Sleepiness: How a biological drive can influence other risky road user behaviours

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Abstract

The Safe System approach to road safety utilises a holistic view of the interactions among vehicles, roads, and road users. Yet, the contribution of each of these factors to crashes is vastly different. The role of road users is widely acknowledged as an overwhelming contributor to road crashes. Substantial gains have been made with improvements to vehicle and roads over a number of years. However, improvements of the road user's behaviour have been (in some cases) less substantial. A road user behaviour that is relatively unregulated is driver sleepiness, which is part of the 'fatal five' of risky road user behaviours. The effect of sleepiness is ubiquitous – sleepiness is a state that most, if not all drivers on our roads has experienced, and is habitually exposed to. The quality and quantity of daily sleep is integral to our level of neurobehavioural performance during wakefulness and as such can have a compounding effect on a number of other risky driving behaviours. This paper will discuss the potential influence of sleepiness as an interceding factor for a number of risky driving behaviours. Little effort has been given to increasing awareness of the deleterious and wide ranging effects that sleepiness has on road safety. Given the wide ranging influence of sleepiness, improvements of 'sleep health' as a protective factor at the community or individual level could lead to significant reductions in road trauma and increases of general wellbeing. A discussion of potential actions to reduce sleepiness is required if reductions of road trauma are to continue.

Keywords

Australian drivers; risky driving behaviours; sleepiness; neurobehavioural performance; protective factors; sleep health

Introduction

In recent years the Safe System Approach has been adopted by regulatory bodies in Australia, as a means of improving road safety outcomes. The Safe Systems Approach utilises a holistic view of the interactions among vehicles, roads, and road users (Organisation for Economic Co-operation and Development/International Transport Forum, 2008). This holistic view recognises that errors will occur by road users and in order to reduce road trauma, the entire road system needs to be more forgiving when errors occur.

Generally, the three factors of the vehicle, the road environment, and the road user are identified as mechanisms that contribute to road crashes. Regarding the overall involvement of these three factors with crashes, it is estimated that vehicle defects, road conditions, and risky road user behaviours contribute to 10%, 30%, and 90% of crashes respectively, with some overlap occurring between factors (Shinar, 1978). Similarly, Sabey and Taylor (1980) found that 95% of crashes were due to road user behaviours. Advances with engineering and safety equipment have provided substantial improvements for vehicles and roads over a number of years (Australian Transport Council, 2011). The safety improvements of vehicles and roads are important and are consistent with the Safe Systems Approach to reduce the overall burden from crashes. However, a reduction in risky road behaviours can lead to far greater reductions of crashes given its large involvement in crashes.

A group of risky road user behaviours that have been referred to as the 'fatal five' (i.e., distracted driving, drink driving, speeding, driving without wearing a seatbelt use, and sleepy/fatigued driving) continue to be major causes of road trauma. A number of enforcement practises have been developed to reduce incidents of drink driving (e.g., Random Breath Testing (RBT)) and speeding (e.g., speed cameras) as well as the enacting of specific laws to reduce driving without a seatbelt and driver distraction. However, no objective measurement of a driver sleepiness level exists and as such, driver sleepiness is relatively unregulated. Driver sleepiness is a significant contributor to road trauma. The current best estimates suggests that approximately 20% of all fatal and severe crashes are due to acute sleepiness (Connor et al., 2002; Kecklund, Anund, Wahlström, & Åkerstedt, 2012). Crashes often have multifactorial causes, and therefore a degree of sleepiness may be involved in crashes that were primarily attributed to other factors.

Levels of Societal Sleepiness

The prevalence and magnitude of sleep disruption, sleep disorders, poor sleep habits, and daytime sleepiness is becoming more apparent. Sleep disorders (e.g., obstructive sleep apnoea, insomnia, and circadian disorders) are a cause of excessive daytime sleepiness. A substantial proportion of society's members' excessive daytime sleepiness, may be due to inadequate sleep durations and irregular sleep patterns (Kryger, Roth, & Dement, 1994).

