THE EFFECTS OF REST BREAKS ON DRIVER FATIGUE

FINAL REPORT

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EXECUTIVE SUMMARY

Driver sleepiness contributes substantially to road death and trauma. Effective countermeasures to reduce driver sleepiness are critical to reducing the incidence of driver sleepiness. Study one determined the effectiveness of a nap break and an active rest break. It was found that a nap break provided objective benefit for reducing driver sleepiness. Study two examined drivers' ability to recognise increasing sleepiness, and to self-regulate their behaviour by taking a break. The results suggest that drivers were able to identify increasing sleepiness during the test period, and could make the decision to cease driving. However, the ability among participants to identify their increasing sleepiness varied. Strategies to improve perception, detection and mitigation of sleepiness while driving should be pursued.

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ABBREVIATIONS AND TERMS

ECG – Electrocardiography

EEG – Electroencephalography

EMG – Electromyography

EOG – Electrooculography

Epoch – A quantified amount of time. Typically, 30 second epochs are utilised in sleep studies.

ESS – Epworth Sleepiness Scale

HPT – Hazard Perception Test

KSS – Karolinska Sleepiness Scale

Polysomnography (PSG) – a multi-measure test used in the study of sleep and as a diagnostic tool in sleep medicine, otherwise known as a sleep test

Power band – A grouping or range of frequencies; for example the EEG alpha power band (8-13 Hz) which is indicative of drowsiness

PSQI – Pittsburgh Sleep Quality Index

PVT – Psychomotor Vigilance Test

REM – Rapid eye movement

Sleep architecture/staging – Represents the structure of sleep as defined by specific electrophysical indicators from EEG, EOG, and EMG recordings

Sleep debt – Experiencing sleep deprivation results in the accumulation of a sleep debt; which is the under accumulation of enough sleep to ensure homeostasis/optimal daytime functioning

WAVT – Wilkinson Auditory Vigilance Test

PREFACE

This project was approved by the Queensland University of Technology Human Research Ethics Committee (project number: 0900000678). In addition, an occupational health and safety risk assessment for this project was completed and approved by the Health and Safety officers from the Queensland University of Technology.

RESEARCH DISSEMINATION

The outcomes from study one have been disseminated in a number of formats. These include:

1) Smith, S., & Watling, C. N. (2010). *Asleep at the wheel: A simulated task to assess sleepiness while driving.* Paper presented at the Australasian Sleep Association Conference, 21st – 23rd October, Christchurch, New Zealand.

2) Master of Applied Science (research) thesis of Christopher N. Watling (2012) with the Queensland University of Technology.

INTRODUCTION

The role of sleepiness as a major contributor to vehicle crashes is widely recognised, both within Australia (ATSB, 2006; Dobbie, 2002) and internationally (Åkerstedt, 2000; Connor *et al.*, 2002; Dinges, 1995; Horne & Reyner, 1995). The population attributable risk for fatal and severe crash associated with sleepy driving is 19% (Connor *et al.*, 2002), of a similar magnitude to the contribution made by drink driving (Australian Transport Council, 2011). The extent of the involvement of sleepiness in less severe crashes may be as great or greater. The factors causing crashes are often multifactorial and sleepiness may be involved in a proportion of crashes that are primarily attributed to other factors.

Driving is a complex task that requires the successful completion of a number of psychological processes to ensure the safety of the driver and other road users. These psychological processes comprise: learning, memory, perception, motor control, attention, decision making, and executive functioning (Groeger, 2002; Horswill & McKenna, 2004; Spiers & Maguire, 2007; Uchiyama, Ebe, Kozato, Okada, & Sadato, 2003). Drivers are at an increased risk of having a crash when sleepiness impacts upon these processes (Åkerstedt, Connor, Gray, & Kecklund, 2008; Stutts, Wilkins, Scott Osberg, & Vaughn, 2003). A number of simulator studies (Campagne, Pebayle, & Muzet, 2004; Horne & Reyner, 1996; Lowden, Anund, Kecklund, Peters, & Åkerstedt, 2009) and on-road studies (Kecklund & Åkerstedt, 1993; Schmidt *et al.*, 2009; Simon *et al.*, 2011) have shown that sleepiness has a detrimental effect on the safe operation of a vehicle.

Younger drivers appear to be at increased risk for sleepiness-related crashes. One component of this risk is their sensitivity to sleep deprivation. Younger people can be more impaired than older people on specific vigilance tests after sleep deprivation (Philip *et al.*, 2004). This is consistent with data demonstrating that younger drivers make more steering errors than older drivers during night-time driving (Campagne *et al.*, 2004). Lowden *et al.* (2009) has shown that younger drivers, when compared to middle aged adults, exhibit higher levels of physiological sleepiness during early morning and night-time driving. The physiological and behavioural impairment that younger drivers experience with increases in sleepiness is consistent with their increased crash risk (Åkerstedt & Kecklund, 2001; Smith, Armstrong, Steinhardt, & Haworth, 2008).

An assessment of sleepiness levels when driving can be obtained via three general methods: (1) physiological measures (e.g. EEG), (2) subjective measures, and (3) behavioural measures. A number of studies have found electroencephalography (EEG) recordings to detect increases in sleepiness during simulated driving studies (e.g., Horne & Reyner, 1996; Lowden *et al.*, 2009) and on-road situations (Kecklund & Åkerstedt, 1993; Schmidt *et al.*, 2009). Increased power in the EEG theta and alpha bands has been found to reflect increases in sleepiness (e.g., Kecklund & Åkerstedt, 1993; Reyner & Horne, 1998a). Subjective ratings of an individual's sleepiness levels can be elicited by verbal ratings or rating scales. Subjective ratings of sleepiness generally have a significant and positive relationship with independent physiological measures (e.g., Dorrian, Lamond, & Dawson, 2000; Kaida *et al.*, 2006). Behavioural measures such as maintaining vehicle control have been found to be affected by increases in sleepiness levels (e.g., Åkerstedt, Peters, Anund, & Kecklund, 2005; Campagne *et al.*, 2004). While measures of vehicle control provide some evidence for the decrement associated with sleepiness, these represent only one element of the driving task that may be impacted. Other safety-critical elements include higher-order cognitive functions such as hazard perception.

Hazard perception has been described as the skill required to notice or to predict that a specific traffic circumstance may result in a dangerous situation, requiring a reaction from the driver to avoid an incident (Horswill & McKenna, 2004; McKenna & Crick, 1991). Of all the driving-specific skills commonly assessed in simulator studies (e.g., vehicle control, skid control, etc), only hazard perception identification has been found to be reliably associated with crash involvement (Drummond, 2000; Hull & Christie, 1992; McKenna & Horswill, 1999; Pelz & Krupat, 1974; Quimby, Maycock, Carter, Dixon, & Wall, 1986).

