Sleep and Driving in Young Adults

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Abstract

Sleepiness is a significant contributor to car crashes and sleepiness related crashes have higher mortality and morbidity than other crashes. Young adult drivers are at particular risk for sleepiness related car crashes. It has been suggested that this is because young adults are typically sleepier than older adults because of chronic sleep loss, and more often drive at times of increased risk of acute sleepiness. This project aimed to determine the relationship between sleep and driving patterns in young adult drivers. Three estimates of the risk of driving while sleepy were calculated from the data: 1) a model incorporating known circadian and sleep factors influencing sleepiness, 2) time-of-day accident statistics; and 3) self-reported sleepiness. Attitudes and behaviours toward driving and sleep were also assessed. Results from each model suggested that young drivers frequently drive while at risk of crashing, at times of predicted sleepiness and at times they felt themselves to be sleepy. The results of this study will help preventative programs to specifically target factors leading to increased sleepiness when driving.

Keywords

Sleepiness, Fatigue, Young drivers, Crash, Risk exposure, Driving, Young adults, Attitudes, Behaviour

NOTES:
(1) FORS Research reports are disseminated in the interests of information exchange.
(2) The views expressed are those of the author(s) and do not necessarily represent those of the Commonwealth Government.

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EXECUTIVE SUMMARY

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INTRODUCTION

Sleepiness[1] is a significant contributor to crashes[2]. Sleepiness has been identified as a major risk factor in motor vehicle accidents (NTSB, 1990,1995; Horne & Reyner, 1995a,1995b; Phillip, Taillard, Quera-Salva, Bioulac & Åkerstedt, 1999). However, the estimated proportion of automobile crashes caused by sleepiness varies considerably. A meta-analysis of reported crash statistics by Lyznicki, Doege, Davis and Williams (1998) suggested sleepiness as a causative factor in 3% of all motor vehicle crashes in the U.S. However, most recent commentary suggests that that these figures are underestimated (Åkerstedt, 2000). For example, the proportion of all highway vehicle accidents related to sleepiness in Italy has been estimated as 22% (Garbarino, Nobili, Beelke, Phy & Ferrillo, 20001), while the contribution of sleepiness to accidents occurring at night has been estimated as18.6% in a Norwegian sample (Sagberg, 1999). Horne and Reyner (1995b) estimate that sleepiness was a contributing factor to between 16 and 23% of all accidents in the U.K. A consensus statement on the contribution of sleepiness to transport accidents (Åkerstedt, 2000) identified sleepiness as '*the largest identifiable and preventable cause of accidents in transport operations (between 15 and 20% of all accidents), surpassing that of drug or alcohol related incidents in all modes of transportation*', including non-commercial transportation. Further, sleepiness related crashes are likely to be more severe than other crashes and are more often fatal (Haworth et al., 1988; Horne & Reyner, 1995b).

Young adults crash more than older drivers and more of their crashes are related to sleepiness. Young adults (aged 15-24) make up 15% of the Australian population but account for 31% of crash fatalities (Triggs & Smith, 1996). Similarly, the 16-20 age group makes up 7% of the U.S. population, but accounts for 14% of all motor vehicle

[1] Used as the reciprocal of alertness, but not strictly interchangeable with fatigue. Fatigue refers to processes such as bodily feelings of energy depletion and muscular aches and pains, while sleepiness reflects an individual's propensity for sleep.
[2] Used interchangeably with motor vehicle accident

crash fatalities. Further, motor vehicle crashes are the leading cause of death in this age group in the U.S. (NCSCR/NHTSA, 1999.)

Younger drivers are at particular risk for sleepiness-related crashes. Young adults are more likely to be involved in fall-asleep crashes than older drivers, and account for almost two-thirds of sleepiness related crashes (Horne & Reyner, 1995b; Maycock, 1996). Drivers younger than 30 years are four times more likely to have sleepiness related crashes than drivers aged over 30 (Knipling & Wang, 1994), while Pack, Pack, Rodgmen et al., (1995) identified the peak age of occurrence in sleepiness related crashes as 20 years, with 55% of all sleepiness related crashes occurring in individual aged 25 years or less. Finally, Lyznicki, Doege and Williams (1998) estimated that most sleepiness related crashes involve non-commercial traffic (96%), rather than commercial transport, and identified youth as a particular risk factor for sleepiness-related crashes.

Sleepiness leads to crashes because of predictable impairments in skills required for safe driving. Sleepiness is characterised by diminished alertness (e.g. Carskadon & Dement, 1979; Harma et al., 1998), and diminished cognitive performance (Thomas, Sing, Belenky et al., 2000). Not only is performance impaired on measures of reaction time, vigilance and attention (e.g. Dinges & Kribbs 1991; Kribbs & Dinges 1994; Dinges, 1995; Horne, 1998a; Gillberg & Åkerstedt 1998), but also on more complex measures of decision making and judgment (e.g. Harrison & Horne, 1999). These performance skills are essential for operating a motor vehicle safely (Dinges, 1995).

A relatively small degree of sleep loss can lead to significant impairment of performance. Lamond and Dawson (1999) reported performance impairment on a range of tasks assessing neurobehavioural function after approximately 17 hours of wakefulness. Significantly, they reported that the performance impairments on these tasks after 20 hours of wakefulness were equivalent to those observed at a blood alcohol concentration of 0.10%. Arendt, Wilde, Munt and McLean (2001) also found the ability to maintain speed and road position on a driving simulator is significantly impaired when the awake period is prolonged by 3 hours. The magnitude of the decrements were similar to those found at, and above, the legal limits of alcohol consumption (0.05%). Similar levels of decrement in driving performance have been reported by Powell, Schnechtman, Riley, Li, Troell and Guilleminault (2001). These studies indicate that moderate levels of sleepiness can significantly impair the ability to drive safely, even before the individual actually falls asleep.

The timing of crashes related to sleepiness is predictable. Time of day is a strong influence on driver sleepiness and subsequent crash risk. Crashes attributed to the driver having fallen asleep occur primarily in the hours from midnight to 7.00 a.m., and during the mid-afternoon. These are periods during the 24 hour day/night cycle of increased sleepiness (Pack, Pack, Rodgmen, Cucchiara, Dinges & Schwab, 1995). However, sleepiness while driving is much greater during the night than during the day, with drowsiness peaking in the hours from late evening until dawn. The increased risk of sleepiness related crash during the nighttime hours is particularly evident among younger drivers. In comparison, drivers aged over 45 have fewer nighttime crashes, while drivers aged older than 65 are most likely to have sleepiness related crashes during the mid-afternoon (Pack et al., 1995; Wang, Knipling, Goodman, 1996).

The time of day distribution of crash occurrence is likely to reflect biological sleep propensity in addition to demographic related driving patterns. Models of sleep-wake regulation incorporate an interaction between circadian and sleep homeostatic factors. (Borbély, 1982: Daan & Beersma, 1984). The two-process model of sleep regulation (Borbély & Achermann, 1999) describes this interaction. The first component of this model is a homeostatic process. Homeostasis refers to a biological need for sleep that rises during wake (increasing sleepiness), and falls during sleep (decreasing sleepiness). The second component is a circadian process. The circadian pacemaker is a clock-like mechanism with a cycle of approximately 24 hours. It functions to regulate periods of increased and decreased sleep propensity, largely independent of the homeostatic need for sleep. The two-process model suggests that homeostatic factors (increased by chronic and acute sleep loss) and circadian factors (time of day of driving episodes) determine sleepiness at a given point in the day.

Young adults are sleepier than older drivers when driving because of chronic sleepiness and the time of day of driving episodes. Young drivers are more likely to experience sleepiness, and are also more likely to be driving at times of increased sleepiness (Horne & Reyner, 1995a). Philip et al (1999) evaluated the degree of sleep deprivation experienced by French drivers. They found that being young was a factor significantly associated with sleep debt. Specifically, young drivers reported that they restricted their sleep in the previous 24 hours to a greater extent than older drivers.

