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Are drivers aware of sleepiness and increasing crash risk while driving?

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ABSTRACT

Drivers are advised to take breaks when they feel too tired to drive, but there is question over whether they are able to detect increasing fatigue and sleepiness sufficiently to decide when to take a break. The aim of this study was to investigate the extent to which drivers have access to cognitive information about their current state of sleepiness, likelihood of falling asleep, and the implications for driving performance and the likelihood of crashing. Ninety drivers were recruited to do a 2 h drive in a driving simulator. They were divided into three groups: one made ratings of their sleepiness, likelihood of falling asleep and likelihood of crashing over the next few minutes at prompts occurring at 200 s intervals throughout the drive, the second rated sleepiness and likelihood of falling asleep at prompts but pressed a button on the steering wheel at any time if they felt they were near to crashing and the third made no ratings and only used a button-press if they felt a crash was likely. Fatigue and sleepiness was encouraged by monotonous driving conditions, an imposed shorter than usual sleep on the night before and by afternoon testing. Drivers who reported that they were possibly, likely or very likely to fall asleep in the next few minutes, were more than four times more likely to crash subsequently. Those who rated themselves as sleepy or likely to fall asleep had a more than 9-fold increase in the hazards of a centerline crossing compared to those who rated themselves as alert. The research shows clearly that drivers can detect changes in their levels of sleepiness sufficiently to make a safe decision to stop driving due to sleepiness. Therefore, road safety policy needs to move from reminding drivers of the signs of sleepiness and focus on encouraging drivers to respond to obvious indicators of fatigue and sleepiness and consequent increased crash risk.

It is well-known that fatigue affects our ability to perform. Fatigue is an acknowledged road safety hazard of a similar magnitude to alcohol while driving (Transport for NSW, 2011) and is involved in around 19% of fatal crashes in NSW (Transport for NSW, 2011) and 31% of fatal crashes where three or more people are killed (Roads and Traffic Authority (RTA), 2001). Other countries show similar statistics including the UK where fatigue is attributed to up to 20% of crashes (Jackson et al., 2011) and the USA with 16.5% of fatal crashes involving drowsy driving (American Automobile Association Foundation for Traffic Safety, 2010). Surveys of drivers report that the experience of sleepiness while driving is common, with more than half of French (57.3%) and US (64%) drivers questioned reporting drowsiness or sleepiness at the wheel over the past 12 months (Philip et al., 2010; Swanson et al., 2012) which has been associated with higher risk of self-reported sleep-related crashes (Connor et al., 2002; Sagaspe et al., 2010).

Fatigue and sleepiness are related states that in many studies of driving performance are not differentiated; the term fatigue often encompasses sleepiness. In fact, the term fatigue is often used to describe an overarching category that includes sleepiness and other mental fatigue phenomena such as task-related fatigue, fatigue resulting from illness, etc. There is considerable debate over the definition and conceptualization of fatigue (Noy et al., 2011) and the extent to which it should be distinguished from sleepiness (Balkin and Wesensten, 2011). Part of the problem is that although the antecedents of fatigue and sleepiness may be argued to be different, their effects on subjective feelings of loss of alertness and tiredness and on performance are similar. The causes of sleepiness uniquely relate to sleep (i.e., amount, quality, time since awakening and time of day effects) whereas the causes of fatigue can relate to task-related factors (i.e., duration and workload) as well as sleep-related factors. In this paper, both terms are used but the primary focus of the study is on understanding awareness of sleepiness.

Managing fatigue (including sleepiness) is not a simple matter for road or workplace safety. Unlike other road or work safety problems, there are no clear exposure limits and fatigue management

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approaches often take the form of guidance rather than prescribing specific actions through regulation. Fatigue management strategies on the road and in the workplace involve driving or working hours limits and advice that people take breaks when they feel tired. A major assumption inherent in this advisory approach is that drivers have access to cognitive information about their personal levels of fatigue and drowsiness that allow them to make the decision to stop and rest before their performance is too adversely affected that their safety becomes compromised. There is considerable debate about the validity of this assumption.

Research suggests that people can detect decreasing alertness and increasing fatigue and sleepiness. Many studies have shown the expected decreases in alertness and increases in self-rated fatigue and sleepiness when sleep deprived (Dinges et al., 1997), when required to work at vulnerable times in the circadian rhythm (Monk, 1991) or for prolonged periods without a break (Rosa and Colligan, 1988). One study (Nilsson et al., 1997), showed that under simulation conditions drivers can make a judgment about when they should stop driving due to fatigue, apparently based on their physical symptoms. Interestingly, driver ratings of fatigue at the time they stopped were very similar, no matter whether the drive had been for only 40 min, or for as long as 180 min. This study suggests that drivers can detect changes in fatigue but it is not clear when performance effects begin for a fatigued person and whether fatigued people have the capacity to detect the effect of these changes in state on performance. These are critical questions for safety. It may not be enough simply to be aware of changes in alertness or feelings of fatigue and sleepiness. Drivers need to be able to detect and, importantly, to respond to changes which have impact on their capacity to drive safely.