Hazard perception performance is likely to be impaired by sleepiness. Smith, Horswill, Chambers, and Wetton (2009a) investigated the effects of extended wakefulness on hazard perception performance with novice drivers (< three years driving experience) and experienced drivers (> 10 years driving experience). Consistent with other work, the hazard perception performance of the novice drivers was found to be worse than that of the experienced drivers during the daytime. When the two driving samples were tested at 03:00, *both* groups showed worse hazard perception performance compared with their daytime performance. However, the novice drivers displayed a more pronounced reduction in hazard perception performance than did the experienced drivers. The results of this study indicated that younger drivers' hazard perception performance is more critically affected by increasing sleepiness levels.

STUDY ONE: THE EFFECTIVENESS OF NAP AND ACTIVE REST BREAKS

Three broad strategies have been proposed to reduce sleepiness-related crashes: prevention, avoidance and intervention. For instance, prevention could involve ensuring that drivers receive sufficient night-time sleep to allow optimal daytime functioning. Avoidance involves drivers discontinuing or not driving at all when sleepy, although this may be difficult to implement in some circumstances due to external pressures (i.e., professional drivers). Intervention involves employing strategies or countermeasures designed to reduce sleepiness.

Taking a brief nap or stopping for a rest break are two highly publicised countermeasures for driver sleepiness. Drivers tend to rate both of these strategies as effective in reducing sleepiness (Armstrong, Obst, Banks, & Smith, 2010; Nordbakke & Sagberg, 2007; Pennay, 2008; Vanlaar, Simpson, Mayhew, & Robertson, 2008). Despite this belief, there is scarce evidence to support the utility of these countermeasures for reducing driver sleepiness levels, and their impact on hazard perception performance is unknown. Most importantly, the relative benefits of a nap break and an active rest break have never been directly evaluated.

A number of non-driving studies have found that brief naps can reduce EEG-defined sleepiness signs (i.e., EEG theta and alpha power levels) and improve cognitive functioning (Gillberg, Kecklund, Axelsson, & Åkerstedt, 1996; Hayashi, Ito, & Hori, 1999). Moreover, these effects can endure for several hours. Nap breaks also have a beneficial effect on subjective sleepiness (Smith, Kilby, Jorgensen, & Douglas, 2007; Tietzel & Lack, 2002); with reduced subjective sleepiness levels for up to one and a half hours after the nap. Naps can facilitate quicker reaction times on a number of tasks (e.g., Psychomotor Vigilance Task, Mackworth Clock vigilance task, two-choice visual reaction time test) (Purnell, Feyer, & Herbison, 2002; Sallinen, Härmä, Åkerstedt, Rosa, & Lillqvist, 1998; Smith-Coggins *et al.*, 2006) in sleepy individuals.

A number of non-driving studies also suggest that rest breaks (without a nap) have an alerting effect. Physiological indices of sleepiness reveal that rest breaks decrease sleepiness levels

after sleep deprivation (e.g., LeDuc, Caldwell, & Ruyak, 2000; Sallinen *et al.*, 2008). Rest breaks have consistently been found to immediately reduce subjective sleepiness levels (e.g., Gillberg, Kecklund, Göransson, & Åkerstedt, 2003; Horne & Foster, 1996; Sallinen *et al.*, 2008). Rest breaks also facilitate quicker reaction time on vigilance tasks (Caldwell, Prazinko, & Caldwell, 2003; Horne & Foster, 1996). In contrast, the effects of rest breaks on cognitive measures are equivocal. That is, studies have shown rest breaks facilitate better cognitive functions or have no effect at all (LeDuc *et al.*, 2000; Sallinen *et al.*, 2008). However, an active rest breaks that involve physical activity such as cycling or paced walking appear to have greater effect in reducing sleepiness than do less active or inactive rest (e.g, passive sitting) breaks (Bonnet & Arand, 2005; Horne & Foster, 1996; Sallinen *et al.*, 2008).

Within the driving literature, some studies have found that nap breaks reduce EEG sleepiness, subjective sleepiness, and driver performance levels (i.e., driving incidents; Horne & Reyner, 1996; Leger, Philip, Jarriault, Metlaine, & Choudat, 2009). However, other studies have found that a nap break has no effect on EEG sleepiness signs or vehicle performance measures (Rogé, Otmani, Bonnefond, Pébayle, & Muzet, 2009). There is some evidence that rest breaks have little effect on EEG sleepiness signs while driving, but can result in an improvement in vehicle control measures (Gillberg, Kecklund, & Åkerstedt, 1996; Phipps-Nelson, Redman, & Rajaratnam, 2009). These rest break studies were carried out during night-time hours and the effects of rest break during daytime hours are not known.

The type of countermeasure used by drivers is a critical concern for road safety. The use of countermeasures that are less effective for reducing sleepiness may provide drivers with a sense of 'false security' about their sleepiness level. The "Stop, Revive, and Survive" campaign recommends that drivers take regular breaks of at least 15 minutes for every two hours of driving (Department of Transport and Main Roads, 2008). These recommendations give no guidance as to which countermeasure is the most effective for reducing sleepiness.

The aim of the current study was to determine the relative magnitude of improvement of the two break types. For the purpose of the current study signs of sleepiness were defined by spectral power in the EEG theta and alpha bands, HPT reaction time latencies, and subjective sleepiness levels. It was hypothesised that the nap break would reduce signs of sleepiness to a greater extent than would the active rest break.

METHOD

DESIGN

The current study utilised a repeated-measures design, with the break type (nap or active rest) as the independent variable. The effect of the independent variable was assessed by three outcome variables: EEG theta and alpha power, reaction time latency from the Hazard Perception test, and subjective sleepiness levels. Assignment of participants to their initial experimental condition (i.e., nap or rest break), the undertaking of the HPT test version (i.e., test one or two), and the time of day of undertaking the testing sessions (i.e., morning or afternoon) were all counterbalanced.

PARTICIPANTS

Younger drivers aged 25 years or less are over-represented in sleep-related crashes (Connor *et al.*, 2001; Horne & Reyner, 1995; Pack *et al.*, 1995) and are more critically affected by

sleepiness (Campagne *et al.*, 2004; Lowden *et al.*, 2009; Smith *et al.*, 2009a). For the present study, we recruited participants between 20-25 years of age, with at least two years driving experience.

The six exclusion criteria were as follows:

1) Being a shift worker or having travelled overseas in the past month
2) Having a habitual bedtime that is later than 12 midnight
3) Having significant health problems
4) Taking prescription or illicit drugs or medications and
5) Drinking more than three cups of coffee per day and/or more than two standard drinks of alcohol per day
6) Significant sleep problems not reported (i.e., a Epworth Sleepiness Scale (ESS; Johns, 1991) score <10, Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) Score <5)

The purpose of the exclusion criteria was to exclude excessively sleepy individuals. In order to ensure the results were due to the experimental conditions and the results were not influenced from circadian disruptions (i.e., shift worker or trans-meridian travel), illicit drugs, medications, excessive coffee, or alcohol consumption.

