Prolonged nocturnal driving can be as dangerous as severe alcohol-impaired driving

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SUMMARY In industrialized countries one-fifth of all traffic accidents can be ascribed to sleepiness behind the wheel. Driver sleepiness can have many causes, including the use of medicinal drugs or prolonged driving. The present study compared the effects of prolonged highway driving at night with driving impairment caused by alcohol. A cross-over balanced design tested 14 healthy young men who drove three sessions during night-time on the open road. The driving sessions were of 2, 4 and 8 h (03:00–05:00, 01:00–05:00 and 21:00–05:00 hours) duration. Standard deviation of lateral position (SDLP, cm), measuring the weaving of the car in the last driving hour of each session, was the primary parameter. Only 2 h of continuous nocturnal driving were sufficient to produce driving impairment comparable to a blood alcohol concentration (BAC) of 0.05%; after 3 h of driving impairment corresponds to a BAC of 0.08%. In conclusion, a maximum of two continuous nocturnal driving hours should be recommended.

KEYWORDS alcohol, driver sleepiness, fatigue, nocturnal driving, standard deviation of lateral position, traffic safety

INTRODUCTION

Driver sleepiness is one of the primary causes of accidents on highways. Inattention and reduced concentration compromise traffic safety and may even cause sleepy drivers to fall asleep behind the wheel. In industrialized countries, sleepiness at the wheel accounts for 20% of all traffic accidents (Philip and Åkerstedt, 2006).

Nocturnal driving is particularly recognized as a major risk factor for traffic accidents (Connor *et al*., 2002; Pack *et al*., 1995). Until the present, transport legislation does not take into consideration the interaction between maximal continuous duration of driving and time of day. This is unfortunate, because many people drive at night, either for private or professional reasons (Mitler *et al*., 1997; Philip *et al*., 1999).

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The number of reported sleep-related accidents is probably an underestimation of the true frequency (Rosekind, 2005). This is caused partly by the fact that policy makers and law enforcers generally find it difficult to assess driver sleepiness objectively: unlike breath alcohol devices, police have no adequate methods to determine driver sleepiness. Instead they have to rely on subjective assessment of the driver's appearance, driving style or related information, such as reported duration of driving. Of concern, drivers themselves are sometimes unaware of sleepiness, reduced alertness and corresponding impaired driving (Horne and Baulk, 2004). Moreover, drivers often do not acknowledge the risk of sleepiness behind the wheel (Devoto *et al*., 1999; Horne and Reyner, 1999). Large surveys have shown that about one-third of drivers report nodding off or falling asleep during driving at least once during their life (Gallup Organization, 2003). Approximately half the respondents of the Sleep in America Poll reported that sleepiness did not prevent them from driving (National Sleep Foundation, 2002). Unfortunately, commonly applied countermeasures such as playing loud music or opening the window are of limited use, and have a short effective duration. The single effective countermeasure seems to be stopping driving when one feels tired (Horne and Reyner, 1999; Verster *et al.*, 2009).

A recent study (Sagaspe *et al.*, 2008) showed that extended driving at night significantly impairs performance by increasing the number of inappropriate line-crossings. Previous research has shown that these line-crossings are predictors of potential future accidents (Powell *et al.*, 2007). In an earlier study, Dawson and Reid (1997) compared the effects of alcohol versus extensive wake duration in healthy subjects performing a simple reaction-time task. They showed that 17 h of wake equals a blood alcohol concentration (BAC) of 0.05% and 24 h of wake equals a BAC 0.10%. This study was a first attempt to translate the impact of poor sleep hygiene on driving risk into well-known legal levels of risk (i.e. BAC levels). Unfortunately, this experiment did not test driving on a public highway in normal traffic and did not include time on tasks in the data analysis. Most on-the-road driving studies use the standard deviation (SD) of lateral position (SDLP) as the primary test parameter. The SDLP is a measure of the weaving of the car. SDLP increases when driving is impaired; for example, when drivers experience somnolence (Ramaekers, 2003). A dose-dependent SDLP increment has been found after administration of alcohol (Louwerens *et al.*, 1987). SDLP increments (relative to placebo) were computed for common legal limits for driving; for example, the SDLP increment after BAC 0.05% was 2.4 cm, and the SDLP increment after BAC 0.08% was 4.1 cm. Interpreting the SDLP increments produced by psychoactive medication (or other experimental manipulator) with these BAC levels illustrates clearly the magnitude and relevance of driving impairment. Based on Louwerens' data, the corresponding BAC can be obtained using Menzin *et al.*'s (2001) formula:

