# Stop and Revive? The Effectiveness of Nap and Active Rest Breaks for Reducing Drivers Sleepiness

Christopher N. Watling, Simon S. Smith,
Queensland University of Technology
Mark S. Horswill
The University of Queensland.

## Author Note

Christopher N. Watling, Centre for Accident Research and Road Safety - Queensland, Institute of Health and Biomedical Innovation, Queensland University of Technology; Simon S. Smith, Centre for Accident Research and Road Safety - Queensland, Institute of Health and Biomedical Innovation, Queensland University of Technology; Mark S. Horswill, School of Psychology, The University of Queensland.

This study was an investigator led study with funding provided from a NRMA-ACT Road Safety Trust grant awarded to Associate Professor Simon Smith, Associate Professor Mark Horswill, and Dr James Douglas. The authors would also like to acknowledge the Sleep Disorders Centre of the Prince Charles Hospital for use of their polysomnographic equipment and laboratory facilities during the data collection period, as well as the kind assistance from the staff.

Correspondence concerning this paper should be addressed to Christopher N. Watling, Centre for Accident Research and Road Safety – Queensland, Queensland University of Technology, 130 Victoria Park Road, Kelvin Grove, Queensland, Australia. 4059. Email: christopher.watling@qut.edu.au, Phone: +61 7 3138 7747

# Abstract

The purpose of this study was to compare the effects of two commonly utilised sleepiness countermeasures: a nap break and an active rest break. The effects of the countermeasures were evaluated by physiological (EEG), subjective, and driving performance measures. Participants completed two hours of simulated driving, followed by a 15 minute nap break or a 15 minute active rest break then completed the final hour of simulated driving. The nap break reduced EEG and subjective sleepiness. The active rest break did not reduce EEG sleepiness, with sleepiness levels eventually increasing, and resulted in an immediate reduction of subjective sleepiness. No difference was found between the two breaks for the driving performance measure. The immediate reduction of subjective sleepiness after the active rest break could leave drivers with erroneous perceptions of their sleepiness, particularly with increases of physiological sleepiness after the break.

*Keywords:* sleepiness, driving, nap break, active rest break, hazard perception

# Stop and Revive? The Effectiveness of Nap and Active Rest Breaks for Reducing Drivers Sleepiness

The role of sleepiness as a major contributing factor for vehicle crashes is widely recognised (Connor et al., 2002; Horne & Reyner, 1995). Younger drivers aged 25 years or less are over-represented in sleep-related crashes (Connor et al., 2001; Horne & Reyner, 1995) and their driving ability is critically affected by sleepiness (Smith, Horswill, Chambers, & Wetton, 2009). Sleepiness impairs alertness, cognitive functioning, and reaction time, all of which are associated with an increased risk of crashing. Efforts to reduce the incidence of sleep-related crashes are largely reliant on driver behaviour. This approach requires the driver to have self-awareness of sleepiness and to stop driving and utilise a sleepiness countermeasure. Stopping the vehicle to either take a nap or to have a rest break (without a nap) are two highly publicised countermeasures for driver sleepiness. These two sleepiness countermeasures are also perceived as effective strategies by drivers (Anund, Kecklund, Peters, & Åkerstedt, 2008; Armstrong, Obst, Banks, & Smith, 2010).

The potential effectiveness of short duration nap breaks (e.g., 10-20 minutes) as a sleepiness countermeasure has been demonstrated in other, non-driving, contexts. Nap breaks can reduce EEG defined sleepiness signs, improve cognitive functioning (Gillberg, Kecklund, Axelsson, & Åkerstedt, 1996; Hayashi, Ito, & Hori, 1999), and can reduce subjective sleepiness (Smith, Kilby, Jorgensen, & Douglas, 2007; Tietzel & Lack, 2002), with these effects enduring for several hours. The effect from a nap break occurs by reducing the homeostatic drive for sleep (Borbely, 1982; Folkard & Åkerstedt, 1991).

In contrast, the effect of a rest break is to increase arousal (Bonnet & Arand, 2005). Rest breaks can decrease EEG defined sleepiness (LeDuc, Caldwell, & Ruyak, 2000; Sallinen et al., 2008), and can immediately reduce subjective sleepiness levels (Gillberg, Kecklund, Göransson, & Åkerstedt, 2003; Sallinen et al., 2008). ‘Active’ rest breaks, such as those that involve physical activity of some kind, appear to have a greater alerting effect than those that involve less activity or inactivity (Bonnet & Arand, 2005; Sallinen et al., 2008) with the duration of effectiveness likely mediated by the level of activity performed.

There are potential benefits from either a nap break or a rest break for reducing sleepiness. However, in the context of driving sleepiness, only two studies have demonstrated the effectiveness of naps as a sleepiness countermeasure (Horne & Reyner, 1996; Leger, Philip, Jarriault, Metlaine, & Choudat, 2009). Horne and Reyner (1996) found that a nap break reduced EEG defined sleepiness and subjective sleepiness during simulated driving and Leger et al. (2009) reported the same outcome during real driving on a closed track. Regarding driving performance, Horne and Reyner (1996) found the nap break reduced major and minor lane crossings. In contrast, several studies have found no effect from nap breaks (Gillberg, Kecklund, & Åkerstedt, 1996; Lenne, Dwyer, Triggs, Rajaratnam, & Redman, 2004; Rogé, Otmani, Bonnefond, Pébayle, & Muzet, 2009). Many of these studies were performed when pressure from homeostatic and circadian factors were approaching their maximal intensity (i.e., late night driving) or after complete sleep deprivation and thus any effect from a nap might not have been sufficient to overcome the increased sleep pressure. Even fewer studies have examined the effects of rest breaks on driver sleepiness (Gillberg, Kecklund, & Åkerstedt, 1996; Lisper & Eriksson, 1980), and only the simulated driving study from Phipps-Nelson, Redman, and Rajaratnam (2011) reports any benefit from the rest break in the form of improved lane positioning.

The importance of the cognitive task load is a vital concern for safe driving and for examination a sleepiness countermeasure. Driving is a complex task that requires the successful operation of a number of diverse psychological processes. These psychological processes comprise: learning, memory, perception, motor control, attention, and decision making. Indices of vehicle control (lane positioning, vehicle speed) that are typically used in sleepy driving studies utilise motor control and perceptual processes. Yet, for the experienced driver, vehicle control is a highly learned task that requires relatively few cognitive resources for effective performance (Horswill & McKenna, 2004).

