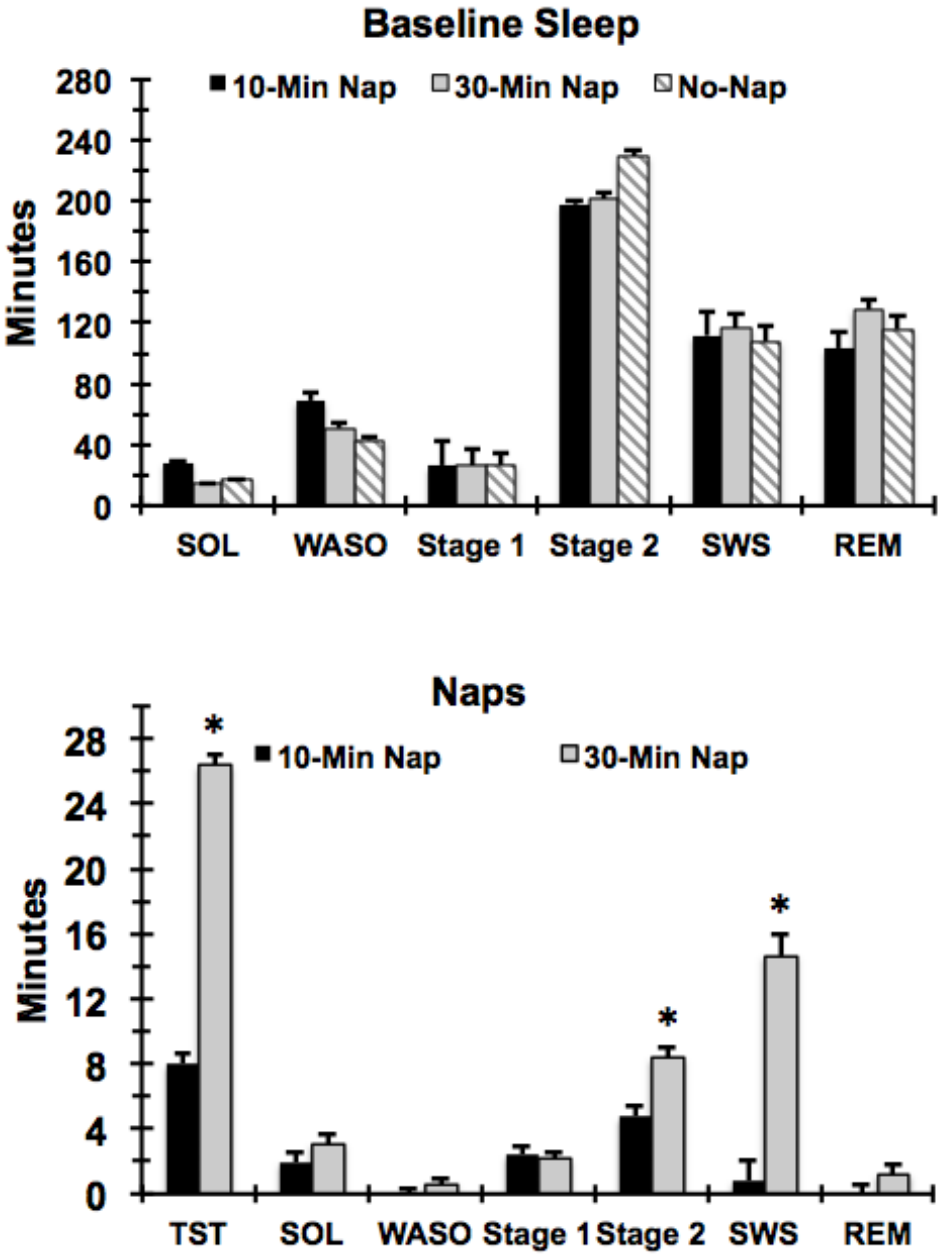

Figure 2. Mean ± SEM for sleep variables during baseline sleep opportunity (top panel) and nap opportunities (bottom panel). Black bars display the 10min nap condition, grey bars display the 30min nap condition, and striped bars (top panel) represent the no-nap control condition. Asterisks show statistically significant differences ($p<0.05$) between conditions.

