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Falling asleep whilst driving: are drivers aware of prior sleepiness?

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Abstract Falling asleep at the wheel is a common cause of road accidents, but little is known about the extent to which drivers are aware of their sleepiness prior to such accidents. It is an area with medico-legal implications. To simulate this situation 28 healthy young adult experienced drivers, sleep restricted the night before drove for 2 h in the afternoon in an interactive real-car simulator incorporating a dull and monotonous roadway. Lane drifting, typifying sleepy driving, was subdivided into minor and major incidents, where the latter was indicative of actually falling asleep. A distinction was made between the subjective perceptions of sleepiness and the likelihood of falling asleep which drivers reported separately. Increasing sleepiness was closely associated with an increase in the number of incidents. Major incidents were preceded by self-awareness of sleepiness well beforehand and typically, subjects reached the stage of fighting sleep when these incidents happened. Whilst the perceived likelihood of falling asleep was highly correlated with increasing sleepiness, some subjects failed to appreciate that extreme sleepiness is accompanied by a high likelihood of falling asleep. It was not possible for our subjects to fall asleep at the wheel and have an "accident" without experiencing a sustained period of increasing sleepiness, of which they were quite aware. There is a need to educate at least some drivers that extreme sleepiness is very likely to lead to falling asleep and a high accident risk.

Key words Sleepiness · Driving · Accidents · Driver awareness

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Introduction

Falling asleep at the wheel is a common cause of vehicle accidents on dull and monotonous roads [1, 2]. These accidents carry a higher risk of death and serious injury as often the impact is at high speed [1]. One might wonder why drivers allow themselves to fall asleep, whether they are aware of sleepiness prior to the accident and whether it is possible to fall asleep at the wheel without any forewarning of sleepiness? This has medico-legal implications for driver liability and is important for accident prevention. After such accidents drivers asked whether they had fallen asleep at the wheel tend to deny it. Possible reasons include embarrassment to admit to what may be viewed as "bad driving", incriminating oneself or losing insurance indemnity. On the other hand, the driver genuinely may have no recollection of having fallen asleep, not necessarily because of the trauma of the accident. Laboratory studies show that subjects who fall asleep typically deny having been asleep if awoken within 2 min [3] and that, subjectively, sleep onset appears to be a relatively lengthy period during which the perception of sleep is blurred and uncertain [3]. As a driver cannot remain asleep for more than a few seconds without having an accident, this may account for why such recollection is poor in drivers having had sleep-related accidents.

Whilst these drivers may not acknowledge having fallen asleep, it is more likely that they were aware of the precursory feeling of sleepiness. In the only published study [4] to monitor subjective sleepiness in healthy, sleepy drivers whilst they were driving, the authors noted that all their subjects were aware of their lowered arousal, and those who fell asleep had to fight sleep beforehand and in doing so knew the risk of falling asleep. Unfortunately, the study [4] was extreme in that driving continued for many hours until the drivers fell asleep. These findings from drivers whilst driving contrast with two other related studies [5, 6] asking drivers to think back often weeks, months, and even years after a sleepiness-related driving accident, where it was claimed that drivers who fall asleep

at the wheel can have no foreknowledge of sleepiness and for them the sleep episode was a surprise [5, 6]. But this conclusion was based on the same misleading questions used in both studies. One being the ambiguous and seemingly unanswerable, "while driving I become drowsy before I am aware of it", which does not differentiate between knowledge of prior sleepiness and knowledge of having fallen asleep. The other question, "I have gone to sleep for short periods while driving without being aware that I am going to sleep", only enquires about having fallen asleep, not prior sleepiness. To our knowledge, there are few, if any other relevant published reports.

Our study assessed the association between subjective sleepiness and driving impairment in sleepy drivers driving a full-size, interactive car simulator, and under moderate conditions of sleepiness. We also examined the progress of sleepiness prior to falling asleep and the possibility that drivers who feel very sleepy misperceive or disassociate this from the perceived likelihood of actually falling asleep. We present unreported data from nil-treatment conditions forming part of a series of studies evaluating countermeasures to driver sleepiness [7, 8], each following a standard experimental protocol.

Materials and methods

Subjects

Most sleep-related vehicle accidents occur in young adults [9] and we targeted this group. A total of 28 (14m + 14f, mean age 24 y [s.e. = 2.0y]), healthy, medication-free, experienced drivers (driving > 2 years, averaging > 3 h per week), good sleepers, sleeping regular hours and infrequent daytime nappers (< once a month), were recruited by advert, screened by interview, had the procedures explained, signed consent forms, and were paid to participate. The study had been approved by our University's ethical committee.

