



Driver sleepiness (No.21)

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BACKGROUND

From accident surveys undertaken with many UK police forces we have found that sleepiness accounts for 15-20% of accidents on monotonous roads, especially motorways ^[1]. Typically, these accidents involve running off the road or into the back of another vehicle, and are worsened by the high speed of impact (i.e. no braking beforehand). Many of these accidents are work-related (e.g. trucks, goods vehicle and company car drivers).

The body's natural biological clock has a major influence on sleepiness, as these accidents peak around 02:00h-07:00h and 14:00h-16:00h, when daily sleepiness is naturally higher ^[1].

Sleep-related vehicle accidents are more evident in young male drivers in the early morning and among older male drivers during the mid-afternoon, as the afternoon "dip" tends to become more apparent as one gets older ^[2]. Of course, young men are more likely to be on the road in the early morning. However, as the effects of sleep loss and sleepiness are more profound in younger than in older people, which young men tend to deny, they are at a much greater risk when driving during the small hours.

Using a real-car simulator we have been undertaking laboratory studies of falling asleep at the wheel. In the earlier Phases 1 and 2 of this DETR sponsored research programme we examined the process of falling asleep at the wheel and the extent to which sleepy drivers are aware of their sleepiness. We also evaluated practical methods for the driver to overcome sleepiness. Our methodology has been validated on

a real driving track ^[3]. We have shown that sleep does not occur spontaneously without warning, and is preceded by feelings of increasing sleepiness ^[4] to the point that drivers who fall asleep would have reached the stage of "fighting-off" sleep when they will try and keep themselves awake, for example, by winding down the window for cold air, turning up the radio, stretching at the wheel, etc. They must be aware of these acts and their sleepiness at the time. Nevertheless, after having fallen asleep at the wheel, drivers are unlikely to recollect having done so, and may even claim that it was an unforeshadowed 'sleep attack'. What many sleepy drivers do not appreciate is that sleep itself can ensue more rapidly than they imagine, and that their driving impairment is worse than they realise ^[4]. Sleepiness can also cause mild euphoria and increased confidence in one's driving ability ^[2].

Continuing to drive whilst sleepy, and relying on cold air to the face and turning up the car radio, are of limited benefit ^[5] - effective for only a matter of minutes - sufficient only to enable the driver to find a safe spot to take a break. The fact that drivers are aware of their sleepiness underlies the decision of the DETR to instigate the erection of permanent signs on most motorways - 'Tiredness can kill - take a break'.

In taking a break (e.g. 30 minutes), what should the sleepy driver do? We have found that exercise (e.g. brisk walking) is of little use ^[6]. Short naps (less than 15 minutes) are very effective ^[7], as is caffeine (150mg - as in about 2 cups of coffee or two cans of 'functional energy drinks'). Better still, take this caffeinated drink and then take the nap ^[8]. Caffeine takes 20-30 minutes to be absorbed and act on the brain; hence there is the opportunity for a nap. Caffeine (200mg) in the form of a beverage is particularly good for the early morning driver having had little sleep that night ^[9]. These findings from Phase 1 and 2, concerning caffeine and naps, have been incorporated into the latest edition of the Highway Code.

KEY FINDINGS FROM PHASE 3

Our research has indicated that:

1. Sleep-related vehicle accidents (SRVAs) are more likely to result in serious injury than the 'average' road accident.
2. Few accidents we investigated seemed to have alcohol as a contributory cause.
3. Men aged 30 years and under are more likely to have a SRVA, and seem to be at a higher risk.
4. Drivers from skilled manual occupations are also more likely to have a SRVA, probably because of a higher exposure to driving.
5. Driving between 02:00h and 07:00h presents a particular risk for SRVAs, as this is when one's 'body clock' is in a daily trough. There is another, smaller trough between about 14:00h and 16:00h.
6. Low traffic density is probably not a major risk factor for SRVAs. It is the associated factors, such as driving in the early morning, during the 'trough', when traffic density also happens to be low.