3.2 Performance

3.2.1 Pre-nap performance (09:00h-03:00h)

No significant main effect of condition was observed for PVT lapses, Fastest10%, positive affect, or negative affect during pre-nap trials Figure 3, left panel). There was a significant main effect of trial for PVT lapses ($F_{8,216}$=15.26, p<0.001), Fastest10% ($F_{8,216}$=9.55, p<0.001), positive affect ($F_{8,224}$=39.28, p<0.001), and negative affect ($F_{8,224}$=4.58, p<0.001), such that PVT performance and positive affect decreased across trials, whilst negative affect increased across trials.

There was no significant main effect of condition for KSS ($F_{2,18}$=2.73, p=0.083) (Figure 3, left panel). There was a significant main effect of trial ($F_{8,224}$=65.69, p<0.001) and a significant condition*trial interaction, such that the 10min nap condition had significantly higher KSS scores at 19:30h compared to the 30min nap (p=0.002) and no-nap (p=0.010) conditions, at 21:00h compared to the 30min nap condition (p=0.007), and at 23:00h compared to the 30min nap (p=0.001) and no-nap control conditions (p=0.035). At 01:00h the 30min nap condition had significantly lower KSS scores than the 10min nap (p=0.039) and no-nap control (p=0.003) conditions, however KSS scores did not differ at 03:00h.

3.2.2 Post-nap performance controlling for pre-nap scores

When controlling for pre-nap scores, there was no significant main effect of condition on PVT lapses ($F_{2,26}$=0.68, p=0.517) or Fastest10% ($F_{2,26}$=0.61, p=0.551) (Figure 3, right panel). There was a significant main effect of trial for PVT lapses ($F_{1,27}$=15.92, p<0.001) and Fastest10% ($F_{1,27}$=16.43, p<0.001), with performance declining between the first and second post-nap trials. There was no significant condition*trial interaction for PVT lapses ($F_{2,27}$=0.81, p=0.456) or Fastest10% ($F_{2,27}$=0.97, p=0.392).

When controlling for pre-nap scores, there was a significant main effect of condition for KSS scores ($F_{2,27}$=4.27, p=0.025) (Figure 3, right panel), such that the 30min nap condition had significantly lower KSS scores post-nap than the 10min nap and no-nap control conditions. There was also a significant main effect of trial ($F_{1,28}$=8.98, p=0.006), with KSS scores increasing between the first and second post-nap trials. There was no significant condition*trial interaction ($F_{2,28}$=1.55, p=0.230).

When controlling for pre-nap scores for positive affect, there were no significant main effects of condition ($F_{2,27}$=2.81, p=0.078), trial ($F_{1,28}$=2.93, p=0.098), or their interaction ($F_{2,28}$=0.62, p=0.547) (Figure 3, right panel). For negative affect, there was a significant main effect of condition ($F_{2,27}$=5.61, p=0.009) with higher negative affect in the 10min nap condition compared to the no-nap control at 05:30h, and compared to the no-nap control and 30min nap conditions at 06:30h. There was no significant main effect of trial ($F_{1,28}$=0.43, p=0.519), or condition*trial interaction ($F_{2,28}$=1.66, p=0.208).