Design and procedure

On a preparatory day subjects underwent a 2 h practice drive on the car simulator, and later underwent three afternoon, randomised treatment conditions (1 week apart), including the nil-treatment condition on which this report is based. Afternoon sleepiness was enhanced by sleep restriction to 5 h (delayed bed-time) the night before. Subjects slept at home, with sleep monitored by wrist-actimeters [10]. The 2 h driving period began at 14:30 h. Subjects drove an immobile car having a realistic, interactive computer-generated full-scale front projection of a dull and monotonous dual-lane roadway with gentle bends (see ref 10 for details). Subjects drove at their normal cruising speed within white lane markings. Lane drifting is the usual manifestation of sleepy driving and two levels were identified from continuously logged steering data: 1) "Minor incident"- when a car-wheel crossed a lateral lane marking, and 2) "Major incident" – when all wheels ran out of the lane. Our previous work using EEGs [10] showed that the latter are almost invariably due to falling asleep, whereas the former are linked to drowsiness. Every 200s subjects gave verbal (number or letter) responses to two scales:

Sleepiness. Using the 9-point Karolinska Sleepiness Scale (KSS) [11]: 1 = extremely alert, 2 = very alert, 3 = alert, 4 = rather alert, 5 = neither alert nor sleepy, 6 = some signs of sleepiness, 7 = sleepy, no effort to stay awake, 8 = sleepy, some effort to stay awake, 9 = very sleepy, great effort to keep awake, fighting sleep.

Likelihood of falling asleep. To the question "what is the likelihood of you falling asleep during the next few minutes", they responded: A = very likely, B = likely, C = possibly, D = unlikely, E = very unlikely.

Results

The circadian mid-afternoon peak in sleepiness was clearly apparent in most subjects, with an initial rise in all parameters, peaking around 1600 h and then declining. Table 1 gives the percentage of total time spent in each subjective sleepiness category, subdivided by likelihood of falling asleep (total = 1008 responses). Of the driving time 60% was spent in KSS categories 7–9. Increasing KSS levels were highly significantly correlated with an increased likelihood of falling asleep (Pearson's r = 0.78; df = 1043; $P = 0.001$ [n.b. one scale has 9 divisions and the other 5, which will create statistical "noise"]). However, there were obvious deviations, for example at KSS = 8 ("sleepy, some effort to stay awake"), most subjects believed that falling asleep was likely, but on 18% of these

Table 1 Percentage of total time in each sleepiness rating, subdivided into categories of likelihood of falling asleep. (28 subjects, each driving for 2 h). Increasing sleepiness is generally perceived to be associated with increasing likelihood of falling asleep

KSS categories	% of epochs in response to'How likely are you to fall in asleep?'				
	Very unlikely	Unlikely	Possibly	Likely	Very likely
(1) Extremely alert	0.2	0.0	0.0	0.0	0.0
(2) Very alert	1.5	0.0	0.0	0.0	0.0
(3) Alert	4.4	0.4	0.0	0.0	0.0
(4) Rather alert	5.4	4.9	0.0	0.0	0.0
(5) Neither	5.0	5.4	0.5	0.0	0.0
(6) Some signs sleepness	5.5	3.5	3.2	0.1	0.0
(7) Sleepy but no effort to stay awake	2.8	3.7	7.6	0.2	0.0
(8) Sleepy but some effort to stay awake	0.6	4.1	15.8	5.0	0.5
(9) Very sleepy, great effort to stay awake	0.0	0.0	3.1	5.0	11.7