$$BAC = \{\ln[(16.74 + \Delta SDLP)/16.74]\}/2.9$$

It should be taken into account that individual differences (e.g. gender and weight) influence the actual BAC obtained after consuming alcohol and the impact of alcohol on driving performance. Nevertheless, Menzin *et al.*'s formula gives a useful estimate of the average SDLP increment that can be expected after alcohol consumption.

The purpose of the present study was to compare the effects of prolonged nocturnal highway driving with driving impairment (SDLP increment) observed at different BACs.

METHODS

Participants

Fourteen young healthy men [mean age (±SD) = 23.4 (±1.7) years, range 21–25 years, mean yearly driving distance (±SD) = 14 250 (±4 660) km] participated in the study. Subjects were interviewed by a sleep specialist to check inclusion and exclusion criteria (see Sagaspe *et al.*, 2008). In addition, polygraphy was performed to determine sleep disturbances. Subjects sleep was monitored for 7 days before inclusion in the study. Actimeters (Actiwatch®; Cambridge Neurotechnology, Cambridge, UK) were used to check compliance to the protocol by quantifying sleep duration, nocturnal sleep episodes and duration of awakenings.

Time in bed was also computed as the time difference between going to bed in the evening and getting up in the morning. Sleep efficiency was calculated as the ratio of time asleep to the time in bed, in percentage.

During the study, subjects were instructed to maintain a regular sleep–wake schedule, i.e. to sleep from 23:00 to 07:00 hours the night before driving. This was monitored by actimetry during the 3 days proceeding each test day. Subjects were included if they had a mean sleep efficiency of at least 85% during the 3 days of recordings. No stimulant of any kind was allowed during the study. On test days, sleeping was not allowed (and prevented by study personnel) until the start of the driving session.

Study design

The study by Sagaspe *et al.* (2008) was designed to be the first to use a dose–response duration of driving design while controlling for effects of prior time awake, prior sleep time and time of day.

The study had a cross-over balanced design, with all participants having three nocturnal driving sessions on a public highway. Subjects drove (i) a short session of 230 km (143 miles) from 03:00 to 05:00 hours (2 h of driving), (ii) an intermediate session of 460 km (286 miles) from 01:00 to 05:00 hours (4 h of driving) and (iii) a long session of 920 km (572 miles) from 21:00 to 05:00 hours (8 h of driving). At least 5 days elapsed between two sessions. Driving took place on a straight, two-lane highway on weekdays under comparable (light) traffic and weather conditions.

Subjects were instructed to maintain a constant speed (130 kph; 80 mph) and steady position in the middle of the traffic lane. The same section of 115-km highway was driven in one direction and then back for the short condition. For the intermediate condition, two laps were driven and for the long condition, four laps were driven.

Subjects were instructed not to cross the lane borders, except to overtake a slower vehicle. During the whole experiment, a professional driving instructor equipped with dual controls monitored the safety of the participants. In order to allow sufficient rest for the co-pilots, three instructors alternated every 2 h of driving during the 8-h driving condition.