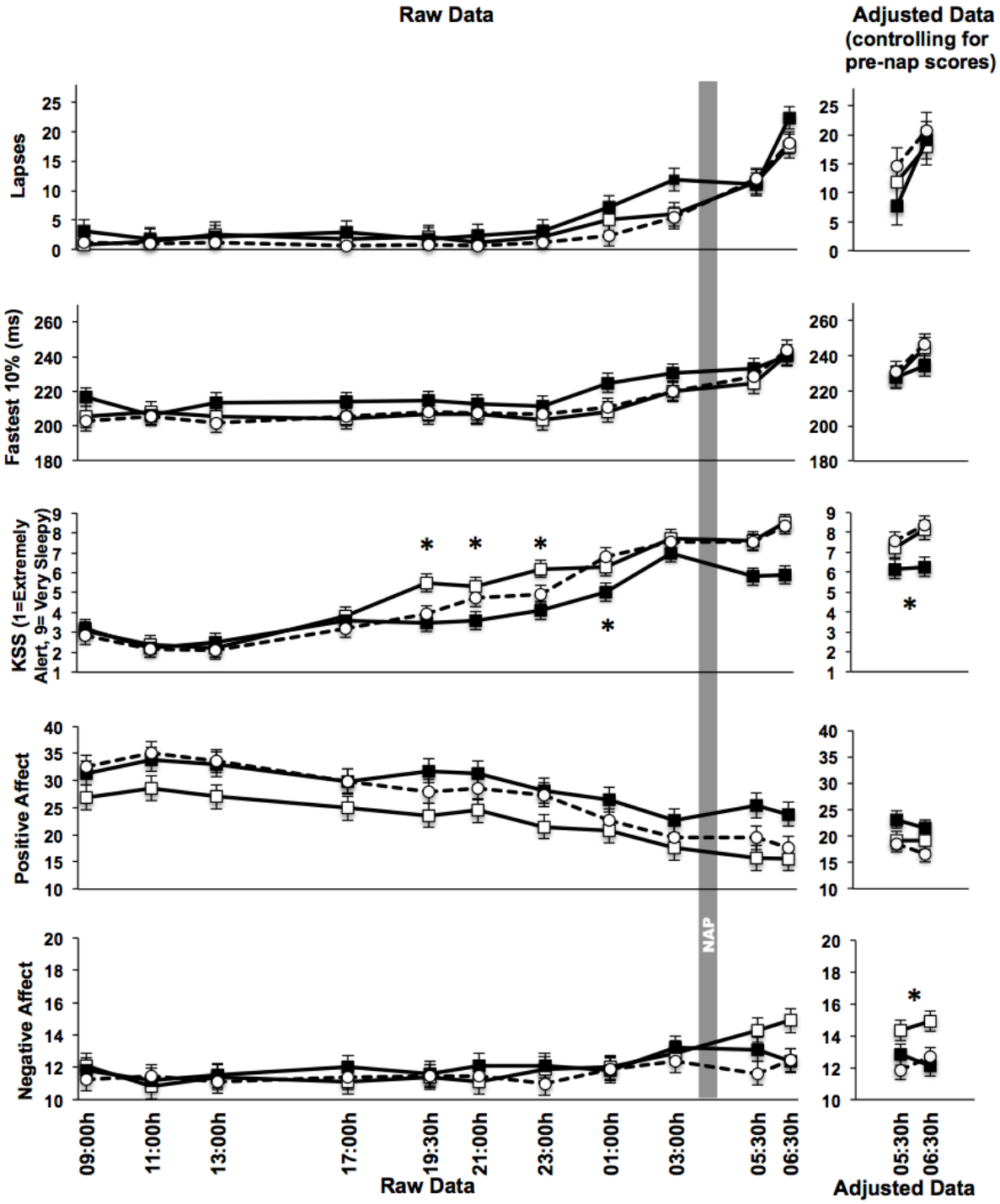

Figure 3. Mean ± SEM for PVT, KSS and PANAS variables. Left panel displays raw data for all NTBs, and adjusted (right) panel shows EMM for post-nap NTBs, covarying for the grand mean of all pre-nap scores. ■ markers display 30min nap condition, □ markers display 10min nap condition, and O markers display no-nap control condition. Asterisks show statistically significant differences ($p<0.05$) between conditions.