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) and reported having driven an average of 12,986 kilometres per year over the last three years (*SD* = 8,767.57; range = 1,500-35,000). Seven participants reported having a crash (i.e., where they were the driver and there was damage to property or persons) in the last three years. All participants were paid $100 AUD for participating in the study.

MATERIALS

Participants completed a questionnaire booklet that included a number of measures including demographic information, assessment of quality of sleep, and daytime sleepiness.

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 (Buysse *et al.*, 1989). The questionnaire utilises 19-items to generate seven component scores ranging from 0-3. The seven components are: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The seven component scores are summated to produce a global PSQI score that has a range of 0-21, with higher scores indicative of poorer sleep quality. In accordance with Buysse *et al.* (1989) a score of five or less was utilised as a cut-off point between 'good' and 'bad' sleepers.

Epworth sleepiness scale. The Epworth Sleepiness Scale (ESS; Johns, 1991) is a measure of general level of excessive daytime sleepiness in adults. The ESS was constructed based on observations of the occurrence and nature of daytime sleepiness (Johns, 1991). Participants respond to eight items of how likely they are to doze off or fall asleep in various situations (e.g., "sitting and reading", "sitting and talking to someone", and "in a car, while stopped for a few minutes in the traffic"). Potential responses range from 0-would never doze, 1-slight chance of dozing, 2-moderate chance of dozing, and 3-high chance of dozing.

The range of possible composite scores is 0-24, with increasing scores being indicative of greater daytime sleepiness. A score below of 10 or less is considered to be within the normal range (i.e., no potential sleep disorder) (Johns, 1993, 2000; Johns & Hocking, 1997).

Actigraphy. Actigraphy is a non-invasive method of inferring the wake/sleep cycles of an individual. Often worn on the wrist, the sensor measures the relative movement of the individual (with piezo-electric accelerometers). Rest/activity periods are calculated using custom computer software and sleep/wake periods are subsequently inferred based on these calculations. Increased movement is regarded as an indicator of wake periods and reduced movements is thought to signify sleep.

Karolinska sleepiness scale. The Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) is a self-report measure of the level of subjective sleepiness an individual is experiencing. Individuals are required to indicate on a nine point Likert scale how sleepy they are currently feeling. The question posed to the participants is "Right now how sleepy are you feeling?"

Polysomnography. Polysomnography (PSG) is the term that refers to the battery of physiologic measures utilised in sleep medicine. The PSG montage that was utilised for the current study includes electroencephalography (EEG), electrooculography (EOG), and electrocardiography (ECG), which are standard with PSG.

The software that was utilised to record the physiological data was the Profusion PSG 2 v2.1 (Build 138) software (Compumedics, Melbourne, Victoria, Australia). The EEG, EOG, ECG recordings were sampled at 256 Hz (i.e., 512 samples per second) with 0.3 Hz high pass filter and a 30 Hz low pass filter. Recording epochs of 30 seconds were utilised in accordance with standard PSG recordings and sleep medicine practices (Rechtschaffen & Kales, 1968).

The utilised EEG recording sites were: C3, C4, O1, O2, A1, and A2; electrode placement utilised the 10-20 system derivations from Jasper (1958). As shown in Figure 1 (over page), the central (i.e., C3 and C4) and occipital (i.e., O1 and O2) electrodes were referenced the contralateral electrode site of A1 or A2. These six electrodes sites utilised Ag-Al electrodes. The EOG recording sites used were the standard sleep study placement for EOG electrodes. That is, the right eye electrode was placed approximately one cm lateral and one cm dorsal to the outer corner of the eye (outer canthus), with the left eye electrode placed one cm lateral and one cm ventral the outer canthus. The ECG measurements utilised the modified two-lead recording setup. One electrode is placed approximately three to five cm below the right clavicle (collarbone) with the second electrode placed on the left lower ribcage (i.e., V6 location) that is direct under the midpoint of the armpit. Self adhesive electrodes were used for the EOG, ECG, reference, and ground recording sites.

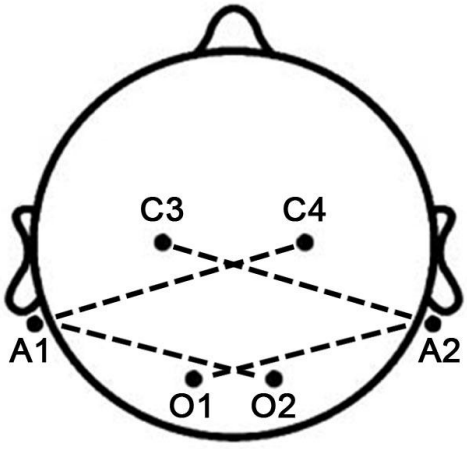

Figure 1. Diagram of the EEG electrode sites utilised in the current study. O electrodes used for spectral analysis, C electrodes used for sleep staging.

Hazard perception test. Hazard perception has been described as the skill to anticipate traffic situations that may result in a crash or near miss (Horswill & McKenna, 2004; McKenna & Crick, 1991). The Hazard Perception Test (HPT) is a video-based reaction time latency measure designed to measure this ability that has been developed in previous work (Horswill *et al.*, 2008; Smith *et al.*, 2009a; Wetton *et al.*, 2010).

The HPT is completed by watching video footage of genuine on-road traffic situations. The footage was recorded from the driver's perspective (during daylight hours) from both the ACT and QLD road networks. Each video segment requires the individual to determine if a potentially hazardous situation could eventually lead to a traffic conflict if no defensive action was initiated by the driver of the car with the camera. If a potentially hazardous situation is identified by the participant then they are required to click on the relevant location with a mouse pointer. The reaction time latency is determined from when the potential hazard first appears in the video to when it is identified using the computer mouse.

The format of HPT used in the present study was based on a previously developed and validated methodology developed by McGowan and Banbury (2004), which requires participants to click on the identified hazard with a mouse pointer. This scoring method minimizes ambiguous responses as participants have to identify the location, as well as the timing of each identified hazard (other tests often involve timing-only responses).

Two three-hour versions of the test (Test 1 and Test 2) were developed for the current study, which contained video footage of measured hazards used in previous work (Horswill *et al.*, 2008; Smith *et al.*, 2009a; Wetton *et al.*, 2010), interleaved with new traffic footage (without measured hazards). The new footage was inserted to simulate the experience of an extended drive. The two alternative versions of the HPT were created to facilitate the repeated measure design methodology; such that participants did not view the same footage twice over the two testing sessions (they viewed Test 1 in one session under one experimental condition and Test 2 in the other session under the other experimental condition, where these variables were all counterbalanced). The two alternative versions of the test were designed to be as equivalent as possible, containing approximately the same number of measured hazards (54 and 55), with the distribution of hazardous footage to non-hazardous footage being approximately the same across the duration of the tests.

Figure 2 shows an example of a potential hazard sequence that was utilised by the current study. The HPT was run on a laptop with the video footage displayed to participants on a separate 4:3 aspect, 17 inch monitor, situated directly in front of them. Audio was muted for all video segments.