7. About 40% of SRVAs are probably work-related, inasmuch as they involve commercial vehicles (HGVs, light goods vehicles and vans etc).
8. Sleepy drivers are aware of their sleepiness, particularly when they reach the stage of 'fighting sleep' (i.e. doing things to keep themselves awake, such as winding down the window).
9. Reaction time devices are of little practical use in detecting driver sleepiness.
10. Drivers already chronically, mildly sleepy (e.g. due to chronic levels of sleep disturbance or insufficient sleep), are more vulnerable to any transient, additional sleep loss, and may not so easily perceive this increase in sleepiness.
11. Caffeine (150mg) is an effective countermeasure to sleepiness, as is a short (less than 15 minutes) nap or doze. The two combined together (caffeine in the form of a caffeinated drink, then a nap) are particularly effective. The efficacy of these treatments will depend on the magnitude of the sleepiness. Even 'relaxing with the eyes closed' is worthwhile.
12. Sleep related accidents should no longer be viewed as 'accidents' but as road crashes due to easily preventable human error.
13. We feel strongly that driver education, linked to greater public awareness of the potential dangers of sleepiness, together with greater employer responsibility with regard to their employees' fitness to drive, present the best approaches for reducing sleep related crashes.

PHASE 3

Phase 3 of the research programme comprised five components:

- (1) Completion of the journal publication of research undertaken in Phase 2.
- (2) Further road accident audits to identify objectively the prevalence of sleep related vehicle accidents.
- (3) A pilot study to examine the usefulness of tachograph charts for detecting sleep related vehicle accidents.
- (4) Extension of the countermeasures research, to evaluate reaction time measures to detect driver sleepiness.
- (5) An investigation to ascertain whether 'naturally sleeper' individuals are more liable to show drowsy driving impairments.

1. Journal Publications

As well as producing reports of our work for the DETR, we endeavour to have our research published in "high impact", international scientific journals. The preparation and submission of manuscripts is a time consuming process requiring different presentation styles to those of DETR reports. Two papers [9, 10] from Phase 2 have recently been published, following extra preparation undertaken in Phase 3 (summaries in Appendix).

2. Further Road Audits

Following the M40 road audit undertaken in Phase 2 and an earlier, initial pilot study on the A180/M180, we have conducted two further audits on: i) a section of the M5 (between junctions 5 and 8) policed by West Mercia Constabulary, and ii) a larger scale, with North Yorkshire Police, involving four roads: A1(T), A1(M), A19(T)/ A168(T) dual carriageway and A19(T) single carriageway. All the audits covered the period 1st January 1997 until 31st December 1998. Full reports are with the DETR.

We have developed criteria [1] for determining whether a RTA is likely to be caused by sleepiness - i.e. a Sleep Related Vehicle Accident (SRVA):

1. Good weather conditions and clear visibility
2. Breathalyser/blood alcohol levels below the legal driving limit
3. No mechanical defects to the vehicle
4. Elimination of 'speeding' and 'driving too close to the vehicle in front'
5. Driver had no known medical disorder to cause accident
6. Vehicle either ran off the carriageway, or ran into another vehicle that was clearly visible for several seconds beforehand - i.e. the incident was easily avoidable, and implying prolonged inattention
7. No signs of pre-impact emergency swerving or braking e.g. no skid marks before the impact
8. The police officer at the scene suspected 'sleepiness'

If all criteria 1-7 applied then the accident was a 'possible' SRVA. The inclusion of criterion 8 classified it as a 'probable' SRVA. The absence of this last criterion when criteria 1-7 applied does not imply that the investigating officer excluded sleepiness. It should be noted that SRVAs are particularly likely to occur between approximately 02:00h and 07:00h, and 14:00h to 16:00h, when people are naturally more sleepy.