4 Discussion

This study investigated the sustained recovery benefits of a 30min nap opportunity compared to a 10min nap opportunity in the 3h post-nap, once potential sleep inertia had dissipated (Hilditch et al., In press). We found that a 10min or 30min nap ending at 04:00h did not ameliorate decrements in PVT performance during the early morning hours of a simulated night shift compared to a no-nap control. However, a 30min nap reduced subjective feelings of sleepiness for up to 2.5h post-nap, whilst a 10min nap led to increases in negative affect compared to a 30min nap or not napping.

The current findings for the 30min nap are consistent with those from previous studies showing that 30min nap opportunities taken at around 04:00h improve subjective alertness, but not reaction time compared to no nap (Howard et al., 2010; Sallinen et al., 1998). The discrepancy in improvements of subjective sleepiness and performance following a 30min nap highlights the need to educate shift workers about the fact that their cognitive performance may still be impaired following a nap, despite feeling less sleepy. These findings are in contrast to the study by Lovato and colleagues (2009) who found that a 30min night-time nap did improve performance from 04:00h to 07:00h. The same study found that subjective ratings of sleepiness were closely correlated with PVT performance in both the nap and no-nap conditions (Tremaine et al., 2010). However, these disparities could be due to methodological differences. For example, the current study used a 30min nap opportunity rather than a 30min nap length. Participants in Lovato's study also had a 2h prophylactic nap opportunity in the prior afternoon, and therefore, disparities may have been due to both a longer nap, and less prior wakefulness.

This is the first study to investigate the effects of a 10min night-time nap opportunity. Napping opportunities of 10min in length are important because they appear to be favourable for obtaining the restorative benefits of sleep without sleep inertia (Brooks & Lack, 2006; Hilditch, Centofanti, Dorrian, Van Dongen, & Banks, 2014; Takahashi et al., 1998; Tietzel & Lack, 2001, 2002), whilst also being more feasible to implement during a busy night shift. Our results show that a 10min nap did not improve PVT performance or subjective sleepiness. This is in contrast to findings based on 10min naps taken in the afternoon, which found some improvements in

cognitive performance and subjective alertness from 1-2.5h post-nap (Brooks & Lack, 2006; Tietzel & Lack, 2001, 2002). This difference may be due to the fact that testing in the current study started 1.5h post-nap. This is because participants undertook sleep inertia testing for an hour post-nap (Hilditch et al., In press). Therefore, it is possible that effects of the 10min nap may have dissipated before testing resumed 1.5h post-nap.

The 10min nap in the current study led to an increase in negative affect compared to the 30min nap and no-nap control. Qualitative data from questionnaires completed at the end of the current study lend support to this negative mood following the 10min nap. When asked what the hardest aspect of the simulated shift schedule was, eight of ten participants in the 10min condition listed the naps as the worst part of the study. No participants in the 30min nap condition listed the naps as being the worst or hardest parts of the simulated shift schedule. Rather, three out of ten participants said having a nap was the *best* part of the simulated shift schedule. Naitoh, Kelly, and Babkoff (1993) also found a 'sleep aversion' effect in their study of 20min nap opportunities. Findings regarding worse mood following naps on night shift warrants further investigation, as mood can impact upon a range of physical and mental health outcomes, and also influence the effectiveness of teamwork (Bartel & Saavedra, 2000; Pressman & Cohen, 2005). In addition, if shift workers find these naps aversive, it is unlikely that short naps will be a strategy with effective worker uptake.

Sleep efficiency was high for both nap conditions, which is similar to other studies investigating 30min nap opportunities at approximately 04:00h (Sallinen et al., 1998). This could be due to the culmination of increased prior wake and the circadian low occurring around this time point. This difference in circadian timing and sleep propensity may also account for the differences observed in the current study's findings compared to findings on 10min afternoon naps (Brooks & Lack, 2006; Tietzel & Lack, 2001, 2002). In the afternoon, the circadian rhythm promotes wakefulness despite increasing time awake. A short nap may reduce sleep pressure, resulting in both circadian and homeostatic factors promoting stable performance. In contrast, homeostatic sleep pressure from time awake and the circadian low during the early morning hours results in performance impairments. Therefore, as the circadian

system is also causing impairment, reducing homeostatic pressure with a short nap at approximately 04:00h may not result in stabilised performance overall.