Young adults are sleepy due to chronic predisposing factors, and to acute factors. Factors contributing to increased chronic sleepiness in this age group identified by Caskadon (1990) include maturational changes that increase the need for sleep, changes in sleep patterns that reduce nighttime sleep or lead to circadian disruptions and cultural and lifestyle factors leading to insufficient sleep. These lifestyle factors reflect the demands of schoolwork, part-time jobs, extracurricular activities; and late-night socializing. Specific behavioural factors, such as driving between midnight and 6 a.m., are more common in this age group and further increase their exposure to driving while sleepy (Carskadon, 1990). Thus, young drivers have both an increased homeostatic drive to sleep, and an increased chance of driving when circadian drive to sleep is also high.

Sleepiness when driving can be predicted by models that incorporate sleep homeostasis and circadian components of sleepiness. Models of alertness and performance while awake have been developed from the earlier sleep regulation models (Folkard & Åkerstedt,1992; Achermann & Borbély, 1994; Czeisler et al., 1994; Jewett et al., 1996a, 1996b). For example, the subjective alertness model of Folkard and Åkerstedt (Åkerstedt & Folkard, 1987; Åkerstedt & Folkard, 1990; Folkard & Åkerstedt, 1992; Folkard, Åkerstedt, McDonald, Tucker & Spencer, 1999) involves a homeostatic component that rises during sleep and falls during wake (Process S) and a sinusoidal 24-h circadian component (Process C) and an additional component representing sleep inertia

(Process W). Alertness (sleepiness) at a particular time can be predicted by the arithmetic sum of these three processes

Sleep inertia refers to reduced levels of alertness observed upon awakening (Dinges et al 1981, Bonnet, 1993; Bonnet and Arand, 1995; Jewett et al., 1999c). Dinges (1990) suggested that sleep inertia lasts for 1-20 minutes. However, Jewett, Wyatt, Ritz-De Cecco et al. (1999) found that subjective alertness and cognitive throughput scores could be impaired for more than 2 hours after waking, even in subjects who were not sleep deprived and were sleeping at their habitual times. Ferrara and Gennaro (2000) suggest that cognitive tasks that require more attention seem to be much more affected by sleep inertia than simple motor ones, performance accuracy being more impaired than speed. Sleep inertia may therefore represent an important component of a model of sleepiness and driving.

The homeostatic component of these models (Process S) is determined by the amount of prior sleep, and increases with sleep loss. Sleep loss of 2-3 hours a night contributes to increased sleepiness across the day (Carskadon & Roth, 1991; Dinges et al., 1994). Further, sleep loss is cumulative and repeated sleep loss leads to 'sleep debt', exacerbating these effects (Carskadon & Roth, 1991; Dinges et al., 1994). Jewett and Kronauer (1999) have presented a recent modification of the three-process model. This model incorporates process S, process C and process W to provide estimates of subjective sleepiness and cognitive throughput. This model allows relative sleepiness at particular times of the day to be estimated. Specifically, this model allows the relative sleepiness experienced during a particular driving episode to be estimated.

In summary, car crashes are a major cause of death and injury in young drivers. Sleepiness contributes significantly to crashes. Young drivers are more sleepy while driving than older drivers and have more sleepiness-related crashes. Sleepiness during a specific driving episode can be predicted from models that incorporate time of day and sleep loss. Specifically, sleepiness, and the subsequent risk of crash, can be predicted in young drivers if both their sleep and their driving patterns are recorded. Exposure to risk of a sleepiness-related crash can then be calculated.

Sleepiness is a factor significantly increasing the risk of crash in young adult drivers. However, the particular interaction of sleep behaviours and driving patterns that leads to increased sleepiness while driving needs to be determined. Measuring sleep and driving patterns simultaneously across time provides a measure of sleepiness and crash risk that can be compared to the risk perceived by individual drivers. The beliefs and attitudes of young adult drivers toward sleepiness and driving risk also need to be assessed in conjunction with their actual sleep and driving patterns.

AIMS

The aim of this study was to estimate exposure to risk of crashes as a consequence of sleepiness in a young adult population. Actual sleep behaviours and driving patterns were assessed over a four-week period. Exposure to increased risk of sleepy driving was estimated using three methods. The first involved application of a sleepiness model based on time since awakening and circadian phase. The second was based on published crash statistics for this age group, and the third was based on self-reported sleepiness and perceived risk of crashes. The aim was to determine what proportion of driving episodes in young subjects would occur at times at which circadian phase and sleep deprivation lead to increased sleepiness.

METHOD

Sample

Young adult drivers were recruited from the general population via advertisement. The inclusion criterion for participation was age between 18 and 25 years, and ownership or unrestricted access to a vehicle. Participation was open to drivers with provisional driving licenses as well as those with unrestricted licenses. Participants were compensated for their time ($160 AUD).

A sample of 50 young adult drivers was recruited for participation. The mean age of participants was 21.4$\pm$1.6(SD), with a range of 18-25. 55% of the sample was female. 87.2% of the sample reported their relationship status as 'single', 12.8% 'married or cohabiting'. 83% of the sample was engaged in full-time or part-time study. Mean body mass index (BMI) of the sample was 23.6$\pm$3.2(SD).

Materials

Two sets of instruments were used. Initially a number of questionnaires were administered to characterise the participant's current driving habits and beliefs about driving, and to assess their current sleep habits and the presence of potential sleep disorders. The second set consisted of a sleep diary and driving diary which participants completed over a four-week period subsequent to the initial assessment.

Driving Habits

The Driver Attitude and Behaviour Questionnaire (DABQ, Mills, Hall, McDonald & Rolls 1998; adapted from Parker, Reason, Manstead & Stradling, 1995; Parker, Stradling & Manstead, 1996) was used to asses prior driving experience, beliefs about driving and crash risk, and self-reported driving behaviours. The DABQ consists of items assessing driver behaviours, and items assessing driver attitudes.

The driver behaviour questions record self-reported frequency of problematic driving behaviours. The driver attitudes questions record attitudes toward problematic driving behaviours. These behaviours include lapses, errors and violations. Lapses are defined as ‘absent minded behaviours with consequences for the perpetrator but pose no threat to other road users’. Errors are defined as ‘typically misjudgments and failures of observation that may be hazardous to others’, while violations were defined as ‘deliberate contraventions of safe driving practices’.

Sleep Habits

Four self-report measures of sleep and sleep disturbance were administered to participants. The particular questionnaires were selected because they have received wide usage, and assess a range of factors associated with sleep, including daytime consequences and psychological sequelae of disturbed sleep.

The Sleep Impairment Index (SII, Morin, 1994) is a self-report instrument that elicits the subject’s perception of the level of severity, distress and impairment of daytime functioning associated with his or her insomnia. The SII comprises five items assessing severity of sleep-onset, sleep maintenance and early morning awakening problems; satisfaction with current sleep patterns; interference with daily functioning; how noticeable impairment due to sleep problem appears; and level of distress caused by the sleep problem.

The Sleep-Wake Activity Inventory (SWAI, Rosenthal et al., 1993) is a 59 item self-report measure of sleepiness. It comprises 6 factors: excessive daytime sleepiness; psychic distress; social desirability; energy level; ability to relax; and nocturnal sleep. This inventory was designed specifically to identify excessive daytime sleepiness and has been validated against MSLT (Rosenthal et al. 1993).

The Sleep Disorders Questionnaire (SDQ, Douglass et al. 1994) is a 176-item questionnaire designed to assess the presence of common sleep disorders. It comprises four main factors: sleep apnea; narcolepsy; psychiatric sleep disturbance; and periodic limb movement disorders. The authors state that the questionnaire is designed for diagnosis rather than description of sleep disorders (an unpublished manual is available from the authors).

The Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS; Morin, 1994) is designed to assess sleep-related cognitions. It comprises five item types: misconceptions about the cause of insomnia; misattributions about the consequences of insomnia; unrealistic expectations about sleep; control and predictability of sleep; and mistaken beliefs about sleep promoting behaviours.

Continuous assessment of sleep and driving patterns

Subjects were asked to complete the Pittsburgh Sleep Diary (Monk, 1994) each morning during the study. Sleep parameters recorded in the diary included daily sleep-wake schedule (sleep time, wake time, sleep duration), napping, and levels of sleepiness upon waking.