M5

This 18.7 mile section is artificially lit. There were 108 road traffic accidents (RTAs) involving slight injury, serious injury or death, to which the Police were summoned. All accident data held by the police were scrutinised. We determined that six were 'possible' sleep related vehicle accidents (SRVAs), and 16 were 'probable' SRVAs, making 22 in all, and comprising 20% of the total RTAs. Although only 5% of

total daily traffic flow occurred during late night/early morning hours, almost one third of the SRVAs occurred at that time. About half of these SRVAs were caused by cars. SRVAs were about twice as likely to result in death or serious injury compared with other RTAs on this road. Most (82%) of the drivers in SRVAs were men, and half were aged 30 years and younger. Almost half (41%) these drivers came from skilled manual occupations.

NORTH YORKSHIRE

This audit consisted of:

- 44 miles of unlit A1(M) and A1(T) from Wetherby to the River Tees (Darlington). The A1 is the major north/south route east of the Pennines.
- 24 miles of unlit A19(T)/A168(T) dual carriageway from Dishforth to Crathorne.
- 19 miles of A19(T) single carriageway, from the A1237(T) York Outer Ring Road, York, to Sowerby, where the A19(T) branches off the main A19(T)/A168(T) dual carriageway. There is intermittent road lighting.

North Yorkshire Police attended 572 RTAs on these roads, of which 16% were 'possible' or 'probable' SRVAs (except for the A19(T) single carriageway, which had a lower incidence of SRVAs). Compared with the daytime, about twice as many SRVAs occurred during the night/early hours of the morning (traffic flow was low) compared with the rest of the day. Put differently, half of all SRVAs happened then, compared with about 20% of all RTAs. As one might expect, the overall incidence of RTAs generally rose with increasing traffic density. However, the A1(T) was particularly bad in this respect, in having an unusually high rate of RTAs. Nevertheless, the proportion of SRVAs on this road remained at approximately 16%. Very few (less than 3%) RTAs were associated with driver alcohol levels beyond the legal limit. Clusters of SRVAs were found on the A1(M); more so on the A1(T) and the A19(T)/A168(T). Road characteristics may facilitate this clustering. 65% of SRVAs were caused by cars. Drivers in these SRVAs were more likely to:

- Sustain serious injuries than in RTAs as a whole.
- Be men (91%)
- Be aged 30 years and under (50%)
- Be employed in skilled manual occupations (41%).

Traffic Density - It is thought that road traffic density may affect driver sleepiness with, for example, a higher density providing greater stimulation for the driver and reducing the likelihood of sleepiness. Our findings from all our road audits do not support this assumption. For the types of non-urban roads we have assessed, the propensity to fall asleep at the wheel is largely dependent on the inherent state of the driver and not on the road conditions.

3. Tachographs & Sleep Related HGV Accidents

When people fall asleep muscle tone relaxes throughout much of the body. In sleepy drivers this can be reflected in the relaxation of foot pressure on the accelerator and, depending on the extent to which the accelerator spring forces the foot up, the vehicle may slow down. If the driver then becomes more alert, muscle tone is restored, foot pressure returns and the vehicle may speed up. Very sleepy drivers can drift in and out of this state of sleepiness/alertness, every few minutes, for some time. In the case of vehicles

equipped with tachometers, and when the driver is particularly sleepy, the possibility arises as to whether these devices reflect this periodicity, as well as a general slowing of speed. Of course this depends on a variety of other factors, such as traffic density, whether the vehicle is going uphill or downhill, the pressure required to depress the accelerator, and the presence of a speed limiter or use of a cruise control.

We analysed tachographs collected in the course of carrying out the road audits (above). All the tachographs were from HGVs having caused an RTA. Without knowing the accident causation (i.e. SRVA Vs non-SRVA) tachographs were studied 'blind', by examining the patterns of speed fluctuations and the time taken for changes in acceleration and deceleration in the final 15 minutes. The likely cause of the accident was then revealed. Findings were unclear, especially as most vehicles had speed limiters set at about 56 mph. Given that many HGV drivers with speed limiters drive with their accelerator near to the floor, then relaxation of the foot, as with sleepiness, still leaves the accelerator depression beyond the level of cut-off for the speed limiter (i.e. no slowing). It was concluded that tachographs can not be used as a reliable indicator for SRVAs. Whilst fluctuations in speed shown on tachographs may be the result of a sleepy driver losing and regaining muscle tonus in the foot, these may be for other reasons. Also, the recent compulsory introduction of speed limiters further militates against this use of tachograph data for the purpose of detecting sleepiness.