An Australian survey that examined the sleep habits of a representative sample of Australians found that approximately one fifth of the participants (18.40%) reported that their habitual sleep duration was less than 6.5 hours per night (Bartlett, Marshall, Williams, & Grunstein, 2008). This might represent chronically insufficient sleep for many people. Levels of chronic daytime sleepiness were found in 11.70% of the sample, with 9.80% of participants aged 18-24 years reporting chronic daytime sleepiness. A second Australian study by Cummins et al. (2012) of sleep habits and personal wellbeing, found 61.00 % of their sample slept between 7 to 8 hours per night. A sizable proportion (31.20%) of the participants slept less than 7 hours per night. Participants sleeping less than 7 hours were found to be significantly below the normative range of personal wellbeing (e.g., satisfaction with their lives, quality of life and wellbeing), with steeper decreases in personal wellbeing with fewer hours slept.

These data highlight that large sections of society have poor sleep health and are potentially accumulating sleep debts. This is supported by statistics showing that approximately two fifths (38.1%) of individuals fall asleep at work due to excessive daytime sleepiness (Dawson, Clarkson, & Ferguson, 2012). Current trends suggest that sleepiness may be increasing, owing to societal and work demands (Dawson et al., 2012; Knutson, Van Cauter, Rathouz, DeLeire, & Lauderdale, 2010).

The Effects of Sleepiness

Sleep deprivation can be described as the restriction to the amount of sleep required by an individual to ensure optimal neurobehavioural functioning during waking hours. Sleep deprivation can be acute/partial (i.e., 1-4 hours reduction of sleep), total (i.e., no sleep), or chronic (i.e., repeated long-term reductions of the optimal amount of sleep). Additionally, having an untreated sleep disorder, being a shift worker, and life circumstances such as having a newborn to care for can facilitate chronic sleep deprivation (i.e., sleep fragmentation).

Sleep deprivation results in the accumulation of a sleep debt and result in excessive daytime sleepiness. Studies have shown that acute sleep deprivation can have a dose-response like effect of performance impairment (Åkerstedt, Peters, Anund, & Kecklund, 2005). Even relatively moderate levels of chronic sleep deprivation (i.e., sleeping 6 hours/ night) over a 14 day period can lead to psychomotor impairments that are equivalent to being completely sleep deprived for up to two nights (Van Dongen, Maislin, Mullington, & Dinges, 2003).

The neurobehavioural impairments from extended wakefulness are similar to the impairments from alcohol consumption. When wakefulness has been sustained for 17 hours, the performance deficits on a simple co-ordination task equate to having a blood alcohol content (BAC) of 0.05% (Dawson & Reid, 1997) which is the legal BAC for Australian drivers. However, after 24 hours of wakefulness, the performance impairments are equivalent to having a BAC of 0.10%. At this level of BAC the relative risk of having a crash are 5-6 times greater than when sober (Blomberg, Peck, Moskowitz, Burns, & Fiorention, 2005). Similar effects of sleep deprivation have been obtained with more demanding cognitive tests (e.g., Williamson & Feyer, 2000).

The effect of sleepiness can be wide ranging with impairments of cognitive, emotional functioning and performance outcomes. At the cortical levels sleep deprivation results in a marked deceases of metabolic activity in cortical and sub-cortical areas including the cerebellum, thalamus, anterior cingulate, posterior parietal, frontal, and prefrontal cortices (Thomas et al., 2000). Many of these cortical areas are vital for efficient functioning of high-order cognitive processes, including: decision-making, attention, motor control, perception, and executive functioning (Fukui, Murai, Fukuyama, Hayashi, & Hanakawa, 2005; Jones & Harrison, 2001; Killgore, Balkin, & Wesensten, 2006; Lim et al., 2010). Likewise, emotional regulation and interpersonal processes are disrupted due to reductions of frontal and prefrontal cortical activity (Killgore et al., 2008; Tempesta et al., 2010).