Subjects were asked to record each driving episode, no matter how brief, each day in a driving diary. An example of the diary is shown in the appendix. The behaviours recorded in the driving diary included time of day of each episode, subjective sleepiness, and subjective risk of crash. In addition, subjects were asked to record additional risk factors including use of alcohol and other drugs or medications.

PROCEDURE

On responding to an advertisement, participants attended the sleep laboratory for briefing, completion of informed consent, initial assessment and distribution of sleep-driving diaries. The initial assessment comprised the intake questionnaires, which took from half an hour to an hour to complete. Participants were required to participate in weekly interviews to ensure compliance with the diary protocol and data integrity, and to return the diaries each week.

RESULTS

Data treatment

Sleep questionnaire data for the SDQ, DBAS, SII and SWAI were scored according to the instructions outlined by the respective authors (Rosenthal et al., 1993; Morin, 1994; Douglass et al., 1994). Sleep diaries and driving diaries were coded into a custom designed database for analysis. The SPSS computer package was used for statistical analyses.

Sleep Questionnaire data

Mean responses to the SDQ are depicted in Figure 1. All scores were regarded as valid. The data suggests that the participants were relatively free of indications of Sleep Apnea, Narcolepsy or PLMS. Further, few participants were above clinical cutoff values for these disorders. However, approximately half the sample had responses suggestive of difficulties initiating or maintaining sleep.

Consistent with this, the mean response to the 30-item DBAS was 37.2± 25.5(SD). Previous work has suggested that a cutoff of 34.9 has high sensitivity and specificity for insomnia in this age group (Smith & Trinder, 2001). Indeed, approximately half of this sample responded with a pattern of sleep complaints suggestive of insomnia using this cut-off value. However, the mean sample response to the SII was only 5.1± 3.1(SD), the SII cutoff score being 14 (Smith & Trinder, 2001). Mean responses to the SWAI are depicted in Figure 2. Mean EDS score in this sample would not lead to a classification of increased sleepiness (to the level of a sleep-disordered patient) using published criteria (Rosenthal, Roehrs & Roth, 1993). Therefore, while this sample reported a range of beliefs and attitudes about sleep that were 'dysfunctional', their overall ratings of the impact of sleep problems on their day to day functioning was low.

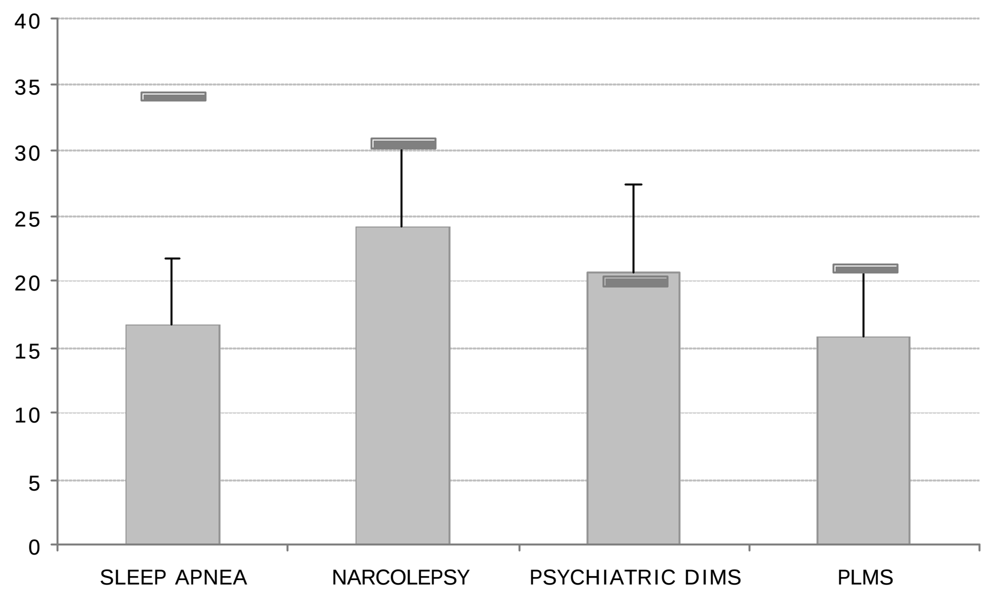

Figure 1. Mean SDQ scale scores for young adult sample. Error bars represent standard deviations. Dark bars represent suggested cut-off values for each scale.

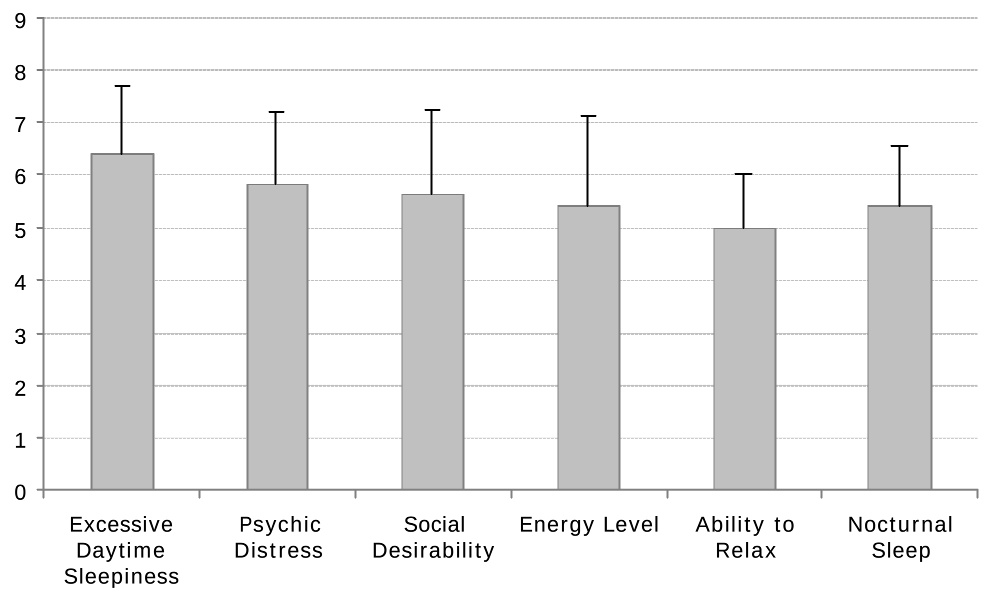

Figure 2. Mean SWAI scale scores for young adult sample. Error bars represent standard deviations.

Driver Attitude and Behaviour Questionnaire Data

Driving patterns

The majority of the sample (59.6%) owned the car they usually drove, 34% drove a car owned by their parents, and 6.3% drove a car owned by a friend or partner. 51% of sample had access to, and drove, vehicles other than the main vehicle. The mean number of years driving was 4.0± 2.3(SD), with 2.8± 2.0(SD) years since gaining their license. Estimated number of kilometres driven each week was 138.0 ±108.6(SD), with the estimated total number of kilometres driven being 25023± 30119(SD). The mean number of professional driving lessons before attaining their license was 10.2 (6.9)

Lapses, errors and violations

Mean scores for each of the original items relating to participant report of lapses, errors and violations in the DABQ are shown in Table 1. Also indicated in this table are the scores for equivalent items reported by previous investigators for Australian female drivers aged 19-24 years (Dobson, Brown & Ball, 1998; Dobson, Brown, Ball, Powers, & McFadden, 1999), and for U.K. males and females aged 17-40 years (Lawton, Parker, Stradling & Manstead, 1997). This data indicated higher mean frequency ratings for violations and lapses in this sample than reported in other samples of this approximate age group.

Subjects were also asked to what extent they agree or disagree with statements regarding attitudes toward cars and driving (Table 2), to rate to what extent health behaviours and personal values were true (Table 3), to rate how seriously they viewed particular behaviours (Table 4) and to rate the importance of behaviours that might cause road traffic accidents (Table 5).

Data from the DABQ suggests that the participants in this sample reported more violations and lapses than participants in previous studies. Particular items rated relatively highly were: disregarding speed limits at night; deliberately driving close behind slower drivers to encourage them to speed up; mistakenly taking the wrong exit from a roundabout: and, forgetting which gear you are in and having to check with your hand. The participants rated drink driving as a particular serious behaviour, and rated items regarding safe driving and wearing seatbelts more highly than items regarding risk taking. They rated 'driving when tired' as less serious than 'drink driving', 'driving too fast' and 'inattention' as a contributor to road accidents.