Figure 2. Images of a traffic hazard used in the present study. The blue car brakes, which means that the car containing the camera (effectively the participant's vehicle) would have to slow in order to avoid a collision. Importantly, it is possible for those participants with good hazard perception ability to anticipate this traffic conflict long before the blue car actually slows, as long as they are actively scanning the road beyond the blue car (where it is possible to see a taxi manoeuvring across the road ahead).

Table 1. Examples of the hazards that were included in the video sequence

i.	A car doing a U-turn in the distance,
ii.	An oncoming car crossing a centre line to pass a bicyclist
iii.	A cherry picker on right causing an approaching car to cross a centre line
iv.	A car in left lane merging to the front to avoid a parked car in lane ahead

Note – video footage and hazards contained scenes from both the ACT and QLD road networks

EXPERIMENTAL INTERVENTIONS

Incorporated into the study methodology were two types of breaks: a nap and an active rest break.

The nap break condition. In this condition, participants were provided with 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 (e.g., Horne & Reyner, 1996; Leger *et al.*, 2009; Purnell *et al.*, 2002). During the nap break, the participant remained in the padded high-back chair. The angle between the back of the chair and its base was adjusted to be 105^{o}. During the nap break, the room light remained on and the participant's electrophysical signals were continually recorded.

The active rest break condition. It has been shown that active rest breaks have a longer effect for reducing signs of sleepiness than inactive rest breaks (Bonnet & Arand, 2005; Henning, Jacques, Kissel, Sullivan, & Alteras-Webb, 1997; Horne & Foster, 1996; Sallinen *et al.*, 2008). Additionally, several studies have found that drivers report using active rest breaks such as getting out of their car and walking around (Anund, Kecklund, Peters, & Åkerstedt, 2008; Pennay, 2008). In the present study, participants in the active rest break condition completed 10 minutes of brisk walking along an indoor corridor (similar to standard physiotherapy 6-minute walk test). The total time of the active rest break was 15 minutes (including travel time to the corridor for the 10 minutes of brisk walking). The distance that the participants walked was recorded by the experimenter.

DATA ACQUISITION

Physiological recordings. The EEG data was subjected to a Fourier Fast Transformation (FFT) utilising a Hanning window prior to spectral analysis. The power (μV) was determined for each 30 second epoch for the frequencies of delta (0.5-4 Hz), alpha (4-8 Hz), theta (8-13 Hz), and beta (13-30 Hz) utilising Rechtschaffen and Kales (1968) criteria. This spectral analysis was performed on the O1-A2 derivations for all but two participants due to excessive artefact on their O1-A2 recordings. For these two participants the O2-A1 derivations were used in the spectral analysis. This was deemed acceptable as Gasser, Bächer *et al.* (1985) found similar correlations between the O1 and O2 electrode sites when examining the test-retest reliability of EEG recordings.

The power for each 30 second epoch was then averaged across relevant time bins. In total, 348 epochs (174 min) were utilised for the EEG recordings. This was broken down into 236 epochs (118 min) for the first two hours of the test (prior to the break) and 112 epochs (56 min) for the last hour of testing (post break). These hourly time bins were then further broken down into half hourly time bins. This included half hour before the break (60 epochs; 30 min) and two half hours after the break (56 epochs; 28 min).

HPT recordings. The HPT was scored by measuring the response latency between the time when each of the measures hazards first appeared in the video footage to the first

time that the participant clicked on that hazard with the mouse pointer. Faster response times are indicative of better hazard perception performance. Custom written software, developed for previous studies (e.g., Horswill *et al.*, 2008; Smith *et al.*, 2009a; Wetton *et al.*, 2010) was used to determine whether participants were clicking on the measured hazards event and to extract the relevant response times.

Overall response times were calculated for each pre-intervention 2 hour test and the post-intervention 1 hour test separately by taking the means of responses to individual measured hazards in the respective test segments. If a participant did not respond to a hazard, a mean response time for that scene from the other participants was inserted. Note that, in this context, this is a conservative strategy of dealing with misses that has been used in previous work (Smith, Horswill, Chambers, & Wetton, 2009b; Wetton *et al.*, 2010). We also calculated the proportion of hazards responded to at all as a secondary outcome measure (hazard hit rate), though it should be noted that the test was not designed for this purpose (hazards were selected to favour response time measurement, in that most participants would be likely to respond to them eventually, hence leading to a near-ceiling effect for hit rate).

PROCEDURE

A recruitment email was sent via the QUT intranet and was posted on various QUT online notice boards inviting participants to take part in the current study. The recruitment email explained the inclusion and exclusion criteria and gave a concise description of the experimental procedure. The experimenter met with all potential participants in person. During this meeting participants were given an information sheet explaining the purpose of the research, and the experimenter described in greater detail the experimental procedure. Those participants that wished to take part in the study were asked to sign a written consent form, and were given an Actigraph to wear that monitored their rest/activity patterns. The Actigraphs recorded the participants' activity for seven days before the first and the second testing sessions and as such were worn for a total of two weeks. Additionally, participants completed a sleep/wake diary in the event of the Actigraph malfunctioning. The participants were also instructed to maintain their normal routines prior to and between testing sessions. Participants were instructed to wake up at 5am on testing days, and they were also instructed not to ingest any form of caffeine or alcohol until after the testing session had been completed.

On the first day of testing, the participant was met by the experimenter at the Prince Charles Hospital research site and was escorted to the testing room located in the Sleep Disorders Centre. The participant was then wired-up with the EEG, EOG, ECG electrodes. The skin beneath the electrode sites was abraded until an impedance of five kilo Ω was achieved; this is consistent with guidelines for PSG recordings (Leary, 2007). In addition, the signal quality was visually confirmed in the recording room before commencement of the study. Prior to beginning the HPT, the participant's subjective sleepiness was assessed before the experimenter left the room. The participants completed all of the HPT session alone in a noise proofed and temperature-controlled (23^{o}C) environment. All participants received standardised instructions (see Appendix A).

In order to ensure that all participants were familiar with how to complete the HPT, a five minute instructional video with two examples of 'typical' hazards was shown to all participants. Following the instructional video a two hour session of the HPT was completed. When this two hour pre break session was completed the experimenter re-entered the testing room, readministered the KSS, and informed the participant of whether they were to undertake a nap or an active rest break. At the conclusion of either break, the KSS was

readministered and the PSG signal quality was re-assessed and corrected if necessary. Following this, the participants then completed the final one-hour session of the HPT. Upon completion of the final third hour of the HPT, the experimenter re-entered the testing room and administered the KSS for the last time, then the PSG electrodes were removed.

During the testing sessions, the participants were not aware of the duration of the pre and post break sessions. In addition, participants were not informed of which experimental condition they were partaking in prior to their first testing session. After completing the first testing session the participant completed the remaining experimental condition a minimum of a week later. Figure 3 shows the testing session timeline.