When taken earlier in the night before the circadian nadir, naps of one or more hours in length have shown benefits for performance during the latter part of the night shift (Matsumoto & Harada, 1994; Rogers, Spencer, Stone, & Nicholson, 1989). In the current study, the high sleep efficiency during the naps and increased level of PVT lapses witnessed prior to the nap (Figure 3) indicate that individuals were experiencing high propensity for sleep. Further studies should examine whether a 10min nap opportunity taken earlier than the circadian nadir helps to reduce the level of sleepiness observed at around 03:00h, to the same extent as longer naps.

A consideration when interpreting the current results is that findings are based on healthy, young adult participants in a laboratory setting. The laboratory provides an optimal sleep environment (Dorrian et al., 2003), and is devoid of several factors identified by Fallis et al. (2011) as barriers to napping on night shift. Factors such as workplace stress, knowing only a short time is available for a nap, lack of comfortable sleeping environments, and understaffing could all contribute to lower efficiency of nap opportunities.

The current study found that a 30min nap opportunity ending at 04:00h during a simulated night shift improved feelings of subjective sleepiness, whilst a 10min nap opportunity ending at 04:00h increased negative mood. However, neither of the nap conditions improved performance in comparison to the no-nap control, which challenges the existing industry recommendations for taking short, planned naps on night shift. More studies are needed to trial 10-30min nap opportunities at different time points throughout the night to verify the optimal placement and minimum nap duration required to elicit sustained performance benefits during the second half of a night shift.

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References

Åkerstedt, T. (1995). Work hours, sleepiness and the underlying mechanisms. *Journal of Sleep Research, 4*(s2), 15-22.

Åkerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience, 52*(1-2), 29-37. doi: 10.3109/00207459008994241

Banks, S., & Dinges, D. F. (2007). Behavioral and physiological consequences of sleep restriction. *Journal of Clinical Sleep Medicine:* official publication of the American Academy of Sleep Medicine, *3*(5), 519-528.

Bartel, C. A., & Saavedra, R. (2000). The collective construction of work group moods. *Administrative Science Quarterly, 45*(2), 197-231.

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., Russo, M. B., & Balkin, T. J. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *Journal of Sleep Research, 12*(1), 1-12. doi: 10.1046/j.1365-2869.2003.00337.x.

Brooks, A., & Lack, L. (2006). A brief afternoon nap following nocturnal sleep restriction: which nap duration is most recuperative? *Sleep: Journal of Sleep Research & Sleep Medicine, 29*(6), 831-840.

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Research, 28(2), 193-213. doi: 10.1016/0165-1781(89)90047-4

Caldwell, J. A., Mallis, M. M., Caldwell, J. L., Paul, M. A., Miller, J. C., & Neri, D. F. (2009). Fatigue countermeasures in aviation. *Aviation, Space, and Environmental Medicine, 80*(1), 29-59.

Carskadon, M. A., & Rechtschaffen, A. (1994). Monitoring and staging human sleep. In M. H. Kryger, T. Roth & W. Dement (Eds.), *Principles and practice of sleep medicine* (pp. 943-960). Philadelphia: W.B. Saunders.

Crawford, J. R., & Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 43*(3), 245-265. doi: 10.1348/0144665031752934

Cronbach, L. J., & Furby, L. (1970). How we should measure "change": Or should we? *Psychological Bulletin, 74*(1), 68-80.

Dinges, D. F., Orne, M. T., Whitehouse, W. G., & Orne, E. C. (1987). Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. *Sleep: Journal of Sleep Research & Sleep Medicine, 10*(4), 313-329.