Table 1. Mean and Standard deviation for 'violation', 'lapse' and 'error' items on the DABQ scale: comparison with previous research data.

ITEM	Responses Mean±SD	Previous data (1)	Previous data (2)
Violations			
Deliberately disregard speed limits late at night	4.0±1.8	1.60±1.24	2.59±1.37
Take a chance and go through traffic lights that have just turned red when you could have stopped	0.0±0.0	0.48±0.73	1.63±0.86
Become impatient with a slow driver in an outer lane and overtake on the inside	2.7±1.3	1.48±1.19	2.05±1.16
Deliberately drive close behind a slow car to encourage them to speed up	3.5±3.2	1.14±1.18	1.75±1.00
Get involved in unofficial 'races' with other drivers	2.4±1.70	0.42±0.71	1.22±0.62
Drive when you realize you might be over the legal blood alcohol limit	2.1±1.4	0.32±0.62	1.16±0.52
Lapses			
Mistakenly take the wrong exit from a roundabout	3.9±1.7	0.57±.74	
Intend to switch on the windscreen wipers, but use the wrong switch or suchlike	3.0±1.3	0.77±.84	
Forget where you left the car in the car park	2.7±2.1	1.18±1.08	
Inadvertently get into the wrong lane at a junction	0.0±0.0	1.02±0.81	
Errors			
Forget which gear you are in and have to check with your hand	4.0±1.8		
Plan your route badly and drive further than was necessary	2.5±1.7		
Overtake in a situation which you realize is slightly risky	2.7±1.5		
Miss your motorway exit and have to make a lengthy detour	2.8±3.3		

Items rated from 1 (Never) to 7 (Nearly all the time)

(1) Dobson, Brown & Ball, 1998
(2) Lawton, Parker, Stradling & Manstead, 1997

Table 2. Mean (and SD) for 'health behaviours and personal values' items on the DABQ

ITEM	Mean±SD
I take regular exercise to stay fit	4.3±1.8
I have regular dental check ups	3.6±1.8
Regular drinking is bad for your health	4.1±1.7

Items rated from 1 (Not at all) to 7 (Completely)

Table 3. Mean (and SD) for 'Assessment of different behaviours' items on the DABQ scale. Items were rated for level of seriousness.

ITEM	Mean±SD
Smoking in a non-smoking area	5.0±1.7
Parking on double yellow lines	4.7±1.6
Drink driving	6.7±0.8
Being drunk in public	3.6±1.5
Shoplifting	5.4±1.2
Playing loud music in a public park	3.0±1.4

Items rated from 1 (Not at all serious) to 7 (extremely serious)

Table 4. Mean (and SD) scores for 'attitudes toward cars and driving' items on the DABQ scale

ITEM	Mean±SD
I feel excited when I get behind the wheel	4.0±1.5
The best drivers are skilful drivers	5.2±1.3
The majority of accidents occur by chance or bad luck	2.4±1.3
I will insist that every passenger fastens their seatbelt	5.9±1.5
One or two minor accidents in the first few years of driving are inevitable and will not bother me	3.5±2.0
I would like to own a fast and powerful car one day	5.0±1.7
I would not normally go out for a drive just for enjoyment	3.8±2.0
I occasionally take risks to impress passengers	2.9±1.8
It is OK to speed if traffic conditions allow you to do so	3.7±1.8
I enjoy talking about cars and driving	3.1±2.1
Few of my friends are interested in cars and driving	4.7±1.7
I like to test out the limits of my car	3.3±2.0
It is OK to drive faster than normal if you have a high performance car	2.4±1.6
The best drivers are safe drivers	5.8±1.4
I am interested in motor sport	2.5±1.8
I will have my car regularly serviced by a qualified mechanic	4.7±1.5
I think that taking the occasional risk whilst driving will be exciting	3.6±1.8

Items rated from 1 (Strongly disagree) to 7 (Strongly agree)

Table 5. Mean (and SD) for 'contribution to road traffic accident' items on the DABQ

ITEM	RATING	RANK
Driving too close	5.4±1.3	9a
Driving too fast for the conditions	6.4±0.8	2
Drinking and driving	6.8±0.6	1
Driving when tired	6.0±0.9	4
Driving a defective vehicle	4.6±1.2	12
Drivers not signaling	4.7±1.3	11
Drivers not using their mirrors	4.9±1.6	10
Drivers overtaking when unsafe to do so	5.6±1.2	7
Drivers not paying attention	6.3±0.9	3
Drivers taking risks	5.9±1.2	5
Drivers breaking the speed limit	5.5±1.6	8
Drivers having the wrong attitudes	5.4±1.4	9b
Drivers lacking in experience	5.7±1.2	6
Pure chance	3.2±1.4	13

Items rated from 1 (Not at all) to 7 (Very)

In summary, participants in this sample reported sleep quality that is likely to be within normal limits. However, they may have had an increased tendency to report traffic violations. Parker et al. (1995) suggests that accident liability can be predicted by self-reported tendency to commit violations but not by the tendency to make errors and lapses.

Sleep Diary data

Habitual sleep patterns for the sample were calculated from sleep diary data. The mean sleep onset time for the sample was 12.50am (±2.3 hours), mean waking time was 9.06am (±2.2 hours), and the mean sleep duration was 8.1 hours (±2.7 hours).

Relative sleep loss for any day was estimated from the variance in sleep duration across each four-week period for each subject. Thus the duration of sleep over the preceding day was subtracted to provide an index of relative sleep loss for each day. The frequency of days with sleep duration above and below each individual mean is depicted in Figure 3 for all days. While variation about the mean was anticipated, the extended tail at the short sleep duration end of the distribution was note worthy. The data indicates that subjects sustained sleep loss relative to their own mean sleep duration of 3 hours or more on 14.3% of days across the four week period, and lost 6 hours or more on 3.3% of days.

Subjective alertness upon waking was reported using a 10cm visual analogue scale (VAS). Mean self-reported sleepiness upon waking was 54±28cm (VAS scale). The relationship between hours of relative sleep loss and subjective sleepiness upon awakening was assessed by correlation analyses for each subject. Correlation coefficients for individual participants ranged from 0.04 to 0.74. The mean correlation was calculated using the square root transform method, and was significant ($r = 0.375$, $p<.001$).

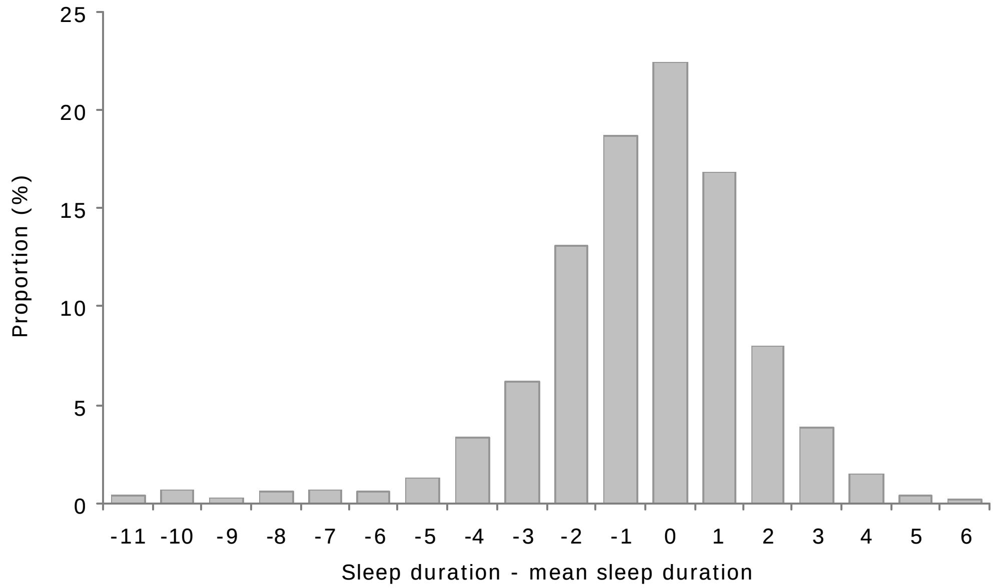

Figure 3. Proportion of days with relative sleep loss (negative values) and sleep gain (positive values) in hours for all subjects.