4. Reaction Time Measures to Detect Driver Sleepiness

A driver's response time in braking in an emergency is generally thought to be impaired by sleepiness (although there is little good evidence to support this notion - [11], [12]), and reaction time (RT) used as an artificial task secondary to driving has been seen to be a good method for monitoring sleepiness. RT can be measured by means of the driver pushing a steering-wheel switch or a foot operated button in response to stimuli generated from within the vehicle. However, laboratory studies [11] indicate that a sleepy driver will either respond almost normally to an emergency or not at all (hence a collision). That is, response time becomes disrupted by sleepiness rather than reflects a gradual decline. This has been clearly demonstrated outside the field of driving, whereby deterioration in RT performance with sleepiness is reflected only in a portion of responses being impaired, often through momentary lapses [13]. Thus, the majority of responses, even in sleepy people, usually remain within normal parameters.

In sum, little is known about what might be expected with RT as a secondary task in moderately sleepy drivers who otherwise show impaired driving (lane drifting) and declare themselves to be sleepy. Unfortunately, lapsing detected by these RT methods may be too late for a speeding driver to avoid a collision, as the vehicle may already be running off the road during the lapse. On the other hand, a RT response within normal parameters, even in a sleepy driver, will be of little use in detecting sleepiness. Another issue concerning the application of RT as a secondary task during monotonous driving is that the very act of responding to the RT stimuli could have an arousing effect, particularly if the stimuli are frequent. Whilst this might seem to be advantageous, it masks underlying sleepiness and causes RT to be less sensitive to sleepiness.

With these viewpoints in mind we further evaluated simple RT as a secondary task to determine sleepiness in drivers and/or whether it otherwise affected driving behaviour in moderately sleepy people. They drove our real-car interactive simulator for two, 2-hour afternoon monotonous drives, with and without RT (counterbalanced). Lane wandering (driving 'incidents'), subjective and EEG measures of sleepiness were obtained. For both conditions all three of these latter measures worsened during the course of the afternoon circadian 'dip'. However, this was not reflected in RT, which remained relatively stable. In fact,

RT did provide more 'stimulation' for the sleepy driver, and significantly reduced subjective sleepiness, with a trend for fewer incidents and a more alert EEG. We concluded that RT did not provide a useful guide to driver sleepiness; it was merely a mechanism for increasing task load and reducing monotony. That is, the more the sleepy driver has to keep him/herself occupied, the lesser the adverse effects of sleepiness. Also clear from the findings was that the drivers' own insight into their sleepiness was better than RT in this respect.

TESTING OF A COMMERCIALY AVAILABLE RT DEVICE

Despite the doubtful validity of such RT devices, commercial products are coming on to the market. These may be problematic as they may simply encourage sleepy drivers to take further risks and continue to drive, with drivers believing that the device will alert them when necessary. We tested one such device that was claimed by the manufacturers to fulfil two functions: a) maintain/improve driver alertness by requiring immediate responses (via a foot switch) to frequent audio bleeps, and b) to monitor driver RT and, if responses slowed down, warn the driver by emitting a loud warning alarm. Utilising our driving simulator and standard driving protocol, sleepy drivers drove for two hours continuously, on three occasions: twice using the device (to measure adaptation effects) and once as a control condition without the device. There was no clear evidence that the device reduced driving errors due to sleepiness. Instead, it caused more driving errors, as it seemed that during moderate sleepiness, responding to the frequent tone caused distraction and increased lane wandering.

5. Driving Ability in 'Sleepier' or 'Alert' People Within Normal Limits of the Epworth Scale

The Epworth Sleepiness Scale (ESS) is a commonly used self-assessment tool for assessing chronic (trait) levels of sleepiness. Scores of 10 or under are regarded to be within the normal range, and largely exclude those people with pathological, excessive daytime sleepiness, such as those suffering from obstructive sleep apnoea. In a large survey of UK car drivers, Maycock [14] included the ESS, and reported that those respondents who did not snore, but had ESS scores higher in this range (i.e. more sleepy but probably without any serious sleep disorder), had a greater accident tendency than those with low ESS scores. Although Maycock could not establish whether this increased tendency was associated with sleep related accidents rather than with accidents in general, it does suggest a link.