Given the complexity of driving and the diverse psychological processes used, evaluating the effectiveness of driver sleepiness countermeasures using less demanding tasks (e.g., low-order cognitive tasks, lateral positioning) may be misleading. For instance, tasks such as the psychomotor vigilance task have shown reductions in response time latencies after a nap and rest break (Caldwell, Prazinko, & Caldwell, 2003; Smith et al., 2007). Furthermore, measures of vehicle control (lateral positioning) have been found to improve after both a nap and a rest break (Horne & Reyner, 1996; Phipps-Nelson et al., 2011). Yet the relationship between lateral positioning in a driving simulator and on-road driving performance is unknown (Philip et al., 2005). Therefore, measures of aspects of driving performance, known to be associated with on-road behaviour and crash risk, are needed to evaluate specific driver sleepiness countermeasures.

One key higher-level component of driving performance, which has been found to be associated with both on-road behaviour and crash risk, is hazard perception. Hazard perception has been described as the skill required to predict when a traffic situation might become dangerous (Horswill & McKenna, 2004; Jackson, Chapman, & Crundall, 2009). If a driving hazard is not promptly identified and recognised as potentially dangerous then this could result in a crash. The process of hazard perception is a multi-staged skill with each skill reliant on the one before it. Hazard perception requires active scanning of the road environment, identification of a potentially hazardous event, followed by a judgement that the hazard will cause a conflict, before finally requiring a decision as to whether a response is necessary from the driver (Wetton et al., 2010). Faster hazard perception performance has been found to consistently correlate with decreased on-road crash involvement (Drummond, 2000; Hull & Christie, 1992; McKenna & Horswill, 1999; Pelz & Krupat, 1974; Quimby, Maycock, Carter, Dixon, & Wall, 1986). In contrast, other on-road driving skills, such as vehicle control and skid control, have an inconsistent relationship with crashes (Katila, Keskinen, Hatakka, & Laapotti, 2004). Hazard perception is a multi-component and a high-order cognitive skill (Wetton et al., 2010), which has been found to correlate with on-road driving performance (Wood, Horswill, Lacherez, & Anstey, 2013), and is impaired by sleepiness (Smith et al., 2009). It is typically measured using computer-based Hazard Perception Tests (HPT).

The aim of the current study was to examine the effectiveness of nap and active rest breaks with partially sleep deprived young adults. The effectiveness will be evaluated by physiological (EEG theta and alpha absolute power), subjective (Karolinska Sleepiness Scale), and driving performance (a validated computer-based HPT) measures. The following hypotheses were proposed: (1) both break types will reduce physiological and subjective signs of sleepiness and hazard perception response times; (2) the alerting effect of the nap break will be sustained with the alerting effect of the active rest break will be transient and; (3) the nap break will reduce physiological and subjective signs of sleepiness and HPT response times to a greater extent than will the active rest break. The second aim was to examine the 'napability' (i.e., the ability to fall asleep during a nap opportunity) of participants, the sleep staging of the naps, as well as any changes in heart rate that occur from the active rest break.

## Method

### Design

The current study utilised a within-subjects design, which included two factors. The first factor was break type (nap or active rest break). The second factor was time bin (pre- and post-break). The effects of the factors were assessed by four outcome variables: EEG theta and alpha absolute power, response time latency from the Hazard Perception test, and subjective sleepiness levels. Assignment of participants to their initial experimental condition (i.e., nap or active rest break), the version of the HPT used (Test 1 or Test 2), and the time of day of undertaking the testing sessions (i.e., morning or afternoon) were all counterbalanced.

## Participants

Current drivers were invited to take part in the study via university intranet and online notice boards. Individuals were excluded if they were a shift worker, had travelled overseas in the past month, had a habitual bedtime later than 12 midnight, had significant health problems, took prescription medications or illicit drugs, drank more than three cups of coffee per day and/or more than two standard drinks of alcohol per day, had sleeping difficulties Pittsburgh Sleep Quality Index score of > 5 (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), or had excessive daytime sleepiness Epworth Sleepiness Scale of > 10 (Johns, 1991). No participant reported having any type of sleep disorder. These exclusion criteria are consistent with previous studies of sleep-wake and performance (Smith, Cheng, & Kerr, 2012).

In total, 20 participants (12 females and 8 males) completed the study. The participants had a mean age of 22 years (*SD* = 2; range = 20-25). Participants reported an average vehicle licensure of five years (*SD* = 1.7; range = 2-9). All participants were compensated 100 AUD.

## Measures

**Pittsburgh Sleep Quality Index.** The Pittsburgh Sleep Quality Index (PSQI: Buysse et al., 1989) is a self-report questionnaire that assesses subjective sleep quality and sleep disturbances during the preceding month. The items of the PSQI represent standard themes that sleep clinicians routinely assess. A score greater than five was utilised as a cut-off point to categorise ‘bad sleepers’ (Buysse et al., 1989). The PSQI has demonstrated a high level of reliability and satisfactory validity (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Carpenter & Andrykowski, 1998).

**Epworth Sleepiness Scale.** The Epworth Sleepiness Scale (ESS: Johns, 1991) is a measure of general level of excessive daytime sleepiness in adults and is widely used as a screening tool for sleep disorders. The ESS was constructed based on observations of the occurrence and nature of daytime sleepiness. Participants responded to eight items indicating how likely they were to doze off or fall asleep in various situations. A score below 10 is considered to be within the normal range (Johns, 1991). The ESS has adequate reliability and validity as a measure of excessive daytime sleepiness (Chen et al., 2002; Vignatelli et al., 2003).

**Actigraphy.** Actigraphy is a non-invasive method of inferring the wake-sleep cycles of an individual from the recorded relative movement of the individual's rest-activity patterns. The Actiwatch®-2 (Philips, Amsterdam, Netherlands) was used to collect actigraph data from the wrist. This device contains an accelerometer with a sampling frequency of 32 Hz, a bandwidth of 3 Hz to 11 Hz, and a sensitivity of .05 g-force. The sampling epochs for this study were set to one minute. Wrist actigraphy has been found to be a reliable and valid instrument for inferring sleep-wake periods (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992; Sadeh, Sharkey, & Carskadon, 1994). Participants also filled out a basic sleep diary, designed to provide an alternative way of measuring sleep-wake periods, in case of actigraph failure.