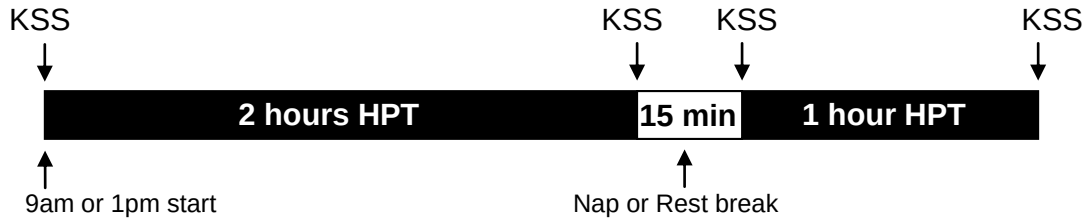

Figure 3. Timeline of the study protocol.

RESULTS

MANIPULATION CHECK

Sleep prior to testing. The amount of sleep achieved before the testing sessions was assessed. Table 2 shows the participants' mean sleep duration as assessed by the sleep diaries and the Actigraphs. It was found that the duration of sleep reported in the sleep diaries did not significantly differ between the two testing sessions, $t(19) = 1.37$, $p = .186$. This result was confirmed by the Actigraphic data, $t(17) = -1.41$, $p = .176$[1]. Therefore, the participants' estimated need for sleep was considered to be equivalent across testing sessions.

Subjective sleepiness. To assess whether the 05:00 wake-up on the testing days induced any subjective daytime sleepiness in the participants, the means of the KSS prior to testing were inspected. Mean KSS before the nap testing sessions ($M = 5.45$, $SE = .34$) did not differ significantly from the active rest testing sessions ($M = 4.75$, $SE = .40$), $t(19) = 1.41$, $p = .176$.

Hazard perception reliability. The internal consistency of the two versions of the Hazard Perception test was evaluated with the Cronbach's alpha statistic. It was found that the reliability was adequate for both Test 1 and Test 2 (.78 and .83 respectively).

Table 2. Mean Amount of Hours of Sleep before the Two Testing Sessions for the Sleep Diary and Actigraphic Data

	Sleep diary data			Actigraph data		
Testing session	*n*	*M*	*SE*	*n*	*M*	*SE*
Hours of sleep before 1st session	20	6.35	0.159	20	6.15	0.151
Hours of sleep before 2nd session	20	6.075	0.192	18[a]	6.403	0.181

[a] Two participants' Actigraphs failed to record their rest/activity patterns for the second week of testing.

TESTS OF HYPOTHESES

To examine the relative benefit of each nap type for reducing EEG signs of sleepiness in the hour post-break, a pair of paired samples *t*-tests were performed for the theta and alpha power levels. The paired samples *t*-test performed on the EEG theta power levels revealed that the post-nap break ($M = 12.159$, $SE = .418$) EEG theta power levels were significantly lower than the post-active rest break levels ($M = 13.057$, $SE = .573$), $t(19) = -2.416$, $p = .026$. Similarly, the EEG alpha power levels were significantly lower for the nap break ($M = 11.223$, $SE = .73$) than the active rest break levels ($M = 12.426$, $SE = 1.11$), $t(19) = -2.251$, $p = .036$.

To determine which break was more beneficial for maintaining hazard perception performance, a paired *t*-test was carried out on the change in hazard perception response latency between pre- and post-intervention. There was no significant effect of type of break on hazard perception response time, $M_{nap} = -.770$ s (i.e., participants' mean response time to hazards was .8 seconds slower following the intervention), $SE_{nap} = .174$ s, $M_{rest} = -.775$ s, $SE_{rest} = .121$ s, $t(1,19) = .02$, $p = .985$. Note that the same outcome was obtained when the data were analysed as a between-subjects design for each session separately, with post-intervention scores as the dependent variable and pre-intervention scores as a covariate, $F(1,17) = .41$, $p = .529$ (Session 1); $F(1,17) = .35$, $p = .563$ (Session 2). Note that the same analyses were carried out using hazard perception hit rates (the proportion of hazards

[1] Two participants' Actigraphs failed to record their rest/activity patterns for the second week of testing, hence the lowered degrees of freedom.

responded to in each test) as the dependent variables instead of response times and the same pattern of results was observed. That is, there was no significant effect of type of break on hazard perception hit rate, M_{nap} = 9.60% (i.e. participants' responded to 10% fewer of the hazards following the intervention), SE_{nap} = 2.77%, M_{rest} = 8.85%, SE_{rest} = 3.05%, $t(1,19)$ = .19, p = .849 (repeated measures analysis), $F(1,17)$ = .80, p = .382 (Session 1 between-subjects analysis), $F(1,17)$ = 1.36, p = .260 (Session 2 between-subjects analysis).

The subjective sleepiness data revealed no significant difference between nap break (M = 4.6, SE = .343.) and the active rest break (M = 5.0, SE = .465), $t(19)$ = -0.914, p = .372.

NAP AND REST BREAK DATA

Nap break polysomnography data. Complete EEG data was obtained for all participants during the nap break. This data was scored for sleep onset latency, duration, and sleep stages according to Rechtschaffen & Kales (1968) rules for sleep staging and can be found in Table 3. It should 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.

Table 3. Nap Break Sleep Staging Data

		Sleep time (% of total)				
SOL (*SD*)	Duration (*SD*)	Stage 1	Stage 2	Stage 3	Stage 4	REM
10.042 (3.026)	4.958 (3.026)	90.168	8.516	0	0	1.316

Note. Table only includes 12 participants data as scored by Rechtschaffen & Kales (1968) rules for sleep staging. SOL = Sleep onset latency (min); REM = Rapid Eye Movement.

Active rest break data. The mean distance in metres the participants walked during the active rest break was 831.55 metres (SD = 99.14; range = 669-1065). Participants' mean heart rate after the rest break (M = 75.6, SE = 2.74) was significantly higher than the mean heart rate prior to the rest break (M = 66, SE = 2.036), $t(19)$ = -6.05, $p < .001$. The duration of the rest break lasted for approximately 16 minutes (M = 960.3 sec, SD = 74.1 sec; range = 887-1223 sec).

DISCUSSION

The aim of the study was to compare the effectiveness of nap and active rest breaks with partially sleep deprived young adults. The study utilised several convergent measures previously found to be sensitive to changes in sleepiness levels. All three measures showed an increase in sleepiness levels across the first two hours of simulated driving.

PHYSIOLOGICAL EFFECTS

The physiological data indicated that the power in EEG theta and alpha bands was lower for the nap condition than for the active rest break condition during the last 30 minutes of testing. This finding is consistent with the stated hypothesis. The time asleep during the nap differed considerably between the participants; with some participants asleep for a relatively short amount of time when compared to other participants (and some not achieving sleep at all). A dose-response relationship with the duration of napping and the potential alerting effects from a nap has been reported in previous work (Brooks & Lack, 2006). It is possible that the magnitude of improvement in alertness could have been greater if all participants received the same 'nap-dose'. The issue of 'nap-ability' is addressed below.