The car used for the experiment was equipped with a video recording system, which measures and registers 10 times s^{-1} the lateral position of the vehicle from the right lateral lane marker of the road. The primary parameter of the test was the SDLP (cm), i.e. the weaving of the car. SDLP values of the last hour of each driving session (04:00–05:00 hours) were compared. Statistical analysis was performed applying analysis of variance (ANOVA) for repeated measures. SDLP values were then converted to blood alcohol concentration (BAC) levels applying Menzin *et al.* s (2001) formula.

The study protocol was approved by the local ethics committee (Comité de Protection des Personnes Sud-ouest et Outre-mer III de Bordeaux).

RESULTS

Standard deviation of lateral position values increased during prolonged night-time driving ($F_{2,12}$ = 5.04, P < 0.026). Significant differences relative to the second hour of driving were found for the fourth hour of driving ($F_{1,13}$ = 5.31, P < 0.038) and eighth hour of driving ($F_{1,13}$ = 9.88, P < 0.008). No significant difference was found between the fourth and eighth hours of driving.

Fig. 1 shows a clear relationship between hours of driving and SDLP increment (R^2 = 0.87, y = 23.6.1$x^{0.14}$). Also included in Fig. 1 are the most common legal limits for driving for alcohol.

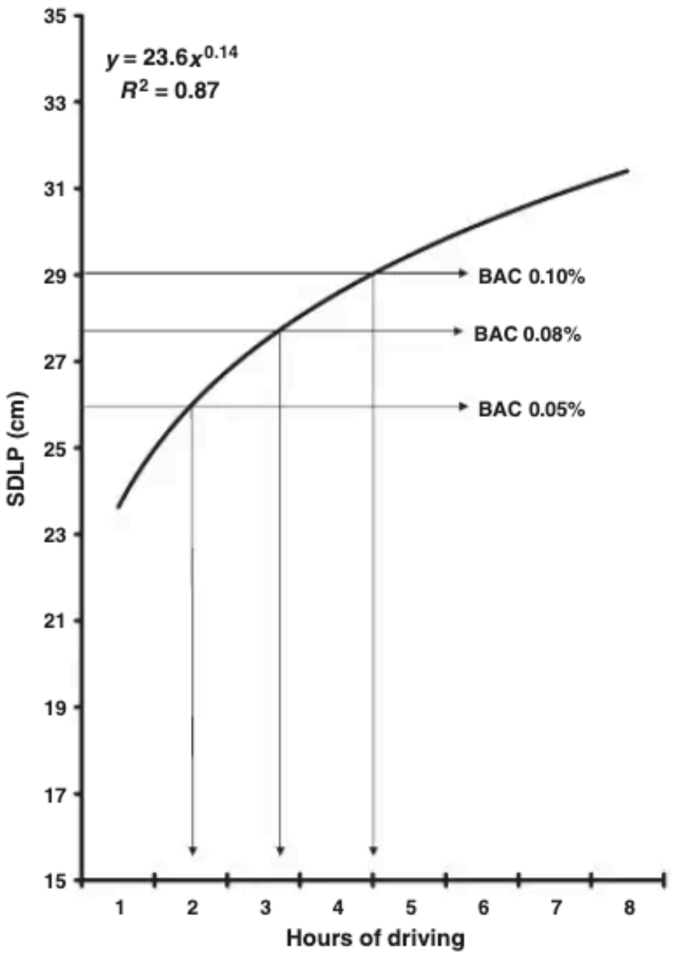

Figure 1. Gradual standard deviation of lateral position increment during prolonged highway driving and its relationship to alcohol-induced impairment. Currently, most common legal limits for driving a car are 0.02% (novice drivers), 0.05% (most European countries) and 0.08% (United Kingdom and some US states). Estimates of these legal limits are included in the figure. BAC: blood alcohol concentration.

DISCUSSION

Our results clearly show a major impact of duration of nocturnal driving on the variability of the lateral position of the vehicle on the road.