Driving Diary data

Subjects responded to 12 items on the driving diary for each driving episode undertaken. Characteristics of the driving episodes are presented in Table 6. The mean number of driving episodes across the four week period was 57.2±31.4(SD), with a range of 8-148 episodes. Complete diary data was collected from 2518 driving episodes.

Table 6. Characteristics of driving episodes

	Mean±SD	Range	% trips
Driving time (hours)	0.3±0.4	0 - 6	
Max speed (km/h)	73.8±23.0	0 - 180	
Distance (km)	12.3±21.9	0 - 450	
Passengers	0.5±0.9	0 - 22	
Alcohol		0 - 10	3.30
Drugs			0.44

Sex differences

The effect of gender on diary recorded driving habits was assessed by comparison of subject's mean responses on the primary diary variables of driving episode time, self-reported sleepiness, and self-reported crash risk. These analyses are presented in Table 7, and suggest no sex differences on these variables. Further analyses of sleep diary data were made on the entire sample.

Table 7. Mean (and SD) for primary driving episode variables for female and male subgroups.

	Female Mean±SD	Male	$\underline{t}_{(49)}$	$\underline{p}$
Time of day	14.4±1.4	14.8±1.0	0.98	>.05
Sleepiness (VAS)	64.7±13.7	66.3±10.6	0.68	>.05
Crash-risk (VAS)	61.5±13.8	62.9±10.2	0.69	>.05

Exposure to increased risk

Exposure to increased risk was defined as the proportion of driving episodes occurring when the participants were sleepy, and was estimated using three methods. The first involved estimating the proportion of driving episodes that occurred at times of increased sleepiness, as predicted by a three-process model (Estimate 1). Jewett and Kronauer (1999) presented a model predicting subjective alertness and cognitive throughput from circadian and homeostatic sleep processes. Elements of this model were used to calculate predicted level of sleepiness for each driving episode based on elapsed time since the onset of wakefulness. The second method was based on published crash statistics for this age group (Estimate 2). The NCSDR/NHTSA (1999) expert panel data on time of occurrence of crash in the 18-25 year age group indicates the time of day that young drivers most often die in crashes. This data suggests significantly increased risk of crash between the hours of 22:00 and 07:00. The proportion of driving episodes that occurred within these hours was calculated. The third method was based on self-reported sleepiness and perceived risk of crash for each driving episode (Estimate 3). That is, the proportion of driving episodes on which the drivers rated themselves as being sleepy or at increased risk of crash. The primary outcome variable under each model was the proportion of driving episodes that occur during periods of increased sleepiness.

Estimate 1

The time elapsed since wake of each driving episode was applied to the Jewett and Kronauer (1999) model to provide an estimate of the proportion of driving episodes occurring at each level of predicted sleepiness. The time since awakening was calculated for each driving episode by subtracting driving episode time (sleep diary) from wake time for that day (sleep diary). The proportion of driving episodes occurring during each hour after waking is depicted in Figure 4. Included in this figure is the general sleepiness curve generated from the Jewett and Kronauer (1999) model. The increased predicted sleepiness in the two hours after waking reflects the sleep inertia component of this model (Process W). Predicted sleepiness is scaled from 1 (maximum possible alertness) to 0 (minimum possible alertness). The proportion of driving episodes occurring at an alertness level of 7 or below (arbitrarily 30% below peak alertness) was 19.3%. The primary component contributing to sleepiness was sleep inertia (process W).

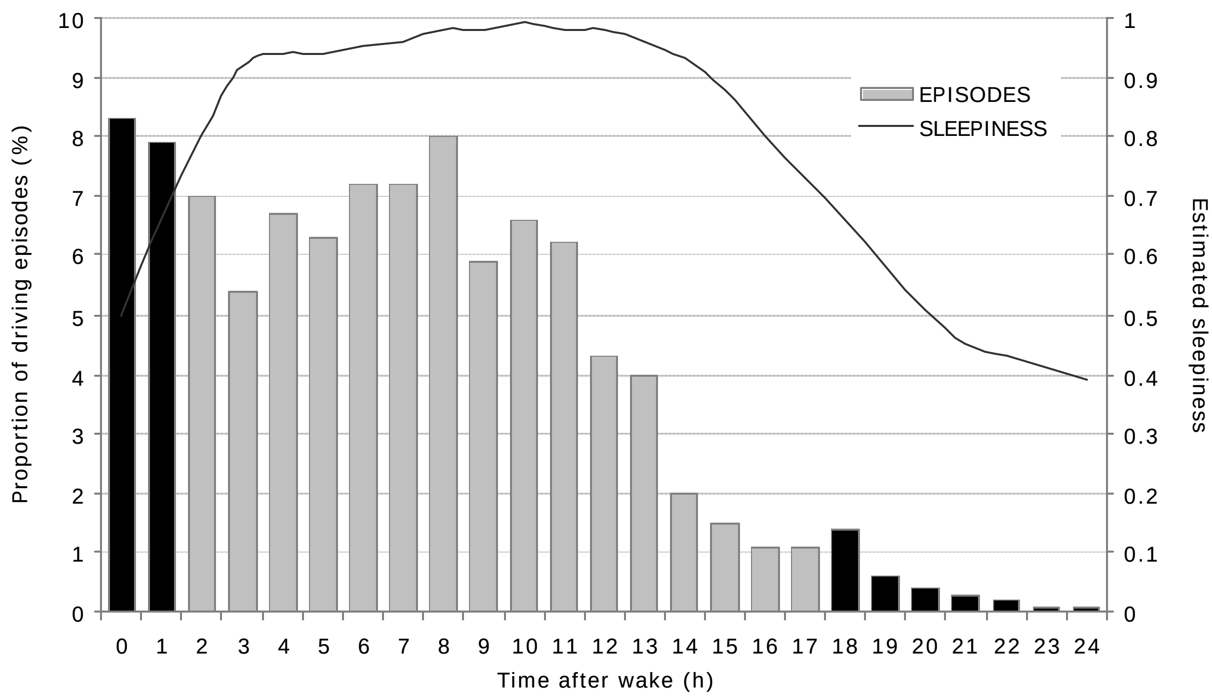

Figure 4. Proportion of all driving episodes at each time after waking (Episodes), and calculated sleepiness for each time after waking (Sleepiness). 1 represents minimum possible sleepiness (maximum alertness) and 0 represents maximum possible sleepiness (minimum alertness). Dark bars denote hours of increased risk.

Because of the variance in waking time from day to day in this sample, this analysis was repeated using mean time of wakefulness across the four week period as an estimated of habitual wake time. This recalculation was intended to provide an improved index of the circadian phase time contribution to sleepiness during each driving episode. The proportion of driving episodes occurring during each hour after the mean time of wakefulness is depicted in Figure 5. The proportion of driving episodes occurring at alertness levels of 7 or below was 13.3%. Again, the primary contributing component was sleep inertia.