SUBJECTIVE EFFECTS

There was no difference in subjective sleepiness between the nap condition and the active rest condition by the end of the test session. This was contrary to the expectation that the nap break would result in less sleepiness. Improvement in subjective sleepiness after the active break was not congruent with physiological data, which revealed no benefit from the active rest break. While the active rest break may have had a genuine effect for reducing subjective sleepiness, there are other potential explanations for this finding. The current study procedures 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, Åkerstedt, 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). This relief is analogous to mental stimulation, which has been noted by Johns (1993; 1998) as a mechanism that can reduce sleepiness. These social factors may be reflected in the reduced subjective sleepiness ratings.

HAZARD PERCEPTION EFFECTS

A novel feature of this study was the use of the hazard perception test as the simulated driving paradigm. While the hazard perception test has been previously found to be sensitive to sleepiness levels (e.g., Smith *et al.*, 2009a), the task has never been used to assess the effectiveness of sleepiness countermeasures.

It was found that there was no difference in hazard perception performance between the nap break and the active rest break across the hour after the break. This suggests that lower order differences found between the two conditions did not appear to manifest in hazard perception performance, which is considered a high-order cognitive task (Horswill & McKenna, 2004). Previous studies have shown an improvement after a rest break for low-order cognitive tasks (e.g., PVT; Caldwell *et al.*, 2003; WAVT; Horne & Foster, 1996) in contrast to high-order cognitive tasks which have not resulted in any improvement (e.g., LeDuc *et al.*, 2000) or a

transient improvement (15 minutes) in performance (e.g., Sallinen *et al.*, 2008). It should be noted however that it is still possible that short term effects on hazard perception might be present but could not be detected in the present study (the post-intervention test was an hour long and performance measures were averaged over this hour, which may mean shorter term effects might be concealed). Conversely, it has also been proposed that the recuperative benefits of a nap emerge slowly upon awakening (Carskadon & Dement, 1982; Lumley, Roehrs, Zorick, Lamphere, & Roth, 1986). For example, Brooks and Lack (2006) found improvement in cognitive performance after sleep deprivation emerged some 35 to 95 minutes after a nap. The issue of time-course of benefit, and differential impact on higher and lower-order cognitive skills requires further investigation. Future work could involve using shorter duration tests (e.g. presenting all measured hazards within a shorter space of time after the intervention rather than spreading them out over an hour), or could involve careful evaluation of variation in performance over time.

NAP AND ACTIVE REST BREAKS AND ROAD SAFETY

The nap break was the only countermeasure to provide a meaningful reduction in both physiological sleepiness and subjective sleepiness. In contrast, the active rest break had no effect for reducing physiological sleepiness but paradoxically reduced subjective sleepiness. When considering all the trends from the three measures (i.e., EEG, HPT, subjective sleepiness) sources together, the effects from a nap break appears to have benefit over an active rest break.

The apparent discrepancy between the active rest break physiological and subjective indicators of sleepiness may be important for safety. A decrease in subjective sleepiness immediately after the active 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 (e.g., Kaplan, Itoi, & Dement, 2007).

It must be noted that the modality of the type of rest breaks may have a benefit for drivers. In this study an active rest break was examined. Other factors such as the consumption of energy drinks (Reyner & Horne, 2002), caffeine (Horne & Reyner, 1996), and food (Lisper & Eriksson, 1980; Reyner, Wells, Mortlock, & Horne, 2012) could affect the effectiveness of a rest break. Our data support a benefit for a nap break over an active rest break; however, the magnitude of benefit of either break type over no break at all remains to be determined.

ON-ROAD IMPLEMENTATION ISSUES

In the current sample it was discovered that only a proportion (60%) of the sample was able to fall asleep during the nap break opportunity. This result is consistent with previous studies (e.g., Horne & Reyner, 1996; Leger *et al.*, 2009; Purnell *et al.*, 2002). However, this finding raises concerns about the use of a nap break as a driver sleepiness countermeasure; as drivers who do not fall asleep cannot receive benefits from the nap.

The current study allowed 15 minutes for the nap break. This may not be enough time for some individuals to fall asleep, even when sleepy, given that the process of sleep onset proceeds at different rates for each individual (Åkerstedt & Gillberg, 1990). Another limiting factor for falling asleep could have been the seated position in which participants were asked to take the nap opportunity. Sleep onset latency has been found to be shorter for positions that are closer to supine than sitting upright (Hayashi & Abe, 2008; Nicholson & Stone, 1987).

Increased sleep inertia associated with increased nap duration is a potential danger. If an individual allows an extra 10 to 15 minutes to fall asleep, but falls asleep much more quickly (e.g., 5 minutes) the longer time spent asleep increases the likelihood of sleep inertia appearing upon awakening. While the effects of sleep inertia are transient, cognitive performance impairments from sleep inertia can be as great as the impairments seen after a night of complete sleep deprivation (Wertz, Ronda, Czeisler, & Wright, 2006). The level of impairment after complete sleep deprivation (i.e., > 24 hours) have been equated to blood alcohol intoxication levels of 0.1% (Williamson & Feyer, 2000). Consequently, education campaigns that recommend the use of nap break, should advise drivers about possible sleep inertia effects.

LIMITATIONS

The methodology of the current study did not include a treatment-as-usual condition (i.e., continue driving with no break). Such a condition could have provided evidence for magnitude of effectiveness of both break types relative to no break. The best 'dose' of a break, its timing and duration could not be determined in a single study.

In summary, this study examined whether a nap or an active rest break was more beneficial for reducing sleepiness. The nap break was more effective for reducing physiological sleepiness. However, there was no subjective difference between the two break types and no difference in hazard perception performance. The disparity between physiological and subjective measures for the active rest may leave drivers with an erroneous belief about their sleepiness levels.

STUDY TWO: SELF-REGULATION OF THE NEED FOR A BREAK

The ability, or inability, of a driver to detect increasing sleepiness is a factor in sleep-related crashes. A number of technological solutions designed to detect sleepiness have been developed, but self-awareness of increasing sleepiness remains a critical component in on-road strategies for mitigating this risk. In order to take appropriate action when sleepy, drivers' perceptions of their level of sleepiness must be accurate. As such, it is important to understand driver's awareness of increasing levels of sleepiness – their ability to self-regulate.

The 'Stop, Revive, Survive' campaign recommends that drivers take a 15 minute break for every two hours of driving or when they feel they need to take a break (Department of Transport and Main Roads, 2008). However, several studies have shown that drivers may not be able to make accurate decisions regarding their level of sleepiness (Reyner & Horne, 1998b). For example, although drivers report being able to drive for up to 5.4 hours before reporting subjective sleepiness (McCartt, Ribner, Pack, & Hammer, 1996), up to one third of drivers have fallen asleep at the wheel during trip durations of less than one hour (Pennay, 2008). Additionally, approximately 60% of drivers continue to drive even when they are feeling sleepy or fatigued (Vanlaar *et al.*, 2008). These reports may suggest a significant gap between perception of sleepiness, driving behaviours, and the requirements for safe driving.