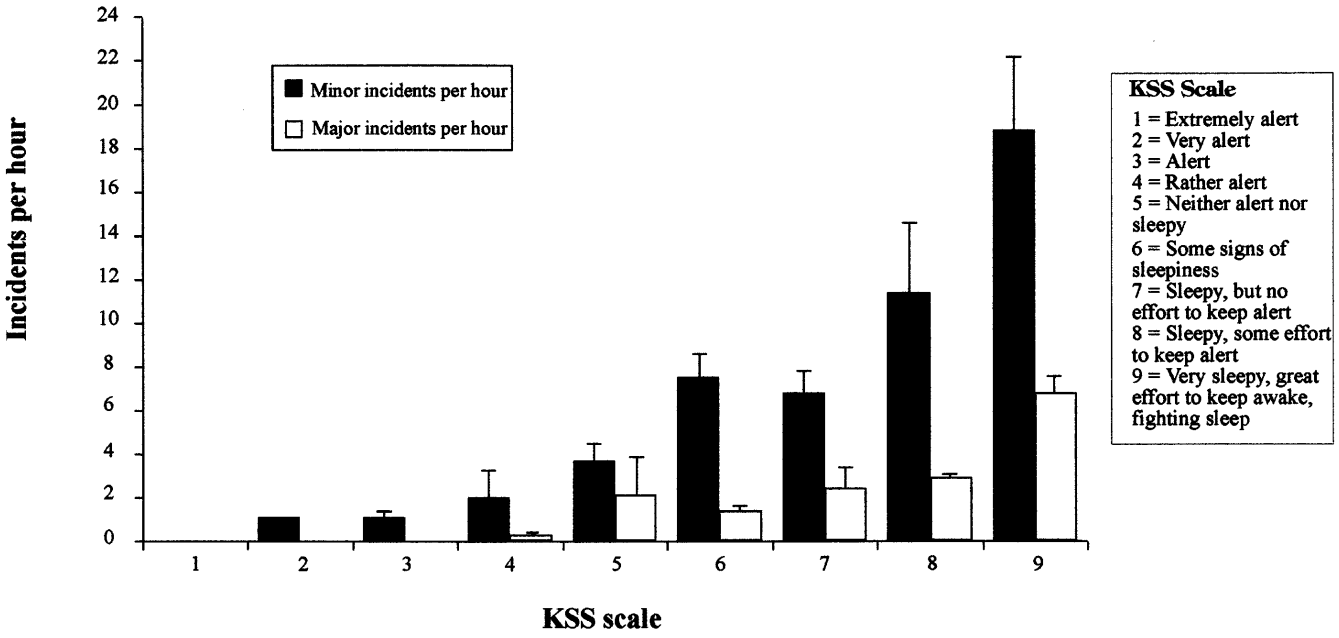

Fig. 1 Mean (and SE) major and minor incidents per hour for each sleepiness rating

occasions some still felt it to be unlikely or very unlikely, and it should be noted that a major incident occurred then. That is, subjects could underestimate the likelihood of falling asleep, despite feeling very sleepy.

Figure 1 shows major and minor incidents per hour within each sleepiness rating. Minor incidents increased to about three per hour with KSS = 5, which doubled when minimal sleepiness (KSS = 6) was reached. When subjects began to fight sleep (KSS = 8), minor incidents rose to about eleven per hour, rising sharply with KSS = 9. Over the total of 56 h of driving there were 80 major incidents due to falling asleep. Most (83%) happened with KSS = 8 or 9, and the few appearing when the subject declared no sleepiness (KSS ≥ 5) occurred within 15 min of when the driver had declared KSS of 8 or 9, but apparently assumed that sleepiness had remitted.

Of all the subjects 12 began the drive declaring themselves not to be sleepy, (i.e. KSS ≥ 5 – most began at 6), and then during the course of the drive had a major incident that was sleepiness related. In all cases the incident was preceded by a period of time when the subject acknowledged being sleepy – that is, there was a forewarning. Of these, 11 subjects declared KSS ratings of 8 or 9 prior to the major incident and for the other subject the declaration was KSS = 7. All 12 subjects had been at KSS = 7 or above for an average of 43.5 min (s.e. 13.8 min) before the major incident, 11 of whom had been at KSS = 6 or 7 for an average of 8.7 min (s.e. 1.7 min) before that. One subject went from KSS = 5 to KSS = 8 during a single 200 s epoch, but did not have the major incident until a further 56 min had elapsed. For all 12 subjects, the average time elapsing from when they declared at least some level of sleepiness (i.e. KSS ≥ 6) to the occurrence of the major incident, was 45.5 min (s.e. 12.7 min).

Discussion

In the Introduction a clear distinction was made between a driver having knowledge of having fallen asleep at the wheel and knowledge of the precursory feelings of sleepiness. Whilst it may be possible that a driver is unaware of the former, our findings clearly show that our sleepy drivers were aware of the latter, and whilst sleepy, generally had insight into the likelihood of falling asleep. However, when sleepiness seemed to subside, there could be an overestimate of alertness and a potential accident. As subjective sleepiness worsened, so did the number of incidents. Moreover, when subjects were fighting sleepiness, by declaring KSS ratings of 8 or 9, both the number of minor and especially major incidents worsened markedly. Major incidents were due to the more profound state of actually falling asleep at the wheel and were indicative of an accident. All happened after many minutes of self-reported sleepiness, and usually after a lengthy period of fighting sleep.

Our drivers underwent modest sleep restriction on the night prior to their drive, which exacerbated the natural mid-afternoon circadian peak in sleepiness [12]. Had we used fully sleep-satiated drivers then afternoon sleepiness would have been minimised, which would have defeated the point of the study. However, it should be remembered that many sleep-related accidents occur at this time of the day [1, 2, 12, 13], presumably in drivers not sleep-satiated.

Ideally, this research would be undertaken on real roads, but this is unacceptably dangerous for everybody. Nevertheless, our experimental setting and findings might be considered too artificial for comparison with real driving which embodies this danger and highly motivates

drivers to keep awake. As our drivers were not so worried about staying within the lane and having minor and major incidents, they probably had far more incidents for any given level of sleepiness than had they been on a real motorway. Thus, it is likely that our estimates of the time elapsing from our drivers first noting sleepiness to having a minor or major incident, are less than would be the case than if they were really on the road. That is, our estimates are probably conservative.

It might be argued that by asking our subjects periodically to report on their sleepiness we may have heightened their perception of sleepiness, otherwise they may not have been so aware of it. This could be so, but it implies that when drivers ask themselves whether they are sleepy, they may become more aware of any sleepiness. Hence, educating drivers about the dangers of driving whilst sleepy may prompt them into asking this question of themselves more often, and in doing so help prevent these accidents.

Our subjects did not fall asleep at the wheel without prior warning of sleepiness. However, as some subjects failed to realise that fighting sleep portended falling asleep and a potential accident, then it would seem prudent that not only should drivers be warned about the dangers of driving whilst sleepy, but that the likelihood of falling asleep at the wheel at a given level of sleepiness may be greater than one might realise.

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