Driving is a complex task that requires the successful operation of a number of psychological processes. These psychological processes comprise: learning, memory, perception, motor control, attention, decision making, and executive functioning (Groeger, 2002; Horswill & McKenna, 2004). Several distinct cortical and sub-cortical areas of the brain are active when driving and many of these same areas show reduced activity during sleepiness. The cortical areas of the occipital lobes, posterior parietal lobes, premotor cortex, thalamic regions, and cerebellum are all active while driving (Spiers & Maguire, 2007). Cortical areas of the right prefrontal cortex are specifically activated when drivers process road traffic rules (Spiers & Maguire, 2007) and the anterior cingulate is active during tasks of collision avoidance and driving at safe distances (Uchiyama, Ebe, Kozato, Okada, & Sadato, 2003). Figure 1a shows cortical and sub-cortical brain areas active during driving tasks, Figure 1b shows cortical and sub-cortical brain areas that have reduced activity when sleep deprived. Comparing these two figures suggests that sleepiness has specific deleterious effects on the safe operation of a vehicle.

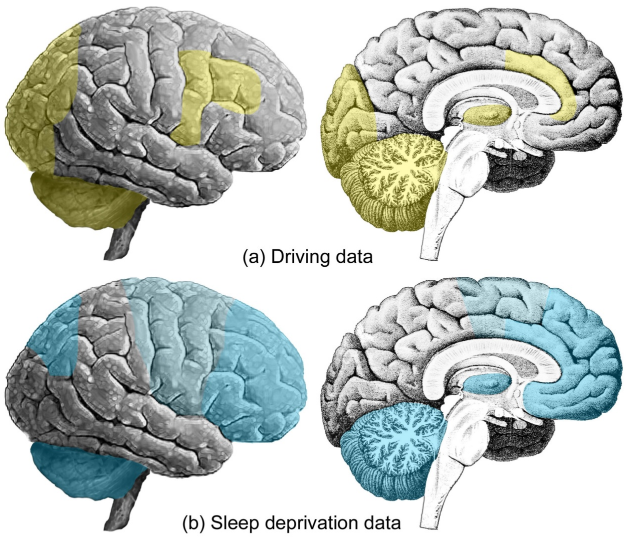

Figure 1a-b
Illustrations of neural areas active during driving tasks (yellow) and neural areas that show decreased activation during sleep deprivation (light blue). Note that the actual neural activity is much more diffuse than as it is seen is the illustration.

Sleepiness and other Risky Road Users Behaviours

Sleepiness is a state that most, if not all drivers on our roads has experienced, and is habitually exposed to. Due to the effect of sleepiness induced reductions in cortical and sub-cortical activity and the subsequent impairment of a number of psychological processes critical for driving and emotional regulation, it is possible that sleepiness might have a compounding effect on a number of other risky driving behaviours. It is acknowledged that the potential causes for risky driving behaviours are numerous and complicated (e.g., attitudes, personality, risk perceptions, and time pressures among others). While, some risky driving behaviours can be situational and have short-medium durations (e.g., speeding, drink driving, distracted driving), the effects of sleepiness are present until restorative sleep is achieved. Therefore, the potential influence of sleepiness as an interceding factor for a number of risky driving behaviours is substantial.

Sleepiness and Drink Driving

Multiplicative effects are found when sleepiness and alcohol (even low BAC concentrations) are combined. When moderate levels of sleep deprivation (5 hours sleep) and moderate levels of blood alcohol concentrations (< .04%) are combined, microsleeps are more frequent and driving performance impairment is greater than the impairment from either sleep deprivation or alcohol (Banks, Catcheside, Lack, Grunstein, & McEvoy, 2004). A similar pattern of results is found when sleep deprivation and low doses of alcohol are combined in professional drivers (Howard et al., 2007). Multiplicative effects are still found when BAC levels have fallen to near zero (Barrett, Horne, & Reyner, 2004).