**Karolinska Sleepiness Scale.** The Karolinska Sleepiness Scale (KSS: Åkerstedt & Gillberg, 1990) is a self-report measure of the level of subjective sleepiness that an individual is experiencing. Individuals are required to indicate on a nine point Likert scale how sleepy they are currently feeling. The KSS has been found to be a reliable measure of sleepiness with a high level of validity when compared to concurrent EEG recordings (Kaida et al., 2006).

**Physiological recordings.** Continuous electroencephalography (EEG), electrooculography (EOG), and electrocardiography (ECG) recordings were made using the Profusion PSG 2 v2.1 (Build 138) software (Compumedics, Melbourne, Australia). The EEG, EOG, ECG recordings were sampled at 256 Hz with 0.3 Hz high pass filter, a 30 Hz low pass filter, and a 50 Hz notch filter. The EEG recordings locations were the C3-A2, O1-A2 pairings. The skin beneath the electrode locations were lightly abraded before attaching the electrode. All EEG electrodes used Ag-Al electrodes with conductive paste with all other electrodes using disposable self-adhesive electrodes. The impedance of all electrode pairings was below 5 kΩ at the start of testing.

**Hazard Perception Test.** The Hazard Perception Test (HPT) is a measure of the ability to predict potential traffic conflicts. The HPT is completed by watching a number of video clips of actual on-road traffic situations, recorded from the driver's perspective (during daylight hours). Examples of potential traffic conflicts include a car doing a U-turn in the distance and an oncoming car crossing a centre line to pass a cyclist. The video was recorded on public roads in and around the cities of Brisbane and Canberra, Australia. Participants were instructed to use the computer mouse to "click on the road user(s) that you believe may be involved in a future traffic conflict with your vehicle". Traffic conflicts were defined as "situations in which a collision or near miss between you and another road user might occur, unless you took some type of evasive action (braking or steering)". Response times to pre-defined potential traffic conflicts were measured by calculating the time between the first possible moment that a driver could have predicted the incident to the moment they clicked on the relevant road user(s). The outcome measure of the HPT was the mean response time across all measured traffic conflicts. Faster response times are indicative of better hazard perception performance (Horswill & McKenna, 2004).

Two equivalent versions of the HPT (Test 1 and Test 2), which were both three hours in duration, were developed in order to incorporate the repeated measure design methodology and to mitigate practise effects from viewing the same footage twice. The two alternative versions of the test were designed to be as equivalent as possible, containing approximately the same number of measured traffic conflicts (54 and 55), with the distribution of hazardous footage to non-hazardous footage being approximately the same across the duration of the tests. The HPT Test 1 contained 14 traffic conflicts in the first hour, 18 in the second, and 22 in the last hour, with Test 2 containing 14 traffic conflicts in the first hour, 17 in the second, and 21 in the last hour. The internal consistency of Tests 1 and 2 were adequate with a Cronbach's alpha of .78 and .83 respectively. The traffic conflicts used in the tests have been previously validated as measures of hazard perception performance (Horswill et al., 2008; Smith et al., 2009; Wetton et al., 2010). Additionally, the HPT has been shown to be sensitive to increases in sleepiness, with slower hazard perception performance (i.e., longer response time latencies) indicative of sleepiness (Smith et al., 2009).

The HPT was run from a laptop computer, with the video footage displayed to participants on an external 4:3 aspect, 17 inch LCD monitor at a distance of approximately 60 centimetres. If a participant did not respond to a traffic conflict, the overall mean (from all participants who did respond to that event) was substituted for that hazard. Note that, in this context, this is a conservative strategy of dealing with misses that has been used in previous work (Smith et al., 2009; Wetton et al., 2010), where a non-response to a hazard essentially becomes a neutral response (note that this is different to group mean substitution, which risks inflating the Type I error). This approach was used because a failure to respond to an event in the hazard perception test is potentially ambiguous (it could mean that the participant has not seen the potential traffic conflict or, alternatively, has seen the potential traffic conflict but does not consider it sufficiently dangerous to be classified as such).

## Interventions

Two types of breaks were incorporated into the study methodology: a nap and an active rest break. The nap break condition provided a 15 minute opportunity to sleep. The nap break was regarded as an intent to treat intervention as a number of studies have shown that some participants are not able to fall asleep during a nap break (Horne & Reyner, 1996; Leger et al., 2009). During the nap opportunity, the participant remained in the padded high-back chair (the angle between the base of the chair and the back rest was 105°). During the nap break, the room light remained on and the participant's electrophysiological signals were continually recorded. An active rest break was used as several studies have shown that many drivers report using an active rest break such as stopping driving and taking a short walk (Anund et al., 2008; Armstrong et al., 2010). The active rest break involved participants completing a 10-minute walk test, which was an extended versions of the six-minute walk test (Enright et al., 2003). Participants were required to continually walk up and down a 20 metre straight track for 10 minutes. The 10-minute walk test was utilised as it was an easily quantifiable amount of activity (i.e., distance and duration). The distance the participants walked was recorded.

## Procedure

The research protocol received ethical approval from the Queensland University of Technology with participants signing a consent form prior to beginning the study. To ensure that the participants experienced some sleepiness during the testing sessions, they were instructed to maintain their habitual bedtimes, which were no later than 12 midnight, but they had to wake up at 05:00 on the day of testing; this was confirmed from sleep diary and actigraphic recordings. Participants were also instructed not to ingest any form of caffeine or alcohol during the entire day that they would be participating in the study. This would have resulted in a minimum of nine hours of abstinence for a morning testing session, or 13 hours of abstinence for an afternoon session (based on a habitual bedtime of no later than 12 midnight). This abstinence of caffeine or alcohol was verbally confirmed by the participant before each testing began. Figure 1 shows the testing procedure and data collection points.