554 Dinges, D. F., Pack, F., Williams, K., Gillen, K. A., Powell, J. W., Ott, G. E.,
555 Aptowicz, C., & Pack, A. I. (1997). Cumulative sleepiness, mood disturbance
556 and psychomotor vigilance performance decrements during a week of sleep
557 restricted to 4-5 hours per night. *Sleep: Journal of Sleep Research & Sleep*
558 *Medicine, 20*(4), 267-277.
559 Dorrian, J., Lamond, N., Holmes, A. L., Burgess, H. J., Roach, G. D., Fletcher, A., &
560 Dawson, D. (2003). The ability to self-monitor performance during a week of
561 simulated night shifts. *Sleep: Journal of Sleep Research & Sleep Medicine,*
562 *26*(7), 871-877.
563 Dorrian, J., Rogers, N. L., & Dinges, D. F. (2005). Psychomotor vigilance
564 performance: Neurocognitive assay sensitive to sleep loss. In C. A. Kushida
565 (Ed.), *Sleep Deprivation – Clinical Issues, Pharmacology, and Sleep Loss*
566 *Effects*: Marcel Dekker New York.
567 Fallis, W. M., McMillan, D. E., & Edwards, M. P. (2011). Napping during night shift:
568 practices, preferences, and perceptions of critical care and emergency
569 department nurses. *Critical Care Nurse, 31*(2), e1-e11.
570 Hayashi, M., Ito, S., & Hori, T. (1999). The effects of a 20-min nap at noon on
571 sleepiness, performance and EEG activity. *International Journal of*
572 *Psychophysiology, 32*(2), 173-180.
573 Hayashi, M., Motoyoshi, N., & Hori, T. (2005). Recuperative power of a short
574 daytime nap with or without stage 2 sleep. *Sleep: Journal of Sleep Research &*
575 *Sleep Medicine, 28*(7), 829-836.
576 Hilditch, C. J., Centofanti, S. A., Dorrian, J., Van Dongen, H. P. A., & Banks, S.
577 (2014). Effects of 10 min and 30 min night-time naps on sleep inertia. *Journal*
578 *of Sleep Research, 23* (Sup. 1 1-331), 616.
579 Hilditch, C. J., Centofanti, S. A., Dorrian, J., & Banks, S. (In press). A 30-minute, but
580 not a 10-minute night-time nap is associated with sleep inertia. *Sleep: Journal*
581 *of Sleep Research & Sleep Medicine.*
582 Howard, M. E., Radford, L., Jackson, M. L., Swann, P., & Kennedy, G. A. (2010).
583 The effects of a 30-minute napping opportunity during an actual night shift on
584 performance and sleepiness in shift workers. *Biological Rhythm Research,*
585 *41*(2), 137-148. doi: 10.1080/09291010903030946
586 Joint Commission (The) (2011). *Health care worker fatigue and patient safety*.
587 Available from http://www.jointcommission.org/sea_issue_48/
588 Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., &
589 Fukasawa, K. (2006). Validation of the Karolinska sleepiness scale against
590 performance and EEG variables. *Clinical Neurophysiology, 117*(7), 1574-
591 1581. doi: 10.1016/j.clinph.2006.03.011
592 Lovato, N., Lack, L., Ferguson, S., & Tremaine, R. (2009). The effects of a 30-min
593 nap during night shift following a prophylactic sleep in the afternoon. *Sleep*
594 *and Biological Rhythms, 7*(1), 34-42. doi: 10.1111/j.1479-8425.2009.00382.x
595 Matsumoto, K., & Harada, M. (1994). The effect of night-time naps on recovery from
596 fatigue following night work. *Ergonomics, 37*(5), 899-907.
597 doi: 10.1080/00140139408963699
598 Mollicone, D. J., Van Dongen, H., Rogers, N. L., Banks, S., & Dinges, D. F. (2010).
599 Time of day effects on neurobehavioral performance during chronic sleep
600 restriction. *Aviation, Space, and Environmental Medicine, 81*(8), 735-744.
601 doi: 10.3357/asem.2756.2010

Mulrine, H. M., Signal, T. L., van den Berg, M. J., & Gander, P. H. (2012). Post-sleep inertia performance benefits of longer naps in simulated nightwork and extended operations. *Chronobiology International, 29*(9), 1249-1257. doi: 10.3109/07420528.2012.719957

Naitoh, P., Kelly, T., & Babkoff, H. (1993). Sleep inertia: best time not to wake up? *Chronobiology International, 10*(2), 109-118.