The perceptions of actual sleepiness levels of younger drivers may be erroneous. Younger drivers will drive significantly longer distances than older drivers before stopping for a break (Philip, Taillard, Quera-Salva, Bioulac, & Åkerstedt, 1999). In addition, younger drivers will frequently drive during times of high levels of sleepiness (Smith, Carrington, & Trinder, 2005). Such behaviours could be expected from an under-recognition of sleepiness signs (e.g., Kaplan *et al.*, 2007) and/or an under-appreciation of the dangers of a sleep-related crash (e.g., Reyner & Horne, 1998b).

A number of studies have found that perceptions of sleepiness (i.e., subjective sleepiness) have significant and positive relationships with physiological measures (e.g., Dorrian *et al*., 2000; Kaida *et al*., 2006). Additionally, subjective ratings of sleepiness have been found to have a positive relationship with simulated driving incidents (Reyner & Horne, 1998b) as well as predicted sleepiness levels and on-road sleep-related crashes (Åkerstedt, Connor *et al*., 2008). However, other studies have found inconsistent relationship between subjective ratings and physiological measures (e.g., Biggs *et al.*, 2007; Hoch *et al.*, 1992; Tremaine *et al*., 2010). These inconsistencies between the two measures are possibly due to individuals having a limited awareness of the physical sleepiness signs such as droopy eyelids, increased blinking, wandering thoughts, increased body posture movements (e.g., Kaplan *et al.*, 2007). Sleepiness also impairs cognitive functioning and it is possible that this too can affect self-awareness of sleepiness levels.

Another factor that could influence the likelihood of perceiving sleepiness is the intrinsic circadian rhythm of an individual. The circadian rhythm of an individual has a sinusoid function during a 24 hour period, which results in low sleep propensity during the day (i.e., ascending phase) and the highest sleep propensity typically during night-time hours (i.e., descending phase) (Richardson, Carskadon, Orav, & Dement, 1982). The descending phase of the circadian rhythm typically begins in the afternoon and is characterised as the post-lunch dip in circadian function (Carskadon & Dement, 1992). As such, the descending circadian phase could lead to higher sleepiness levels in the afternoon.

Determining capacity to accurately identify sleepiness and then to self-regulate driving cessation is necessary for reducing sleep-related crashes. This study aimed to assess capacity to accurately identify sleepiness and self-regulate driving cessation during a validated driving simulator task.

METHOD

DESIGN

An experimental design was utilised for the current study. Participants were randomly assigned to complete the testing during a morning session (i.e., 09:00 start) or an afternoon session (i.e., 14:00 start).

PARTICIPANTS

The same inclusion criteria, exclusion criteria and screening procedure as utilised in study one was also used for the current study (see Study one Method section).

In total, 26 participants (19 females and 7 males) completed the study. The participants had a mean age of 24 years (*SD* = 2; range = 20-28). Participants reported an average vehicle licensure of six years (*SD* = 2.46; range = 2-10). Additionally, the sample reported having driven an average of 14,028.01 kilometres per year over the last three years (*SD* = 14,028.01; range = 1,040-70,000). Altogether, six participants reported having a crash (i.e., where they were the driver and there was damage to property or persons) in the last three years. All participants were paid $100 AUD for partaking in the study.

MATERIALS

The measures utilised for the current study were similar to the measures used for study one. Specifically, the Pittsburgh Sleep Quality Index (PSQI; Buysse *et al.*, 1989) and the Epworth Sleepiness Scale (ESS; Johns, 1991) were used as screening measures. Physiological and subjective sleepiness levels were measured via polysomnography and the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) respectively. The driving stimuli for this study were the hazard perception tests. Due to the varying durations of the driving task the hazard perception data were not treated as dependent variables in this study. See Study one materials section for the descriptions of the measures.

PROCEDURE

A recruitment email was sent via the QUT intranet and was posted on various QUT online notice boards inviting participants to take part in the current study. The recruitment email explained the inclusion and exclusion criteria and gave a concise description of the experimental procedure. Those participants that wished to take part in the study were asked to sign a written consent form. Participants were instructed to wake up at 5am on the day of testing and they were also instructed not to ingest any form of caffeine or alcohol until after the testing session had been completed.

On the day of testing, the participant was met by the experimenter at the QUT's Kelvin Grove campus. EEG, EOG, and ECG electrodes were then attached to the participant as per the protocol outlined in Study 1. Prior to beginning the HPT, the participant's subjective sleepiness was assessed with the KSS. All participants were verbally instructed to, "Stop

when you think you *would be* too sleepy to drive safely on the road". After receiving this instruction the participants began the HPT.

When the participants chose to end the HPT session, they spoke into a microphone to let the experimenter know they wished to take a break. The duration of time that had elapsed for the HPT was noted by the experimenter. The experimenter then entered the testing room administered the KSS and instructed the participants that they now had an opportunity to nap. During this nap opportunity the participants were asked to remain in their chair with their eyes closed. After thirty minutes the experimenter re-entered the testing room, re-administered the KKS for the last time and removed the electrodes. The participants completed the hazard perception testing session and the nap opportunity alone in the noise- and temperature-controlled environment. All time cues were removed from the testing room.

DATA ACQUISITION

Physiological recordings. The EEG recordings during the HPT were visually inspected for signs of sleep and micro sleeps by an experienced polysomnographer. In addition, the EEG nap data was scored for its sleep stages according to the Rechtschaffen and Kales (1968) criteria. The C3-A2 paring of electrodes was utilised for the scoring of sleep stages.

RESULTS

MANIPULATION CHECK

Subjective sleepiness. To assess whether the 05:00 wake-up on the testing day induced any subjective daytime sleepiness in the participants, the means of the KSS prior to testing were inspected. The mean KSS at the beginning of testing was 6.65 (*SE* = .135), where the relevant points on the KSS scale were labelled as "some signs of sleepiness" (= 6) and "sleepy, no effort to stay awake" (=7). This level of KSS suggests that the sample was experiencing a degree of sleepiness prior to beginning the simulated drive.

Increasing levels of sleepiness. A paired samples *t*-test was performed to determine if the subjective sleepiness levels increased from the beginning of testing to the time immediately prior to the break. The paired samples *t*-test revealed that subjective sleepiness levels increased from the beginning of testing (*M* = 6.65, *SE* = .135) to prior to the break (*M* = 8.15, *SE* = .464), $t(25) = -11.802$, $p < .001$.

SELF-REGULATION OF SLEEPINESS LEVELS

It was found that on average participants stopped the task after approximately 40 minutes (*M* = 38.346, *SD* = 18.385, range = 15-76). To determine if the duration was mediated by any circadian effects an independent samples *t*-test was performed. It was found that equal variances could not be assumed across the groups, $F(1, 24) = 4.289$, $p = .049$. With unequal variances accounted for, it was found that there was no significant difference between the morning duration (*M* = 36.462, *SE* = 4.049) and afternoon duration (*M* = 40.231, *SE* = 6.098), $t(20.859) = -0.515$, $p = .612$.