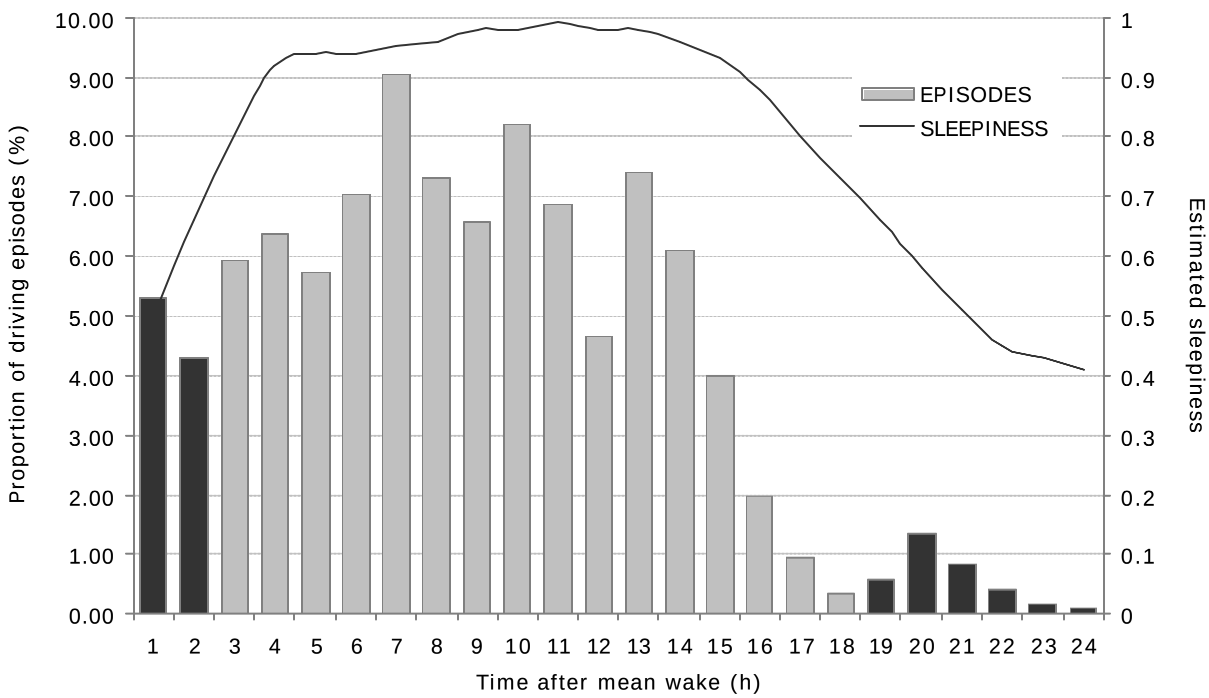

Figure 5. Proportion of all driving episodes at each time after mean individual wake time (Episodes), and calculated sleepiness for each time after wake (Sleepiness). 1 represents minimum possible sleepiness (maximum alertness) and 0 represents maximum possible sleepiness (minimum alertness). Dark bars denote hours of increased risk

Estimate 2

The time of day of each driving episode was extracted from the sleep diary. The distribution of driving episodes across the 24-hour day is depicted in Figure 6, together with the sleepiness related crash distribution calculated from NCSDR/NHTSA (1999) expert panel data. This data reflects the time of occurrence of crashes in drivers 25 years of age or younger in which the crashes were attributed by the police to the driver being asleep but in which alcohol was not judged to be involved. The proportion of driving episodes occurring during the hours of increased risk (10pm to 9am) was 22.5%.

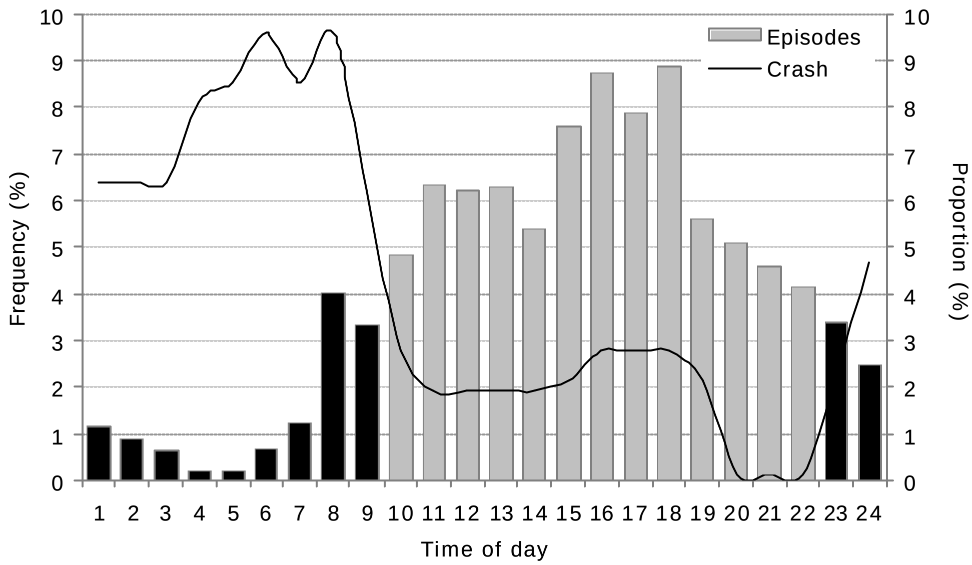

Figure 6. Distribution of driving episodes across the day (bars). The 'Crash' line indicates the proportion of sleepiness related crash fatalities occurring at each time of the day in drivers aged <25 years (NCSDR/NHTSA, 1999). Dark bars denote hours of increased risk.

Estimate 3

Subjects were asked to estimate their sleepiness and perceived risk of crash at each driving episodes. Responses were made on a 10cm visual analogue scale (VAS), with 10cm as least sleepiness or crash risk, and 0cm as highest sleepiness or crash risk . The distribution of ratings is depicted in Figure 7. The proportion of driving episodes rated as 7 or less for sleepiness (arbitrarily 30% below peak alertness) was 78.3%, and 3 or less was 11.2%. The proportion of driving episodes rated as 7 or less for crash risk was 71.4%, and as 3 or less was 7.5%.

The relationship between self-reported sleepiness and self reported crash risk was assessed by correlation analyses for each subject. The mean correlation was calculated using the square root transform method, and was significant (r=0.74, p<.001). That is, participants reported driving episodes during which they were sleepy as more likely to result in crashes.

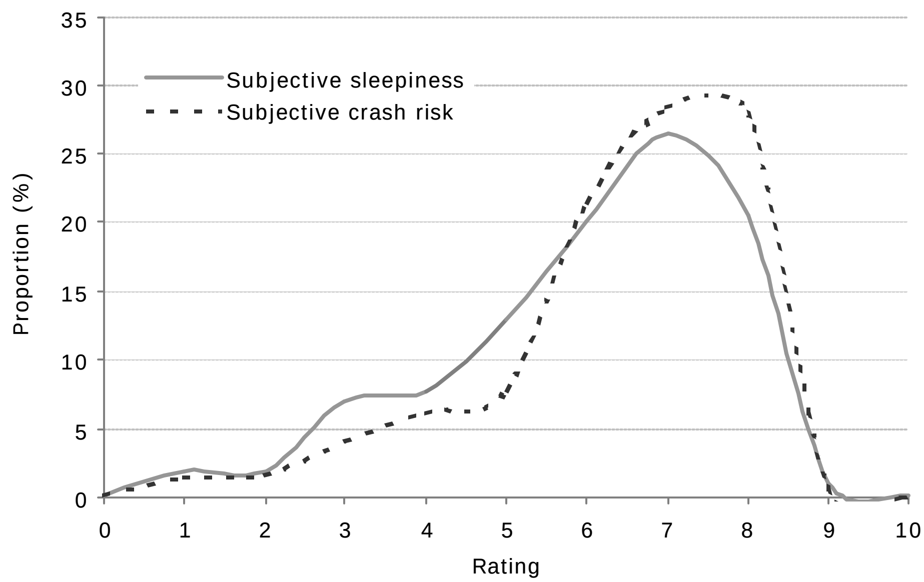

Figure 7. Distribution of VAS estimates of sleepiness and crash risk for all driving episodes (10=minimum sleepiness/minimum risk, 0=maximum sleepiness/maximum risk).

DISCUSSION

The sleep questionnaire data showed that participants did not rate themselves to be excessively sleepy (to the same level as patients with sleep disorders) on retrospective report. They noted symptoms indicative of problems getting to sleep or maintaining sleep, but did not rate these problems as having significant impact on their daily functioning. The driving questionnaire data showed that this sample reported lapses and violations more frequently than some other groups assessed with similar items. In relation to sleep-related crash risk, they reported disregarding speed limits at night more than other violations, and rated driving when tired as fourth in factors contributing to road accidents.

The participants reported drinking alcohol prior to driving on approximately 3% of driving episodes, and taking drugs prior to approximately 0.5% of driving episodes. These relatively low rates of use equate to 82 and 11 driving episodes respectively over the four-week sample period. Alcohol and sleepiness are known to interact to greatly amplify the deficits in performance found with both (NCSCR/NHTSA, 1999.). For example, Roehrs et al. (1994) found that deviations on a driving simulator after a low dose of alcohol (below the legal limit) were 15 times greater with 4 hours less sleep. Thus, further investigation of the co-occurrence of sleepiness and alcohol/other substance use is warranted.