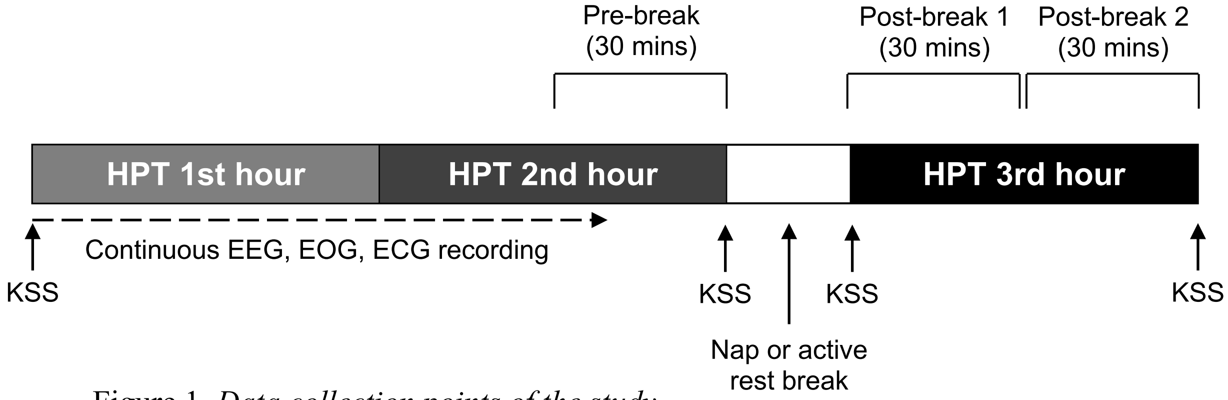

Figure 1. *Data collection points of the study.*

Participants arrived at the laboratory 40 minutes prior to the start of the testing session (i.e., 08:20 for a 09:00 morning session or 12:20 for a 13:00 afternoon session) to have the electrodes attached. Their subjective sleepiness was assessed immediately before starting the driving task with the KSS and the experimenter then left the room. A two-hour session of the driving simulator was completed. When this two-hour session was completed, the experimenter re-entered the testing room, readministered the KSS, and informed the participant which experimental condition (either nap condition or rest condition) they were to complete. Participants then completed the relevant intervention. At the conclusion of the break intervention, the KSS was readministered when the participant was seated in the testing chair. They then completed the post-break driving simulator session (one hour duration). Upon completion of the post break session, the experimenter re-entered the testing room and administered the KSS for the last time.

During the testing sessions, the participant was not aware of the duration of the pre- and post-break sessions nor was the participant informed of which experimental condition they were undertaking prior to the break. Participants repeated the session one week later, using the break intervention (nap or rest) that they did not experience in their first session. The participant was reminded to follow the study protocol of maintaining their habitual bedtimes which were no later than 12 midnight. All participants received standardised instructions and sat in a high-back chair. The testing room was temperature controlled (23°C), light controlled (450 lx), and was devoid of all time cues and participants were instructed to remove their watches and turn off their mobile phones.

## Statistical Analyses

To test the specified hypotheses, a series of repeated measures ANOVAs with planned comparisons were conducted. The EEG data utilised a 2 (nap break, active rest break) x 3 (pre-break, post-break 1, post-break 2) ANOVA design with half hourly time bins. The temporal resolution of half hourly time bins were utilised in order to increase the sensitivity to detect variations in sleepiness. The HPT data utilised a 2 (nap break, active rest break) x 2 (HPT 2nd hour, HPT 3rd hour) ANOVA design. Hourly time bins were used for the HPT data. The subjective sleepiness data utilised a 2 (nap break, active rest break) x 3 (pre-break, post-break 1, post-break 2) ANOVA design. The KSS data was collected at four time points (see Figure 1); the first KSS was used as a manipulation check, the remaining KSS were used in the ANOVA analyses. Breaches of the sphericity assumption used the Greenhouse-Geisser correction.

## Data Acquisition

**Physiological recordings.** Standard recording epochs of 30 seconds were utilised for analysis of EEG, EOG, and ECG. The physiological data was inspected by an experienced polysomnographer (CNW) for artefact. Any epoch that contained movement artefact was excluded from the analysis as per recommendations from Pivik et al. (1993). The waking EEG data was recorded from the occipital site O1-A2 pairing and as the amplitude and hence the degree of eye blink artefact decreases rapidly towards the occipital sites (Somsen & van

Beek, 1998) , eye blink artefact was not corrected. The EEG data from the O1-A2 pairing was subjected to a Fourier Fast transformation utilising a Hanning window prior to spectral analysis. The absolute power ($\mu V^2$) was determined for each 30 second epoch for the frequencies of theta (8-13 Hz) and alpha (4-8 Hz). The power from each 30 second epoch was then averaged across relevant time bins (see Figure 1). During the nap break the C3-A2 pairing was visually scored for sleep onset and sleep staging by standard criteria (Iber & American Academy of Sleep Medicine, 2007).

## Results

### Manipulation Check

**Sleep prior to testing.** The amount of sleep achieved by each participant at home prior to testing before the two testing sessions was assessed via actigraphy. No significant differences were found between the amount of sleep prior to the first testing session (*M* = 6.15; *SD* = 0.68 hours) and the second testing session (*M* = 6.30; *SD* = 0.79 hours), *t*(17) = -1.41, *p* = .18. Two participants' Actigraphs failed to record their rest/activity patterns for the second week of testing – inspection of their sleep diaries revealed they followed the study protocol for sleep-wake times. The amount of sleep debt the participants were experiencing between the two sessions was also examined. No significant differences were found between the amount of sleep debt experienced during the first testing session (*M* = 2.55; *SD* = 1.02 hours) and the second testing session (*M* = 2.40; *SD* = 1.31 hours), *t*(19) = 0.69, *p* = .49. Therefore, the sample's estimated need for sleep was considered to be the same across testing sessions.

**Subjective sleepiness.** Mean KSS before the nap testing sessions was *M* = 5.45, *SD* = 1.54, and for the active rest testing sessions was *M* = 4.75, *SD* = 1.80. A paired samples *t*-test revealed no significant difference between the participants subjective sleepiness levels at the start of testing between the conditions, *t*(19) = 1.41, *p* = .18. The sample's subjective sleepiness was the same between conditions at the beginning of testing.

**Tests of Hypotheses**

The means and standard deviations can be seen in Table 1. Table 2 displays the ANOVA summary and the planned comparisons to test the specific hypotheses. It must be noted that there were no significant main effects between the morning or afternoon testing sessions for EEG theta power *F*(1, 18) = 0.10, *p* = .76, EEG alpha power *F*(1, 18) = 0.29, *p* = .60, HPT *F*(1, 18) = .12, *p* = .74, or KSS *F*(1, 18) = .01, *p* = .95.