We were able to address this issue further using our database from our various driving simulator studies, as we administer the ESS routinely to all volunteers as part of the selection process, to include only those people within the 'normal' range of trait sleepiness. We have data on 68 participants within the ESS range of 0-10. We selected the 10 most alert and 10 most sleepy within this range. They were studied during afternoon driving following a normal night's sleep and after a night of restricted sleep, which causes afternoon sleepiness to be increased. We found no differences in sleep-related lane drifting and subjective sleepiness between the 'more alert' and 'sleepier' groups, although there were trends with respect to the sleepier group showing more lane drifting following sleep restriction. However, of some concern was that the sleepier group tended to perceive themselves to be relatively less sleepy than the alert group following the sleep restriction. That is, unlike the alert group, they failed to realise the extent of their increased

sleepiness, as perceived changes in sleepiness appear to depend on one's general (trait) frame of reference. This may become more evident in people having ESS scores beyond the norm.

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APPENDIX

RECENT PAPERS

Horne J & Reyner L (1999) Sleep related accidents: a review. *Occupational & Environmental Medicine*, Vol. 56: 289-294. (Impact factor = 2.0)

Summary

Falling asleep whilst driving accounts for a significant proportion of vehicle accidents under monotonous driving conditions. Many of these accidents are work-related (e.g. trucks, goods vehicle and company car drivers). Time of day (circadian) effects are profound, with sleepiness being particularly evident during night-shift work, and driving home afterwards. Circadian factors are as important in determining driver sleepiness as is the duration of the drive, but only the latter is built into legislation protecting professional drivers. Older drivers are also vulnerable to sleepiness in the mid-afternoon. Possible pathological causes of driver sleepiness are discussed, but there is little evidence that this factor contributes significantly to the accident statistics. Sleep does not occur spontaneously without warning. Drivers falling asleep are unlikely to recollect having done so, but will be aware of the precursory state of increasing sleepiness; probably reaching a state of fighting off sleep prior to an accident. Self awareness of sleepiness is a better method for alerting the driver than in-vehicle automatic sleepiness detectors. None of the latter are of proven reliability and most have shortcomings. Putative countermeasures to sleepiness, adopted during continued driving (e.g. cold air, use of car radio) are only effective for a short while. The only safe countermeasure to driver sleepiness, particularly when the driver reaches the stage of fighting sleep, is to cease driving and, for example, take a 30 min break encompassing a short (

Reyner LA & Horne JA (2000) Early morning driver sleepiness: effects of 200mg caffeine *Psychophysiology*, Vol. 37: 251-256. (Impact factor = 3.00)

Summary

Sleep-related vehicle accidents are prevalent early morning, especially in younger drivers. In two independent studies following a night of either restricted or nil sleep, young experienced drivers drove for 2h (0600-0800h) continuously in an immobile car on an interactive, computer-generated dull and monotonous roadway. This followed ingestion (at 0530h) of 200mg caffeine (=2-3 cups coffee) Vs placebo, counterbalanced, double blind. Driving incidents (lane drifting), subjective sleepiness, and 4-11Hz EEG activity were logged. Study 1 (sleeping 0000-0500h): caffeine significantly reduced incidents and subjective sleepiness throughout the 2h drive, and EEG power for the second 30min period. Study 2: (no sleep) sleepiness profoundly affected all measures, and driving was terminated after 1h. Nevertheless, caffeine significantly reduced incidents for the first 30 min and subjective sleepiness for the hour. This caffeine dose, feasibly taken via coffee, effectively reduces early morning driver sleepiness for about 30min following nil sleep, and for around 2h after sleep restriction.

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A Survey of Public Education Literature Regarding Driver Sleepiness (*Adobe Acrobat 1.6mb*)

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