Three methods were used to estimate exposure to sleepy driving episodes. Sleepiness was defined as 30% below peak alertness measure for the first two estimates. The estimate based on prediction of sleepiness due to primarily circadian and sleep inertia effects indicated that participants were sleepy on approximately 13-19% of driving episodes. The estimate based on time of day alone indicated that 22% of driving episodes occurred during the hours of increased probability of crash related to sleepiness. Further, the participants rated themselves as sleepy on approximately 78% of all driving episodes, and very sleepy on 11% of episodes. This frequent report may also reflect chronic sleepiness, that is, participants were often sleepy because of accumulated sleep debt, or frequent acute sleep debt. Alternatively, it may reflect a response bias, that is, a tendency not to rate themselves as fully alert for some other reason. Approximately 4.5% of driving episodes occurred after 18 hours of wake. This equates to at least 108 episodes over the four-week sample period with a likely level of driver impairment equivalent to a BAC greater than 0.05% (Lamond & Dawson, 1999; Arendt et al., 2001). In summary, the participants frequently drove at times when sleepiness predicted by the homeostatic component (process S) was likely to significantly impair their capacity to drive safely. They also frequently drove at times predicted by sleep inertia (process W) to impair their capacity to drive safely.

High night-to-night variation was found for sleep habitual duration. This data suggests that the daily basal level of sleepiness also varied widely. Acutely reduced prior sleep would lead to increased sleepiness at all points during the day. This data also suggests a degree of chronic sleep debt in the sample. For example, sleep durations much greater than the mean suggest an attempt to compensate for sleep loss with recuperative sleep.

The participant's self-report of crash risk on each episode was strongly associated with their self-reported level of sleepiness. Further, they identified sleepiness as a contributor to crashes. This data suggests that the participants were able to identify variation in their crash risk, with some understanding of the contribution of sleepiness to this risk. However, they actually drove at the times of this risk estimation. That is, the self-perception of significant risk of crash does not preclude taking that risk. Horne (1999) found that drivers underestimate the probability of falling asleep when sleepy. Thus, the consequences of sleepiness may not be well understood.

The estimate based on crash statistics provides an indication of the consequences of the sum of all risk factors, including circadian, sleep deprivation, night-time factors, drug and alcohol use and risk taking behaviours. The estimate based on models of sleep regulation, on the other hand, provides an indication of the relative contribution of circadian and sleep deprivation factors to crash outcomes. This differentiation may be important in focusing interventions into sleepy driving. Restricting driving to daylight hours in this age group has been reported as an effective, although unlikely, intervention to reduce the circadian contribution to sleepy driving (Triggs & Smith, 1996). Sleep debt, however, has consequences for other aspects of quality of life in this age group, (Carskadon, 1994), and increasing understanding of sleep debt may be the focus of productive interventions.

The present study adds to our knowledge of the factors that increase the risk of sleepy driving in young adults. The methodology employed provided detailed information on driving and sleep behaviours for individual participants on an episode-by-episode basis. The methodology could be implemented in larger scale surveys.

Recommendations

The results suggest that it is important to introduce strategies to reduce sleepy driving in young adults. Further, it is suggested that the following issues be focused on:

- Reduction of chronic and acute sleep loss
- Reduction of circadian based exposure to sleepiness when driving
- Improved understanding of the consequences of sleepiness on performance

Of these we suggest that the third factor is the most important. While it would be beneficial to reduce sleep loss in the community, it is highly unlikely that sleep loss can be entirely eliminated in any population. Thus, self-monitoring of driving behaviour when sleepiness occurs, is likely to be the most effective method of reducing driving while sleepy. However, the current data suggest that younger individuals do not consider sleepiness as a significant contributor to driving accidents. Thus, education as to the potentially potent role of sleepiness will be necessary if the recommended self-monitoring is to be successful.

The interaction of socio-economic indicators, work status (particularly late night and shift-work) and urban/rural driving characteristics with sleepiness in young drivers needs to be further assessed. A longitudinal study with a broader sample will be needed to determine whether the interaction between sleep and driving behaviours lead to increases in driving accidents in this age group, and whether the nature of this relationship changes with age.

REFERENCES

Acherman P. and Borbély A. (1994) Simulation of daytime vigilance by additive interaction of a homeostatic and a circadian process. *Biol Cybern* 71:115-121

Åkerstedt T. (2000) Consensus statement: Fatigue and accidents in transport operations. *J. Sleep Res.* 9: 395

Åkerstedt T. and Folkard S. (1995) Validation of the S and C component of the three-process model of alertness regulation. *Sleep* 18:1-6

Åkerstedt T., Folkard S. (1997) The three-process model of alertness and its extension to performance, sleep latency, and sleep length. *Chronobiol Int*. 14(2):115-23

Arendt J., Wilde G., Munt P. and McLean A. (2001) How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accid Anal Prev*. 33(3):337-344

Blockey P. and Hartley L. (1995) Aberrant driving behaviour: errors and violations. *Ergonomics*; 38(9): 1759-1771

Bonnet M. and Arand D. (1995) Consolidated and distributed nap schedules and performance. *J Sleep Res*. 4(2):71-77.

Borbély A. (1982) A two-process model of sleep regulation. *Hum Neurobiol* 1:195-204

Borbély A. and Achermann P. (1999) Sleep Homeostasis and models of sleep regulation. *J Biol Rhythms*. 14(6):559-568

Carskadon M. and Dement W. (1979) Effects of total sleep loss on sleep tendency. *Percept. Mot. Skills*. 48:495-506

Carskadon M. and Roth T. (1991) Sleep restriction. In Monk T. (ed.) *Sleep, sleepiness and performance*. Chichester, John Wiley & Sons, pp155-167

Committee on Injury and Poison Prevention and Committee on Adolescence, American Academy of Pediatrics (1996). The teenage driver. *Pediatrics*; 98:987-90

Czeisler C., Dijk D-J. and Duffy J. (1994) Entrained phase of the circadian pacemaker serves to stabilize alertness and performance throughout the habitual waking day, In: R. Ogilvie and J. Harsh (eds.) *Sleep onset: Normal and abnormal processes*, pp.89-110. Washington, DC, American Psychological Association

Daan S. and Beersma D. (1984) Circadian gating of human sleep-wake cycles. In: *Mathematical models of the circadian sleep-wake cycle*, M. Moore-Ede and C. Czeisler (eds.) pp129-155, Raven New York

Dinges D. (1995) An overview of sleepiness and accidents. *J Sleep Res*. 4(S2):4-14

Dinges D. (1995) The performance effects of fatigue: In: Proceedings of the Fatigue Symposium. National Transportation Safety Board / NASA Ames Research Centre

Dinges D. and Kribbs N. (1991) Performing while sleepy: Effects of experimentally induced sleepiness. In: T Monk (Ed.) *Sleep, sleepiness and performance*. John Wiley & Sons, ltd., New York: 97-128

Dobson A., Brown W., Ball J. (1998) Women behind the wheel: Driving behaviour and road crash involvement. Federal Office of Road Safety report CR179: http://www.atsb.gov.au/road/research/crreport.cfm

Dobson A., Brown W., Ball J., Powers J., McFadden M. (1999) Women drivers' behaviour, socio-demographic characteristics and accidents. *Accid Anal Prev*. 1999 Sep;31(5):525-35

Douglass A., Bornstein R., Nino-Murcia G., Keenan S., Miles L., Zarcone V. Jr., Guilleminault C., Dement W. (1994) The Sleep Disorders Questionnaire. I: Creation and multivariate structure of SDQ. *Sleep*.17(2):160-7.