Table 1. Means and standard deviations of the EEG, HPT, and KSS data (*N* = 20)

| | Mean (Standard Deviation) | | | | | |
|---|---|---|---|---|---|---|
| | Pre-break | | Post-break 1 | | Post-break 2 | |
| Measure | Nap | Rest | Nap | Rest | Nap | Rest |
| EEG Theta power ($\mu V^2$) | 12.34 (1.90) | 12.83 (2.42) | 12.11 (1.88) | 12.69 (2.36) | 12.16 (1.87) | 13.06 (2.56) |
| EEG Alpha power ($\mu V^2$) | 11.84 (3.76) | 12.04 (3.31) | 11.37 (3.52) | 11.79 (4.22) | 11.22 (3.26) | 12.43 (4.97) |
| HPT[a] (sec) | 4.64 (0.72) | 4.66 (0.59) | 4.86 (0.74) | 4.90 (0.63) | - | - |
| KSS | 6.90 (1.86) | 7.20 (1.91) | 6.90 (1.17) | 4.00 (1.41) | 4.60 (1.54) | 5.00 (2.08) |

[a] HPT data was averaged in hourly time bins.

Table 2. Repeated measures ANOVA summary for break x time interaction and the planned comparisons to test hypotheses (*N* = 20)

| | | | | | Planned comparisons | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ANOVA summary | | | | Pre-break vs. Post-break 1 | | Post-break 1 vs. Post-break 2 | | Post-break 2: Nap vs. Rest |
| Measure | *df* | *F* | $\eta_p^2$ | power | Nap | Rest | Nap | Rest | |
| EEG Theta power ($\mu V^2$) | 2 | $4.87^{*}$ | .20 | .77 | $2.41^{*}$ | 0.92 | -0.77 | $-2.93^{*}$ | $-2.42^{*}$ |
| EEG Alpha power ($\mu V^2$) | 2 | $5.54^{*}$ | .13 | .82 | $2.27^{*}$ | 0.77 | 1.34 | $-2.73^{*}$ | $-2.25^{*}$ |
| HPT[a] (sec) | 1 | 0.01 | .01 | .05 | -1.09 | -1.52 | - | - | -0.16 |
| KSS | 2 | $27.40^{**}$ | .60 | 1.0 | 0.00 | $6.46^{**}$ | $7.19^{**}$ | $-3.08^{*}$ | -0.91 |

*Note*: $^{*}p < .05$, $^{**}p < .01$; Positive planned comparison value indicates a decrease.

[a] HPT data was averaged in hourly time bins.

The tests of the first hypothesis, that both break types will significantly decrease signs of sleepiness can be found in Table 1. Partial support for the first hypothesis was provided by the data, where the EEG data showed a significant decrease in theta and alpha power levels for the nap condition only. The HPT data showed that after the break the response time latencies did not change for either condition. Last, the KSS data revealed only the active rest condition produced a significant decrease in subjective sleepiness immediately after the break.

The second hypothesis stated that the alerting effect of the nap break will be sustained, while the alerting effect of the active rest break will be transient. As shown with the planned comparisons in Table 2, this hypothesis was supported. After the active rest break the EEG theta and alpha power levels increased during the third hour of testing, whereas there was no change in the nap conditions EEG theta and alpha power levels. The KSS data revealed that after the nap condition participants mean subjective sleepiness scores significantly decreased from after the break to the end of testing. In contrast, the active rest break condition mean subjective sleepiness scores significantly increased from after the active rest break to the end of testing.

The third hypothesis stated that the nap break will reduce signs of sleepiness to a greater extent than will the active rest break. Partial support for this hypothesis was found. The EEG theta and alpha power levels were significantly lower for nap to the active rest condition in the last half hour of testing. However, no significant differences were found between the two conditions for the HPT response time latencies or for the KSS scores at the end of testing.

## Break Data

**Nap break polysomnography data.** In order to examine the ‘napability’ and sleep staging of participants, complete EEG and EOG data was obtained for all participants during the nap break. This data was scored for sleep onset latency, duration, and sleep stages, which can be found in Table 3. It must be noted that only 12 participants were determined to have fallen asleep during the nap opportunity, therefore only their data is reported in the table. There was no significant difference between the number of participants who were able to achieve sleep onset during the morning (*n* = 7) or afternoon (*n* = 5) testing sessions $\chi$ (1) = 0.36, *p* = .65.

Table 3. Nap Break Sleep Staging Data (*n* = 12)

| | | Sleep time (% of total) | | | |
|---|---|---|---|---|---|
| SOL (*SD*) | Duration (*SD*) | NREM1 | NREM2 | NREM3 | REM |
| 10.04 (3.03) | 4.96 (3.03) | 90.17 | 8.52 | 0 | 1.32 |

*Note*. SOL = Sleep onset latency (min); NREM = Non-Rapid Eye Movement.

**Active rest break data.** The mean distance in metres the participants walked during the active rest break was *M* = 831.55, *SD* = 99.14 (range = 669-1065). A paired samples *t*-test revealed the mean heart rate after the rest break (*M* = 75.60, *SD* = 12.25) was significantly higher than the mean heart rate prior to the rest break (*M* = 66.12, *SD* = 9.11), *t*(19) = -6.05, *p* < .001. This indicates that the intervention provided an increased level of activity.

## Discussion

The aim of the current study was to compare the effectiveness of nap and active rest breaks for improving sleepiness and performance in partially sleep deprived young adults. The data provided partial support for the first hypothesis, that both break types would reduce signs of sleepiness, where the nap break affected sleepiness but the active break did not. The second hypothesis, that the nap break will have a sustained effect while the active rest break would have a transient effect, was supported by the data. The third hypothesis, that the nap break would reduce signs of sleepiness greater than the active rest break was partially supported, where the EEG sleepiness levels were lower for the nap break.

The nap break was shown to reduce physiological and subjective sleepiness levels. This is consistent with explicit predictions from sleep-wake models (Borbely, 1982; Folkard & Åkerstedt, 1991), as the nap break effects reduces the homeostatic drive for sleep and leads to decreases in sleepiness. After the nap break, levels of subjective sleepiness eventually decreased. The effectiveness of the nap break in reducing physiological indicators of sleepiness (i.e., EEG theta and alpha power) and subjective sleepiness is consistent with previous work (Gillberg, Kecklund, & Åkerstedt, 1996; Horne & Reyner, 1996).