Inspection of the EEG data revealed that no participant could be judged to have fallen asleep by standard criteria (i.e. more than 30 seconds of continuous Stage 1 sleep) before stopping for a break. However, three of the 26 participants did display high levels of sleepiness (e.g., head nodding, micro sleeps of greater than 3 seconds of EEG Theta activity). These three participants requested their breaks on average 12.333 minutes (*SD* = 2.517, range = 10-15) following these microsleep events. At the end of testing two of the three participants reported that they believed they had fallen asleep during the task, with the other participant being unsure if they had fallen asleep.

THIRTY MINUTE NAP BREAK DATA

Nap break polysomnography data. Complete EEG data was obtained for all participants during the nap break. This data was scored for sleep onset latency, duration, and sleep stages according to Rechtschaffen & Kales (1968) rules for sleep staging and can be found in Table 4. Data for the 23 of 26 participants who were determined to have fallen asleep during the nap opportunity is reported in the table.

Table 4. Sleep Staging Data for the Thirty Minute Nap Break.

		Sleep time (% of total)				
SOL (*SD*)	Duration (*SD*)	Stage 1	Stage 2	Stage 3	Stage 4	REM
9.90 (7.531)	15.09 (8.11)	24.33	67.39	6.80	1.48	0

Note. Table only includes 23 participants data as scored by Rechtschaffen & Kales (1968) rules for sleep staging. SOL = Sleep onset latency (min); REM = Rapid Eye Movement.

DISCUSSION

The aim of the current study was to determine how effectively drivers could identify their sleepiness levels and self-regulate their need to stop for a break. The results suggested that the sample subjectively experienced high levels of sleepiness during the testing sessions, and all requested a break within 76 minutes of driving. The majority of participants were then able to fall asleep during the nap break.

EFFECTS OF AWARENESS LEVELS OF SLEEPINESS

The key finding from this study is that all of the participants decided to cease driving and take a break from the driving task. A number of studies describe that drivers have a reasonable ability to judge their sleepiness levels (e.g., Kaplan *et al.*, 2007; Reyner & Horne, 1998b); yet, it is also noted in the literature that there are individual differences regarding the accuracy of determining sleepiness level. In addition, the transition from low levels of sleepiness to high levels of sleepiness and finally into sleep is a subtle progression, and the awareness of these varying levels is also likely to vary between individuals (Bonnet & Moore, 1982). Consistent with this we found that some participant's EEG data suggested brief sleep episodes (i.e., microsleeps) prior to driving cessation. These behaviours could possibly be attributed to under-recognition of sleepiness signs and/or an under-appreciation of the progression of high sleepiness to falling asleep.

All participants ceased driving before two hours had elapsed, with the longest duration being 76 minutes. The duration of driving that the 'Stop, Revive, Survive' campaign recommends drivers attempt before taking a break is two hours of driving or when they feel they need to take a break (Department of Transport and Main Roads, 2008). The recommendation for the maximum duration of continuous driving for professional drivers is greater than that for non-professional drivers. Our data suggests that drivers can experience very significant levels of sleepiness well within this time-based recommendation. Participants reported a high level of subjective sleepiness after a relatively moderate level of sleep restriction provided by early wake time that morning. Similar levels of sleep restriction are commonplace for many people in modern society (National Sleep Foundation, 2008). It has also been reported the younger divers obtain fewer hours of sleep (i.e., obtain a sleep debt) the night before a long drive (Philip *et al.*, 1996). It is possible that the simulated environment *per se* could have contributed to the relatively short duration of completion of the task in the current study. Laboratory conditions have been noted to invoke lower arousal levels than those experienced during on-road conditions (Philip *et al.*, 2005). Future studies incorporating on-road driving paradigms are required to examine this issue.

REPORT CONCLUSION

Driver sleepiness contributes substantially to road death and trauma. The proportion of fatal and severe crashes attributed to driver sleepiness is estimated to be approximately 20% (Connor *et al.*, 2002). Effective countermeasures to reduce driver sleepiness are critical to reducing this risk factor.

The current studies have several theoretical and practical implications. The first key finding was that a nap break provided meaningful benefit for reducing driver sleepiness compared with an active rest break (although hazard perception performance changes were similar for both interventions). The second key finding was that drivers displayed a capacity to perceive increasing sleepiness and self-regulate their behaviour to take a break.

We propose a number of potential future directions for research in this area:

1. The modality of interventions (including use of caffeine and other alerting interventions) should be directly compared for efficacy.
2. The relative efficacy of different timing and doses of interventions should be investigated.
3. Intervention effectiveness should be investigated in the context of driving demands, prior sleep schedules, driver experience and other individual factors.
4. The effects of context and message content of road safety recommendations and media campaigns on self-regulation should be considered.

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APPENDIX A

Script for the Nap Break Condition

Instructions before Test (after PSG hook-up)

"An instructional video will play before the HP Task. When it is finished the HP task will begin when you click ok. Please don't touch the keyboard while the test is running as you only need to use the mouse. Please try to keep your hand on the mouse at all times. I would ask you not to eat during the task. When it is time I will let you take a break from the task. Do you have any further questions?"

"Right now how sleepy are you feeling?" (KSS)

HPT: BLOCK 1 (2 hours)

NAP BREAK OPPORTUNITY

Knock on the door, walk into the room

"Right now how sleepy are you feeling?" (KSS)

"Now I am going to ask you to remain in the chair as you now have an opportunity to nap. The nap opportunity will last for a short amount of time. During this nap opportunity please remain in the chair with your eyes closed the whole time. I will come back when it is time to restart the task"

Walk out of the room and come back in 15 minutes

"Right now how sleepy are you feeling?" (KSS)

"Okay it is now time to re-start the task"

HPT: BLOCK 2 (1 hours)

"Right now how sleepy are you feeling?" (KSS)

Give the Nap break version of the post experiment questionnaire

Script for the Rest Break Condition

Instructions before Test (after PSG hook-up)

"An instructional video will play before the HP Task. When it is finished the HP task will begin when you click ok. Please don't touch the keyboard while the test is running as you only need to use the mouse. Please try to keep your hand on the mouse at all times. I would ask you not to eat during the task. When it is time I will let you take a break from the task. Do you have any further questions?"

"Right now how sleepy are you feeling?" (KSS)

HPT: BLOCK 1 (2 hours)

REST BREAK OPPORTUNITY

Knock on the door, walk into the room

"Right now how sleepy are you feeling?" (KSS)

"Now I am going to let you take a rest break. The rest break will last for a short amount of time. During this rest break you will be asked to complete the ten minute walk test, which involves walking a 20 metre track for ten minutes."

Walk with individual to the walk track.

"Shall we head back to the testing room?"

"Right now how sleepy are you feeling?" (KSS)

"Okay it is now time to re-start the task"

HPT: BLOCK 2 (1 hours)

"Right now how sleepy are you feeling?" (KSS)

Give the Rest break version of the post experiment questionnaire