Ferrara M. and De Gennaro L. (2000) The sleep inertia phenomenon during the sleep-wake transition: theoretical and operational issues. *Aviat. Space Environ. Med*. 71(8): 843-848

Folkard S. and Åkerstedt T. (1992) A 3-process model of the regulation of alertness-sleepiness. In: *Sleep, Arousal and Performance*, R. Broughton and B. Ogilvie (eds.), pp 11-26, Bikhauser, Boston

Folkard S., Åkerstedt T., McDonald I., Tucker P. and Spencer M. (1999) Beyond the Three-Process model of alertness: estimating phase, time on shift, and successive night effects. *Journal of Biological Rhythms*. 14(6):579-587

Garbarino S., Nobili L., Beelke M., Phy F. and Ferrilo F. (2001) The contributing role of sleepiness in highway vehicle accidents. *Sleep*. 24(2): 203-206

Gillberg M. and Åkerstedt T. (1998) Sleep loss and performance: no 'safe' duration of a monotonous task. *Physiol. Behav*. 64:599-604

Harma M., Suvanto S., Popkin S., Pulli K., Mulder M. and Hirvonen K. (1998) A dose-response study of total sleep time and the ability to maintain wakefulness. *J. sleep Res*. 7:167-174

Harrison Y. and Horne J. (1999) One night of sleep loss impairs innovative thinking and flexible decision making. *Organ. Behav. Hum. Decis. Process*. 78:128-145

Horne J. (1988a) Sleep loss and 'divergent' thinking ability. *Sleep*. 11:528-536

Horne J. (1999) Vehicle accidents related to sleep: a review. *Occupational and Environmental Medicine*. 56(5):289-294

Horne J., Reyner L. (1995a) Driver sleepiness. *J Sleep Res*. 4(supl 2):23-29

Horne J., Reyner L. (1995b) Sleep related vehicle accidents. *Br Med J*. 310:565-567

Jewett M., Dijk D., Kronauer R., Dinges D. (1999) Dose-response relationship between sleep duration and human psychomotor vigilance and subjective alertness. *Sleep*. 22(2):171-9

Jewett M., Kronauer R. (1999) Interactive mathematical models of subjective alertness and cognitive throughput in humans. *J Biol Rhythms*. 14(6):588-97.

Jewett M., Wyatt J., Ritz-De Cecco A., Khalsa S., Dijk D. and Czeisler C. (1999) Time course of sleep inertia dissipation in human performance and alertness. *J Sleep Res*. 8, 1-8

Knipling R., Wang J. (1994) Crashes and fatalities related to driver drowsiness/fatigue. Washington, DC: Office of Crash Avoidance Research, U.S. Department of Transportation, Research note

Kribbs N. and Dinges D. (1994) Vigilance decrement and sleepiness. In: J. Harsh and R. Ogilvie (eds.) *Sleep onset mechanisms*. Washington, DC: American Psychological Association, pp. 113-125

Lamond N., Dawson D. (1999) Quantifying the performance impairment associated with fatigue. *J Sleep Res*. 8:255-262

Lawton R., Parker D., Stradling S. and Manstead A. (1997) Predicting road traffic accidents: the role of social deviance and violation. *British Journal of Psychology*, 88: 249-262

Lyznicki J., Doege T., Davis R. and Williams M. (1998) Sleepiness, driving, and motor vehicle crashes. Council on Scientific Affairs, American Medical Association, Chicago. *JAMA*. 279(23):1908-1913

Maycock G. (1996) Sleepiness and driving: The experience of UK car drivers. *J Sleep Res*. 5:229-237

Mills K, Hall R, McDonald M and Rolls G (1998) The effects of hazard perception training on the development of novice driver skills. Transportation Research Group, University of Southampton.
http://www.roads.detr.gov.uk/roadsafety/hazard/appena.htm

Monk T., Reynolds C., Kupfer D., Buysse D., Coble P., Hayes A., MacHen M., Petrie S., Ritenour A. (1994) The Pittsburgh Sleep Diary. *J Sleep Res*. 3(2):111-120

Morin, C. (1994). Insomnia: Psychological assessment and management. New York, The Guilford Press

National Transportation Safety Board (1990) Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-trucker heavy truck crashes. Washington, DC: Safety study, NTSB/SS-95/01

National Transportation Safety Board (1995) Factors that affect fatigue in heavy truck accidents. Vol 1. Washington, DC: safety study NTSB/SS-95/01

NCSCR/NHTSA Expert Panel on Driver Fatigue and Sleepiness (1999). Drowsy driving and automobile crashes.
http://www.nhtsa.dot.gov/people/perform/human/drowsy.html. Washington, DC

Pack A., Pack A., Rodgman E., Cucchiara A., Dinges D., and Schwab C (1995) Characteristics of crashes attributed to the driver having fallen asleep. *Accid Anal Prev*. 27(6):769-75

Parker D., Manstead A., Stradling S., and Reason J. (1992) Determinants of intention to commit driving violations. *Accid Anal Prev*. 1992 Apr;24(2):117-31.

Parker D., Reason J., Manstead A. and Stradling S. (1995) Driving errors, driving violations and accident involvement. *Ergonomics*; 38(5):1036-1048

Philip P., Taillard J., Guilleminault C., Quera Salva M., Bioulac B. and Ohayon M. (1999) Long distance driving and self-induced sleep deprivation among automobile drivers. *Sleep*. 22(4): 475-480

Philip P., Taillard J., Quera-Salva M., Bioulac B and Åkerstedt T. (1999) Simple reaction time, duration of driving and sleep deprivation in young versus old automobile drivers. *Journal of Sleep research*; 8(1):9-14

Powell N., Schnechtman K., Riley R., Li K., Troell R., and Guilleminault C. (2001) The road to danger: the comparative risks of driving when sleepy. *Laryngoscope*. 111(5):887-893

Reason J., Manstead A., Stradling S., Baxter J., and Campbell K. (1990) Errors and violations on the roads: a real distinction? *Ergonomics;* 33(10/11):1315-1332

Roehrs T., Beare D., Zorick F. and Roth T. (1994) Sleepiness and ethanol effects on simulated driving. *Alcohol Clin Exp Res*. 18:154-158

Rosenthal L., Roehrs T., Roth T. (1993) The Sleep-Wake Activity Inventory: a self-report measure of daytime sleepiness. *Biol Psychiatry*. 34(11):810-20.

Sagberg F. (1999) Road accidents caused by drivers falling asleep. *Accid Anal Prev*. 31(6):639-649

Smith S. and Trinder J. (2001) Detecting insomnia: A comparison of four self-report measures in a young adult population. *J Sleep Res* (in press)

Thomas M., Sing H., Belenky G., Holcomb H., Mayberg H., Dannals R., Wagner H., Thorne D., Popp K., Rowland L., Welsh A., Balwinski S. and Redmond D. (2000) Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24h of sleep deprivation on waking human regional brain activity. *J. Sleep Res*. 9:335-352

Triggs T. and Smith K. (1996) Young Driver Research Program: Digest of Reports and Principal Findings of the Research. Australian Transport Safety Bureau Consultant's report CR164 http://www.atsb.gov.au/road/research/crreport.cfm

Wang J., Knipling R. and Goodman M. (1996) The role of driver inattention in crashes: new statistics from the 1995 crashworthiness data system. Fortieth annual proceedings of the Association for the Advancement of Automotive Medicine, pp.377-392

APPENDICES

APPENDIX 1 – Example of Driving Diary

Driving Diary

Driving Trip 1

What time did you start this trip?	hour		minute		DATE:
Driving time?	hours		Minutes		
From where (home, work etc.)?			Suburb		
To where (home, work etc)?			Suburb		
Approximate distance?	Km				
Maximum speed reached?	Km/h				
How many passengers in the car?					
How many drinks did you have before this trip?		Type?			
What drugs did you take before this trip?					
Sleepiness during this trip?	High				Low
Risk of crashing?	High				Low
Any accidents or near misses?		Caused by...			

Driving Trip 2

What time did you start this trip?	hour		minute		DATE:
Driving time?	hours		Minutes		
From where (home, work etc.)?			Suburb		
To where (home, work etc)?			Suburb		
Approximate distance?	Km				
Maximum speed reached?	Km/h				
How many passengers in the car?					
How many drinks did you have before this trip?		Type?			
What drugs did you take before this trip?					
Sleepiness during this trip?	High				Low
Risk of crashing?	High				Low
Any accidents or near misses?		Caused by...			