In contrast, the active rest break did not appear to reduce physiological sleepiness. In the current study, physiological sleepiness levels did not significantly change during the 30 minutes after the active rest break, but then increased during the last 30 minutes. The extant literature suggests that the effect of a rest break is small. For instance, an inactive rest break has no effect for reducing physiological sleepiness during night-time testing paradigms when both circadian and homeostatic drives to sleep are approaching their maximal intensity (Gillberg, Kecklund, & Åkerstedt, 1996; Phipps-Nelson et al., 2011). In addition, active rest breaks that take place during the daytime appear to have a small effect on sleepiness, but the duration of the effect is short lived (Bonnet & Arand, 2005; LeDuc et al., 2000). An explanation for the differences between the results of previous work and the current data could be due to the time bins used to average the physiological data. Previous work has used much smaller time bins (< 12 minutes) and discovered changes in physiological sleepiness levels. The current physiological data was averaged in half hourly time bins to ensure the findings had some utility for extended duration driving situations. Additionally, the level of activity of the active rest break used in the current study is potentially lower than the activity of other studies (Bonnet & Arand, 2005; LeDuc et al., 2000). These two factors could have contributed to the null result of the active rest break for physiological sleepiness levels.

While the active rest break had no effect for reducing physiological sleepiness levels, a clear effect was observed with subjective sleepiness levels. An immediate reduction in subjective sleepiness levels following the active rest break was observed and is consistent with previous work (Gillberg, Kecklund, & Åkerstedt, 1996; Phipps-Nelson et al., 2011). However, the apparent discrepancy between objective and subjective indicators of sleepiness after the active break may have implications for road safety. For example, a decrease in subjective sleepiness immediately after a rest break may leave drivers with an erroneous perception of their actual sleepiness level and their capacity to drive safely. This overconfidence could be augmented by poor awareness of the physical signs of sleepiness (Kaplan, Itoi, & Dement, 2007). Alternatively, as the subjective sleepiness was collected at specific time points but the continuously recorded physiological data was averaged over longer time bins, any transient physiological effect from the active rest break could have been lost. Nonetheless, such a transient physiological effect from the active rest break has little utility for extended duration driving situations.

No significant difference in subjective sleepiness was observed between the two break types at the end of the test session. This was contrary to the expectation that a nap break would reduce subjective sleepiness more than an active rest break would. A number of factors could have contributed to the subjective sleepiness levels for the nap and active rest break conditions at the end of test session. The current study procedure required the experimenter to enter the room to obtain a subjective sleepiness rating at the very end of the testing session, a point at which the participants were aware that the test had finished. Situations involving social interaction can lead to lower subjective sleepiness when compared to quiet relaxed situations or to a dull reaction time test (Åkerstedt, Kecklund, & Axelsson, 2008). Moreover, simply asking for a verbal rating of sleepiness has a modest effect on reducing sleepiness levels (Kaida, T, Kecklund, Nilsson, & Axelsson, 2007). In addition, the participants may have been relieved at the notion of having completed an arduous testing session (i.e., 3 hours and 15 minutes of testing) – similar anticipation effects with performance measures have been noted previously (Steyvers & Gaillard, 1993). Nonetheless, the social or relief/anticipation factors may be reflected in the subjective sleepiness ratings for both conditions.

It was found that the nap break led to no significant change in HPT response times. This finding was not consistent with the first hypothesis, where a decrease in response time was anticipated. The finding that hazard perception performance did not significantly change after the nap break may be due to two factors: (a) slow acting effects of the nap combined and (b) task sensitivity. The first factor to consider is the time required for the recuperative effects from a nap to emerge. It has been proposed that the recuperative benefits of a nap emerge slowly upon awakening for performance measures (Carskadon & Dement, 1982; Lumley, Roehrs, Zorick, Lamphere, & Roth, 1986). For example, Brooks and Lack (2006) found improvement on low-order cognitive performance measures after sleep deprivation emerged some 35 to 95 minutes after a nap in the laboratory. Likewise, Smith et al. (2007) found that significantly faster reaction times emerged approximately one hour after a night-time nap during a nightshift. Additionally, only 12 of the 20 participants were able to achieve sleep onset and therefore the dose or amount of sleep the participants received may might have been enough to improve hazard perception performance after the nap. Previous work suggest that a dose-response relationship exists with longer durations of napping and increases of alertness (e.g., Brooks & Lack, 2006).

A second explanation for the hazard perception results after the nap may be due to the nature of the task. The magnitude of benefit from a nap is possibly affected by the type of cognitive task assessed (i.e., low-order or high-order). Studies that have found improved cognitive functioning after short naps have used low-order cognitive tasks such as the symbol-digit substitution task and the letter cancellation task (Brooks & Lack, 2006; Tietzel & Lack, 2001, 2002). Similarly, low-order cognitive tasks have shown improvement after a rest break (Caldwell et al., 2003). These low-order tasks are likely to require relatively few cognitive resources for their operation. In contrast, efficient hazard perception utilises a number of different psychological processes (Wetton et al., 2010), and is considered a high-order cognitive task requiring substantial cognitive resources (Horswill & McKenna, 2004). This notion is supported by findings that, when partially sleep deprived, performance impairment is lower during a working memory task with a low cognitive load when compared to the performance during a higher cognitive load task (Groeger, Lo, Burns, & Dijk, 2011). To thoroughly examine the slow acting effects from naps and issues surrounding task sensitivity, studies that examine the temporal effects of naps for both low- and high-order cognitive tasks during the same testing could be beneficial.

The potential implementation of a nap break by drivers out on the road raises some issues which deserve consideration. It was discovered that only a proportion (60%) of the participants was able to fall asleep during the nap break opportunity. This outcome raises concerns about the use of a nap break as a driver sleepiness countermeasure, as drivers who do not fall asleep will not receive the benefits from the nap. Another issue is the potential for sleep inertia - sleep inertia is the transient impairment of cognitive functioning and feelings of sleepiness following awakening. Consequently, education campaigns that recommend the use of nap breaks should advise drivers about the effects of sleep inertia. Notwithstanding, these potential issues, the magnitude of the effect of the nap break in the current study might have been greater if all participants were able to fall asleep – this could be addressed with future work.

There are some limitations that need to be considered. The methodology of the current study did not include a control condition (i.e., continuing driving without any intervention). A control condition would have provided data regarding the magnitude of effectiveness of both break types relative to not having any intervention. Including a control condition was not feasible for the current study due to the cost involved with creating a third version of the HPT and the excessive demands placed on participants undertaking three consecutive weeks of partial sleep deprivation, which has ethical implications. The current data were obtained under laboratory conditions. The disparity between on-road and laboratory conditions have been noted (Philip et al., 2005), where laboratory conditions facilitate lower arousal levels than on-road conditions. As such, on-road examinations of these breaks are critical for road safety outcomes.