These results are concerning when consideration is given to peak times of alcohol crashes. The majority of alcohol-related crashes and BAC apprehensions are recorded between 01:00 and 04:00 (Queensland Police Service, 2011) which encompasses the peak circadian sleepiness times. The relative risk of having a crash dramatically increases when drivers are experiencing acute sleepiness and when alcohol is present. During periods of acute sleepiness even low levels of BAC (< 0.05%) lead to substantially higher odds ratios for having a crash, and an extreme increase of the odds ratio for crashing occurs with acute sleepiness and BAC levels greater than 0.05% are combined (Akerstedt, Connor, Gray, & Kecklund, 2008).

Sleepiness and Speeding

Studies have linked sleepiness with speeding and there are several proposed reasons as why sleepiness might impact on speeding. The first explanation involves the ability to maintain vehicle speed. The effects of sleepiness on driving performance results in deviations from posted speed limits as well as increases of the variability of these speed deviations (Arnedt, Wilde, Munt, & Maclean, 2000). The magnitude of the variations of speed deviations also increases with longer durations of driving (Gillberg, Kecklund, & Åkerstedt, 1996). These findings suggest that overall speed maintenance is susceptible to sleepiness.

A second explanation is centred on the driver seeking to increase their arousal levels by increased risky driving. That is, some drivers will intentionally increase their driving speed to counteract their sleepiness. Nordbakke and Sagberg (2007) found that a small proportion of their participants reported that an 'effective' countermeasure for driver sleepiness was increasing the vehicles travelling speed. It is likely that a diminutive increase of arousal would occur from the change in sensory and cognitive appraisals. Sleepy drivers arousal levels increase when they perform overtaking tasks in a simulator (Reyner & Horne, 1998). However, this arousal increase is transient in its duration. Speeding reduces the time a driver has to react to critical situations and sleepiness impairs the driver's ability to make swift reactions to critical driving events, suggesting a multiplicative effect.

It has also been observed that many sleepy drivers will actually reduce their driving speed. Reductions in speed by sleepy drivers are typically reported to occur during simulated night-time driving, however, increases in the variability of speed still takes place (Gillberg et al., 1996). This pattern of driving behaviour has also been observed during real on-road driving conditions (Sandberg et al., 2011). A potential explanation for the link between sleepiness and speed reductions could be due to the strategy of sacrificing speed to ensure accuracy (De Gennaro, Ferrara, Curcio, & Bertini, 2001). Notwithstanding these findings, sleepiness reduces cortical functioning and impairs psychomotor reaction times. These occurrences ultimately leave drivers with less time to respond to critical driving events.

Sleepiness and Distracted Driving

Recent empirical studies have suggested a link between sleepiness and distracted driving. A simulated driving study by Anderson and Horne (2013) examined the distractibility of drivers when partially sleep deprived (5 hours sleep) and fully rested. Partially sleep deprived participants made more short diverted gazes (< 3 sec), more long diverted gazes (> 3 sec), and had significantly more distraction-related driving incidents (e.g., defined as two wheels leaving the driving lane) than when fully rested. The combination of low doses of alcohol further impairs driving performance as Iudice et al. (2005) found that prolonged wakefulness, legal levels of BAC, and using a hands-free mobile phone leads to impaired driving performance (i.e., speed deviations, tail gating). The combined and substantial impairment from sleepiness and distracted driving is likely due to restrictions of cortical resources. The cognitive resources needed when driving and performing a secondary task are substantial

(Schweizer et al., 2013) and with cortical activity already reduced from sleepiness (Thomas et al., 2000) the cortical resources available are not enough to ensure accurate task performance.

Laboratory and driving simulator studies reveal that sleep deprivation leads to greater distractibility. Compared to when fully rested, sleep deprived individuals are more likely to be distracted by periphery stimuli, even when directed to ignore these stimuli and focus on the study task (Anderson & Horne, 2006). Sleep deprivation results in an increase of distractibility even when the periphery stimuli are absent. Sleep deprivation limits the ability to filter task-irrelevant stimuli from relevant stimuli (Drummond, Anderson, Straus, Vogel, & Perez, 2012). The effect of sleepiness and distractibility is most evident during sustained laboratory tasks. Distractibility increases with longer durations of testing (Anderson & Horne, 2006) and this has been observed with professional drivers (Hanowski, Perez, & Dingus, 2005). Increases of distractibility that occurs when sleepy could be due to the sleepy individual seeking greater stimulation from their environment to ensure remaining awake and completing the task.