Pressman, S. D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin, 131*(6), 925-971.

Purnell, M. T., Feyer, A. M., & Herbison, G. P. (2002). The impact of a nap opportunity during the night shift on the performance and alertness of 12-h shift workers. *Journal of Sleep Research, 11*(3), 219-227.

Rechtschaffen, A., & Kales, A. (1968). *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*. UCLA Brain Information Service. Brain Research Institute. Los Angeles, CA.

Rogers, A., Spencer, M., Stone, B., & Nicholson, A. (1989). The influence of a 1 h nap on performance overnight. *Ergonomics, 32*(10), 1193-1205.

Sallinen, M., Härmä, M., Åkerstedt, T., Rosa, R., & Lillqvist, O. (1998). Promoting alertness with a short nap during a night shift. *Journal of Sleep Research, 7*(4), 240-247.

Signal, T. L., Gander, P. H., Anderson, H., & Brash, S. (2009). Scheduled napping as a countermeasure to sleepiness in air traffic controllers. *Journal of Sleep Research, 18*(1), 11-19.

Smith, C. S., Reilly, C., & Midkiff, K. (1989). Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *Journal of Applied Psychology, 74*(5), 728. doi: 10.1037/0021-9010.74.5.728

Smith, S. S., Kilby, S., Jorgensen, G., & Douglas, J. A. (2007). Napping and nightshift work: effects of a short nap on psychomotor vigilance and subjective sleepiness in health workers. *Sleep and Biological Rhythms, 5*(2), 117-125.

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 and Occupational Physiology, 78*(2), 93-98.

Tietzel, A. J., & Lack, L. C. (2001). The short-term benefits of brief and long naps following nocturnal sleep restriction. *Sleep: Journal of Sleep Research & Sleep Medicine, 24*(3), 293-300.

Tietzel, A. J., & Lack, L. C. (2002). The recuperative value of brief and ultra-brief naps on alertness and cognitive performance. *Journal of Sleep Research, 11*(3), 213-218.

Tilley, A. J., Wilkinson, R., Warren, P., Watson, B., & Drud, M. (1982). The sleep and performance of shift workers. *Human Factors: Journal of the Human Factors and Ergonomics Society, 24*(6), 629-641.

Tremaine, R., Dorrian, J., Lack, L., Lovato, N., Ferguson, S., Zhou, X., & Roach, G. (2010). The relationship between subjective and objective sleepiness and performance during a simulated night-shift with a nap countermeasure. *Applied Ergonomics, 42*(1), 52-61. doi: 10.1016/j.apergo.2010.04.005

Van Breukelen, G. J. (2006). ANCOVA versus change from baseline had more power in randomized studies and more bias in nonrandomized studies. *Journal of Clinical Epidemiology, 59*(9), 920-925.

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: dose-response effects on

neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep: Journal of Sleep Research & Sleep Medicine, 26*(2), 117-129.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070. doi: 10.1037//0022-3514.54.6.1063

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology, 76*(5), 820-838. doi: 10.1037//0022-3514.76.5.820

Wyatt, J. K., Ritz-De Cecco, A., Czeisler, C. A., & Dijk, D.-J. (1999). Circadian temperature and melatonin rhythms, sleep, and neurobehavioral function in humans living on a 20-h day. *American Journal of Physiology – Regulatory, Integrative and Comparative Physiology, 277*(4), R1152-R1163.