Driver sleepiness contributes substantially to road trauma. Only the nap break provided significant reduction in physiological sleepiness and eventually reduced subjective sleepiness levels. In contrast, the active rest break had no effect for reducing physiological sleepiness but provided a transient reduction of subjective sleepiness levels. It would seem that there may be no substitute for sleep in order to reduce sleepiness.

# References

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

Åkerstedt, T., Kecklund, G., & Axelsson, J. (2008). Effects of context on sleepiness self-ratings during repeated partial sleep deprivation. *Chronobiology International, 25*(2), 271-278. doi: 10.1080/07420520802110589

Anund, A., Kecklund, G., Peters, B., & Åkerstedt, T. (2008). Driver sleepiness and individual differences in preferences for countermeasures. *Journal Of Sleep Research, 17*(1), 16-22. doi: 10.1111/j.1365-2869.2008.00633.x

Armstrong, K. A., Obst, P., Banks, T., & Smith, S. S. (2010). Managing driver fatigue: Education or motivation? *Road & Transport Research, 19*(3), 14-20.

Backhaus, J., Junghanns, K., Broocks, A., Riemann, D., & Hohagen, F. (2002). Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *Journal of Psychosomatic Research, 53*(3), 737-740.

Bonnet, M. H., & Arand, D. L. (2005). Sleep latency testing as a time course measure of state arousal. *Journal Of Sleep Research, 14*(4), 387-392.

Borbely, A. A. (1982). A two process model of sleep regulation. *Hum Neurobiol, 1*(3), 195-204.

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

Buysse, D. J., Reynolds, C. F., 3rd, 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.

Caldwell, J. A., Prazinko, B., & Caldwell, J. L. (2003). Body posture affects electroencephalographic activity and psychomotor vigilance task performance in sleep-deprived subjects. *Clinical Neurophysiology, 114*(1), 23-31.

Carpenter, J. S., & Andrykowski, M. A. (1998). Psychometric evaluation of the Pittsburgh Sleep Quality Index. *Journal of Psychosomatic Research, 45*(1), 5-13.

Carskadon, M. A., & Dement, W. C. (1982). The multiple sleep latency test: What does it measure? *Sleep, suppl2*, S128-146.

Chen, N. H., Johns, M. W., Li, H. Y., Chu, C. C., Liang, S. C., Shu, Y. H., . . . Wang, P. C. (2002). Validation of a Chinese version of the Epworth sleepiness scale. *Quality of Life Research, 11*(8), 817-821.

Cole, R. J., Kripke, D. F., Gruen, W., Mullaney, D. J., & Gillin, J. C. (1992). Automatic sleep/wake identification from wrist activity. *Sleep, 15*(5), 461-469.

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., . . . Jackson, R. (2002). Driver sleepiness and risk of serious injury to car occupants: population based case control study. *BMJ, 324*(7346), 1125.

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Wigmore, B., & Jackson, R. (2001). Prevalence of driver sleepiness in a random population-based sample of car driving. *Sleep, 24*(6), 688-694.

Drummond, A. E. (2000). *Paradigm lost! Paradise gained? An Australian's perspective on the novice driver problem*. Paper presented at the Novice Driver Conference (1st–2nd June), Bristol, U.K. http://www.dft.gov.uk

Enright, P. L., McBurnie, M. A., Bittner, V., Tracy, R. P., McNamara, R., Arnold, A., & Newman, A. B. (2003). The 6-Minute Walk Test. *Chest, 123*(2), 783-785.

Folkard, S., & Åkerstedt, T. (1991). A three process model of the regulation of alerness and sleepiness. In R. Ogilvie & R. Broughton (Eds.), *Sleep, arousal and performance: Problems and promises* (pp. 11-26). Boston: Birkhauser.

Gillberg, M., Kecklund, G., & Åkerstedt, T. (1996). Sleepiness and performance of professional drivers in a truck simulator--comparisons between day and night driving. *Journal Of Sleep Research, 5*(1), 12-15.

Gillberg, M., Kecklund, G., Axelsson, J., & Åkerstedt, T. (1996). The effects of a short daytime nap after restricted night sleep. *Sleep, 19*(7), 570-575.

Gillberg, M., Kecklund, G., Göransson, B., & Åkerstedt, T. (2003). Operator performance and signs of sleepiness during day and night work in a simulated thermal power plant. *International Journal of Industrial Ergonomics, 31*(2), 101-109.

Groeger, J. A., Lo, J. C., Burns, C. G., & Dijk, D. J. (2011). Effects of sleep inertia after daytime naps vary with executive load and time of day. *Behavioral Neuroscience, 125*(2), 252-260. doi: 10.1037/a0022692

Hayashi, M., Ito, S., & Hori, T. (1999). The effects of a 20-min nap at noon on sleepiness, performance and EEG activity. *International Journal of Psychophysiology, 32*(2), 173-180.

Horne, J. A., & Reyner, L. A. (1995). Sleep related vehicle accidents. *BMJ, 310*(6979), 565-567.

Horne, J. A., & Reyner, L. A. (1996). Counteracting driver sleepiness: effects of napping, caffeine, and placebo. *Psychophysiology, 33*(3), 306-309.

Horswill, M. S., Marrington, S. A., McCullough, C. M., Wood, J., Pachana, N. A., McWilliam, J., & Raikos, M. K. (2008). The harard perception ability of older drivers. *The Journals of Gerontology, 63B*(4), 212-218.

Horswill, M. S., & McKenna, F. P. (2004). Driver's hazard perception ability: Situation awareness on the road. In S. Banbury & S. Tremblay (Eds.), *A Cognitive Approach to Situation Awareness*. Hampshire, UK: Ashgate Publishing.

Hull, M., & Christie, R. (1992). *Hazard perception test: The Geelong trial and future development*. Paper presented at the Proceedings of the National Road Safety Seminar, Wellington, New Zealand, Wellington, New Zealand.

Iber, C., & American Academy of Sleep Medicine. (2007). *The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications*: American Academy of Sleep Medicine.