Sleepiness and Driver Aggression

Studies have consistently shown that emotional regulation and interpersonal functioning are compromised by sleepiness. Sleep deprivation leads to reduction of emotional regulation, impulse control, and increased irrational thought processes (Killgore et al., 2008). The magnitude of emotional responses to neutral and negative faces and pictures are greater when sleep deprived (Tempesta et al., 2010). When sleep deprived, greater impairments of impulse control occurs when responding to negative stimuli (Anderson & Platten, 2011). Sleep deprivation also leads to impaired conflict resolution skills and a tendency of blaming others (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006).

Sleep deprived individuals are also more reactive to situations involving low levels of stress. Sleepy individuals report greater levels of subjective stress, anxiety, and anger after exposure to low levels of stress than fully rested individuals (Minkel et al., 2012). However, reactions to high levels of stress from the sleepy and fully rested individuals were similar – suggesting that coping mechanisms used with low levels of stress are disrupted due to maladaptive cognitive processes (e.g., Matthews, 2002). Increased levels of stress can also affect the quality of sleep, which in turn increases levels of sleepiness and by extension, problems with emotional regulation and reactivity to stressful situations (Vandekerckhove & Cluydts, 2010).

To date, few relevant studies have thoroughly examined the interaction of aggression and sleepiness on driver performance. Simulator studies have shown that aggressive drivers tend to engage in risky driving behaviours (Abdu, Shinar, & Meiran, 2012). Driving situations that lead to higher stress levels also compromise efficient regulation of emotions and cognitive functioning and subsequently driver performance levels diminish (Matthews et al., 1998). The combination of sleepiness and poor emotional regulation and interpersonal functioning are likely to have a detrimental effect on road safety.

Sleepiness and Young People

Younger persons' driving performance appears to be more critically affected by sleepiness than are older and more experienced drivers. Younger persons who are sleep deprived show greater impairment on laboratory-based tests of vigilance (Philip et al., 2004), perform worse on driver performance indices than older persons (Campagne, Pebayle, & Muzet, 2004), and hazard perception abilities (Smith, Horswill, Chambers, & Wetton, 2009). Younger drivers, when compared to older drivers, exhibit higher levels of electroencephalographic defined levels of sleepiness during night-time driving (Lowden, Anund, Kecklund, Peters, & Åkerstedt, 2009).

The risk perceptions that younger drivers hold in relation to the dangers of having a sleep-related crash may be erroneous. Younger drivers frequently drive during times of high levels of sleepiness, even when they believe they are experiencing acute sleepiness (Nordbakke & Sagberg, 2007). Such behaviours could be expected from under-recognition of sleepiness signs and/or an under-appreciation of the dangers of a sleep-related crash. The under-appreciation of the dangerousness likely contribute to younger drivers' tendency to drive with greater levels of sleep debt before a long drive (Philip et al., 1996) and a lower likelihood of using sleepiness countermeasures (Watling, 2013). Considered together, younger persons are at greater risk due to their critical impairment from sleepiness and erroneous risk perceptions.

Protective Factors to Reduce Sleepiness

A substantial amount of evidence has accrued regarding the deleterious effects of sleepiness. However, little effort has been given to increasing awareness of the deleterious and wide ranging effects that sleepiness can have on road safety and wellbeing. Improvements of sleep health as a protective factor at the individual and community level (as has been done for alcohol use and drink driving) could potentially lead to significant reductions in road trauma and increases of general wellbeing. The effects from improvements of sleep health will be discussed below.