Unfortunately, the evidence on the relationship between changes in alertness and sleepiness-related states and performance effects is equivocal. There is some evidence that increasing self-reported sleepiness is related to poorer performance in driving tasks. For example, Reyner and Horne (1998) showed in a driving simulator that increasing subjective sleepiness was significantly associated with an increase in the number of safety-related incidents. Horne and Baulk (2004) also found that subjective sleepiness, EEG-recorded sleepiness and lane deviations in a driving simulator were highly correlated. In contrast, some laboratory studies have shown that self-rated alertness or fatigue is significantly correlated with *self-rated* performance but that the correlation of changes in these attributes with changes in actual performance is only moderate at best (Dorrian et al., 2000, 2003). In addition, some on-road studies found no association between self-assessed fatigue and a number of non-driving performance measures (Williamson et al., 2000) or a set of driving-related performance measures (Belz et al., 2004). Further research is needed to clarify when performance effects begin to occur and become noticeable for a fatigued person.

A number of studies have highlighted the differentiation between detecting fatigue and sleepiness and deciding when these experiences might lead to falling asleep and potentially to crashing. Horne and Reyner (1999) found that drivers underestimated the probability of falling asleep when sleepy and seemed to underestimate their likelihood of crashing. There is also recent evidence that even partially sleep-deprived people who are sitting quietly in a darkened room doing a task requiring them to predict how close they are to falling asleep have limited ability to predict when they are going to first fall asleep (Kaplan et al., 2008). In fact it seems that people may not be able to tell when they are in the early stages of sleep. There is evidence that people overestimate the time they take to fall asleep and they can be in the early stages of sleep without being aware of it Baker et al. (1999).

It seems that drivers can detect that they are increasingly becoming fatigued or drowsy, but may be less able to respond to these sensations at the appropriate time by discontinuing what they are doing and taking a rest break. Current solutions to the problem of managing driver fatigue for road safety rely on ill-defined relations between drivers' judgments of their subjective state and their behavioural capacity. If we are to make an impact on driver fatigue, we need to know whether the current advisory approach can be successful. Unlike the issue of drink driving which can be addressed at least in part by proscribing drivers' alcohol consumption and for which there is a clearly defined dose-response relationship between alcohol use and performance effects (Holloway, 1995), for fatigue, the problem is not so clear cut. While we know a considerable amount about what causes fatigue and can make some predictions about when it might occur, our predictions are not perfect. This means that it is not sufficient to simply tell drivers that they must not drive during vulnerable periods such as the middle of the night, or when they have not had enough sleep or have been driving for too long. Such prescriptions need more research before they could be implemented as limits that will have the desired effect of keeping tired drivers off the road and allowing alert drivers to drive. In the meantime, drivers are advised to take a break from driving when tired and to sleep or nap before fatigue and sleepiness begins to affect their driving skills. This approach assumes that drivers have access to cognitive information about their levels of fatigue and sleepiness and are able to make the decision to stop and rest before their performance is sufficiently adversely affected that their risk of crashing becomes too high. As discussed above the validity of this assumption is extremely questionable.

Clearly, a study is needed that explores the relationships between driver awareness of fatigue and sleepiness and the perceived risk of crashing and their likelihood of actually crashing. This was the aim of the current study: to investigate the extent to which we have access to cognitive information about our current fatigue state and levels of sleepiness, and the implications of having access for detection of changes in driving performance and the likelihood of crashes. This study looked at the relationship between driver ratings of sleepiness, likelihood of falling asleep and likelihood of crashing measured at intervals and at driving performance throughout a 2 h simulator drive. The study design extended earlier work by Reyner and Horne (1998) by adding an additional condition to investigate whether drivers can detect changes in crash likelihood as well as sleepiness state and sleep propensity and looked at the relationship between these subjective ratings and driving simulator performance. The study also examined whether the need to make subjective ratings across the drive influenced reported experiences of sleepiness and driving performance.

Table 1
Details of the characteristics of the three conditions assessed in this study.

Condition	Characteristics
Condition 1: button press only	Unprompted button press for crash likelihood, no subjective ratings
Condition 2: three ratings only	Prompted subjective ratings for Karolinska sleepiness scale (KSS), likelihood of falling asleep, likelihood of crashing
Condition 3: two ratings, button press	Prompted subjective ratings for Karolinska sleepiness scale (KSS) and likelihood of falling asleep, unprompted button press for crash likelihood

1. Methods

1.1. Study design

The study involved three conditions (see Table 1), each completed by a separate group of 30 participants. Condition 1 (Unprompted button press) was designed to determine whether