Jackson, L., Chapman, P., & Crundall, D. (2009). What happens next? Predicting other road users' behaviour as a function of driving experience and processing time. *Ergonomics, 52*(2), 154-164.

Johns, M. W. (1991). A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep, 14*(6), 540-545.

Kaida, K., T, A. K., Kecklund, G., Nilsson, J. P., & Axelsson, J. (2007). The effects of asking for verbal ratings of sleepiness on sleepiness and its masking effects on performance. *Clinical Neurophysiology, 118*(6), 1324-1331. doi: 10.1016/j.clinph.2007.03.004

Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., & Fukasawa, K. (2006). Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clinical Neurophysiology, 117*(7), 1574-1581. doi: 10.1016/j.clinph.2006.03.011

Kaplan, K. A., Itoi, A., & Dement, W. C. (2007). Awareness of sleepiness and ability to predict sleep onset: Can drivers avoid falling asleep at the wheel? *Sleep Medicine, 9*(1), 71-79.

Katila, A., Keskinen, E., Hatakka, M., & Laapotti, S. (2004). Does increased confidence among novice drivers imply a decrease in safety?: The effects of skid training on slippery road accidents. *Accident Analysis & Prevention, 36*(4), 543-550.

LeDuc, P. A., Caldwell, J. A., & Ruyak, P. S. (2000). The effects of exercise as a countermeasure for fatigue in sleep-deprived aviators. *Military Psychology, 12*(4), 249-266.

Leger, D., Philip, P., Jarriault, P., Metlaine, A., & Choudat, D. (2009). Effects of a combination of napping and bright light pulses on shift workers' sleepiness at the wheel: A pilot study. *Journal Of Sleep Research, 18*(4), 472-479.

Lenne, M. G., Dwyer, F., Triggs, T. J., Rajaratnam, S., & Redman, J. R. (2004). The effects of a nap opportunity in quiet and noisy environments on driving performance. *Chronobiology International, 21*(6), 991-1001.

Lisper, H. O., & Eriksson, B. (1980). Effects of the length of a rest break and food intake on subsidiary reaction-time performance in an 8-hour driving task. *Journal of Applied Psychology, 65*(1), 117-122.

Lumley, M., Roehrs, T., Zorick, F., Lamphere, J., & Roth, T. (1986). The alerting effects of naps in sleep-deprived subjects. *Psychophysiology, 23*(4), 403-408.

McKenna, F. P., & Horswill, M. S. (1999). Hazard perception and its relevance for driver licensing. *Journal of the International Association of Traffic and Safety Sciences, 23*(1), 26-41.

Pelz, D. C., & Krupat, E. (1974). Caution profile and driving record of undergraduate males. *Accident Analysis & Prevention, 6*(1), 45-58.

Philip, P., Sagaspe, P., Taillard, J., Valtat, C., Moore, N., Åkerstedt, T., . . . Bioulac, B. (2005). Fatigue, sleepiness, and performance in simulated versus real driving conditions. *Sleep, 28*(12), 1511-1516.

Phipps-Nelson, J., Redman, J. R., & Rajaratnam, S. M. (2011). Temporal profile of prolonged, night-time driving performance: breaks from driving temporarily reduce time-on-task fatigue but not sleepiness. *Journal Of Sleep Research, 20*(3), 404-415. doi: 10.1111/j.1365-2869.2010.00900.x

Pivik, R. T., Broughton, R. J., Coppola, R., Davidson, R. J., Fox, N., & Nuwer, M. R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology, 30*(6), 547-558.

Quimby, A. R., Maycock, G., Carter, I. D., Dixon, R., & Wall, J. G. (1986). Perceptual abilities of accident involved drivers. Berkshire, England: Transport and Road Research Laboratory.

Rogé, J., Otmani, S., Bonnefond, A., Pébayle, T., & Muzet, A. (2009). Effect of a short nap on the alertness of young drivers: Repercussion on the perception of motorcycles according to extent of the useful visual field of the driver. *Transportation Research Part F: Traffic Psychology and Behaviour, 12*(2), 143-154.

Sadeh, A., Sharkey, K. M., & Carskadon, M. A. (1994). Activity-based sleep-wake identification: an empirical test of methodological issues. *Sleep, 17*(3), 201-207.

Sallinen, M., Holm, A., Hiltunen, J., Hirvonen, K., Härmä, M., Koskelo, J., . . . Müller, K. (2008). Recovery of cognitive performance from sleep debt: Do a short rest pause and a single recovery night help? *Chronobiology International, 25*(2), 279-296.

Smith, S. S., Cheng, T., & Kerr, G. K. (2012). The effect of extended wake on postural control in young adults. *Experimental Brain Research, 221*(3), 329-335. doi: 10.1007/s00221-012-3175-8

Smith, S. S., Horswill, M. S., Chambers, B., & Wetton, M. (2009). Hazard perception in novice and experienced drivers: the effects of sleepiness. *Accident Analysis & Prevention, 41*(4), 729-733. doi: 10.1016/j.aap.2009.03.016

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.

Somsen, R. J. M., & van Beek, B. (1998). Ocular artifacts in children's EEG: selection is better than correction. *Biological Psychology, 48*(3), 281-300. doi: 10.1016/s0301-0511(98)00041-6

Steyvers, F. J., & Gaillard, A. W. (1993). The effects of sleep deprivation and incentives on human performance. *Psychological Research, 55*(1), 64-70.

Tietzel, A. J., & Lack, L. C. (2001). The short-term benefits of brief and long naps following nocturnal sleep restriction. *Sleep, 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.

Vignatelli, L., Plazzi, G., Barbato, A., Ferini-Strambi, L., Manni, R., Pompei, F., . . . Ginsen. (2003). Italian version of the Epworth sleepiness scale: external validity. *Neurological Sciences, 23*(6), 295-300. doi: 10.1007/s100720300004

Wetton, M. A., Horswill, M. S., Hatherly, C., Wood, J. M., Pachana, N. A., & Anstey, K. J. (2010). The development and validation of two complementary measures of drivers' hazard perception ability. *Accident Analysis & Prevention, 42*(4), 1232-1239. doi: 10.1016/j.aap.2010.01.017

Wood, J. M., Horswill, M. S., Lacherez, P. F., & Anstey, K. J. (2013). Evaluation of screening tests for predicting older driver performance and safety assessed by an on-road test. *Accident Analysis & Prevention, 50*(0), 1161-1168. doi: 10.1016/j.aap.2012.09.009