An obvious improvement to sleep health would be increasing durations of sleep. When healthy young adults with no symptoms of excessive daytime sleepiness have their normal sleep durations of seven hours extended to 8-9 hours of sleep over 10 days, improvements of daytime physiological alertness, neurobehavioural performance, and mood are observed (Kamdar, Kaplan, Kezirian, & Dement, 2004). These improvements seemingly have a dose-response effect, with greater improvements occurring with longer sleep extensions. Neurobehavioural recovery from chronic sleep deprivation does require more than one night of full sleep (Belenky et al., 2003). Moreover, increasing total sleep time before a night of sleep deprivation can reduce the magnitude of neurobehavioural impairment from sleep deprivation (Rupp, Wesensten, Bliese, & Balkin, 2009). These findings suggest that an increase of sleep duration can improve neurobehaivoural functioning, mood, and potentially buffer impairments when sub-optimal sleep occurs.

In addition to sleep duration, quality of sleep is an import aspect that needs to be considered. Some studies suggest that better sleep quality is more strongly associated with less daytime sleepiness and improvements of mood (Pilcher, Ginter, & Sadowsky, 1997). Epidemiological evidence suggests that sub-optimal sleep health have been related to several deleterious health outcomes, including hypertension, diabetes, obesity, and mortality (Gangwisch, 2009).

Another factor that could improve sleepiness is the regularising of sleep-wake times. A number of studies have found that irregular sleep-wake schedules are associated with poorer mood and neurobehavioural performance as well as higher levels of daytime sleepiness (Lund, Reider, Whiting, & Prichard, 2010; Medeiros, Mendes, Lima, & Araujo, 2001). In contrast, when sleep-wake schedules are regularised, improvements of negative mood, daily functioning, and sleep quality occur (Manber, Bootzin, Acebo, & Carskadon, 1996; Takasu, Takenaka, Fujiwara, & Toichi, 2012). Moreover, regularising of sleep-wake times leads to improvements of cardiac indices (Takasu et al., 2012).

Improvement of sleep health as a protective factor is an important first step. In Australia, a substantial change of the acceptability of drink driving occurred at the societal level. This societal attitudinal change as well as sustained policing with RBT and education campaigns lead to dramatic reductions of the incident rates of drink driving and reductions of overall road trauma (Homel, 1988). While there is currently no objective measure of a driver's sleepiness levels for the purpose of enforcement, sleep education campaigns could be applied to effect behaviour and attitudinal change regarding the importance of sleep. An increasing body of literature reveals the effectiveness of sleep education programs for improving sleep health (e.g., Blunden, Kira, Hull, & Maddison, 2012; Cortesi, Giannotti, Sebastiani, Bruni, & Ottaviano, 2004; Morita, Miyazaki, & Okawa, 2012; Nishinoue et al., 2012).

Issues surrounding implementation of a sleep education program are an important consideration. In an ideal world a multiagency association would be formed including agencies from health, educational, research, and regulatory authorities. The implementation of the educational programs can be achieved at multiple levels, beginning with a focus at the familial level, then community, and last societal levels. Notwithstanding these issues, the potential gains could be great for overall road safety outcomes and general wellbeing if concerted efforts could be direct to improve society sleepiness.

Conclusion

Current data suggests that societal sleepiness levels are increasing. Sleepiness impairs neurobehavioral performance, emotional regulation, and is related to several deleterious health outcomes. Sleepiness is a state that most, if not all drivers on our roads have experienced, and are habitually exposed too. Improvements of sleep health as a protective factor at the individual and community could lead to significant reductions in road trauma and increases of general wellbeing. The "Responsibility for road safety is shared by all" (Australian Transport Council, 2011) however, it has to start somewhere – perhaps traffic regulatory authorities are ideally placed to be the vanguard for more concerted actions to address societal sleepiness. The effects of sleepiness contribute greatly to crash incidents and, as discussed, sleepiness potentially has a interaction with other risky driving behaviours. A discussion of potential actions to reduce sleepiness is required if reductions of road trauma are to continue.

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