Alcohol and fatigue are common contributors to road traffic accidents (Philip *et al.*, 2001). Past publicity campaigns on alcohol and driving have proved their effectiveness in reducing alcohol-impaired driving. Drivers are well aware that alcohol and driving do not mix. Sleepiness-related accidents after long-haul driving have been reported in both general and professional drivers (Philip and Åkerstedt, 2006; Philip *et al.*, 1999), but the effects of driver sleepiness on traffic safety are largely unrecognized by the general public.

Our data show that drivers should take sleepiness behind the wheel seriously. The comparison with BAC levels provides policy makers with evidence-based driving duration limits and makes the impact of prolonged nocturnal driving readily understandable to drivers.

After about 2 h of continuous nocturnal highway driving, driving impairment is comparable to that observed for a BAC of 0.05% and 0.08% after 3 h of driving. Given that these are the most common legal limits for driving for alcohol, a maximum continuous nocturnal driving duration of 2 h should be recommended.

The present study has several limitations. The study design aimed to control for homeostatic and circadian factors by comparing performance at the same time at night (i.e. the last hour of driving of sessions of different length). Thus, all three nocturnal driving sessions were performed while having the same sleep pressure. Taking this into account, the differences in SDLP can be attributed to the increase of sleepiness generated by a longer driving session. However, a useful control would have been to include a single hour of early-morning driving (04:00–05:00 hours) and compare this against performance during the second, fourth and eighth hours of driving.

The sample was modest and the subjects were young males. Therefore, generalization of our findings to other type of drivers (i.e. professional drivers, older people, women, etc.) should be conducted with some caution. For example, professional drivers generally have a higher expected frequency of nocturnal driving and more extensive driving experience. Nevertheless, it can be expected that a similar trend of increased impairment during prolonged driving, although of lesser magnitude, will be found in professional drivers. Future studies should be performed using professional drivers with extensive driving experience. Finally, it should be stressed that the current study concerns nocturnal driving. Sleep pressure is much higher during the night than during the daytime. Therefore, it is likely that the observed effects are of lesser magnitude during the daytime. Future studies performed during daytime should further investigate prolonged driving effects.

Taking into account these limitations, the current data show that night-time driving is increasingly impaired as the duration of the trip is extended. A maximum of two continuous nocturnal driving hours should be recommended.

DISCLOSURE

The authors have no potential conflicts of interest to disclose.

REFERENCES

Connor, J., Norton, R., Ameratunga, S. *et al.* Driver sleepiness and risk of serious injury to car occupants: population based case control study. *BMJ*, 2002, 324: 1125.

Dawson, D. and Reid, K. Fatigue, alcohol and performance impairment. *Nature*, 1997, 388: 235.

Devoto, A., Lucidi, F., Violani, C. and Bertini, M. Effects of different sleep reductions on daytime sleepiness. *Sleep*, 1999, 22: 336–343.

Gallup Organization. *National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002* National Highway Traffic Safety Administration, Washington, 2003.

Horne, J. A. and Baulk, S. D. Awareness of sleepiness when driving. *Psychophysiology*, 2004, 41: 161–165.

Horne, J. and Reyner, L. Vehicle accidents related to sleep: a review. *Occup. Environ. Med.*, 1999, 56: 289–294.

Louwerens, J. W., Gloerich, A. B. M., De Vries, G., Brookhuis, K. A. and O'Hanlon, J. F. The relationship between drivers blood alcohol concentration (BAC) and actual driving performance during high speed travel. In: P. C. Noordzij and R. Roszbach (Eds) *Alcohol, Drugs and Traffic Safety*. Excerpta Medica, Amsterdam, 1987: 183–192.

Menzin, J., Lang, K. M., Levy, P. and Levy, E. A general model of the effects of sleep medications on the risk and cost of motor vehicle accidents and its application to France. *Pharmacoeconomics*, 2001, 19: 69–78.

Mitler, M. M., Miller, J. C., Lipsitz, J. J., Walsh, J. K. and Wylie, C. D. The sleep of long-haul truck drivers. *N. Engl. J. Med.*, 1997, 337: 755–761.

National Sleep Foundation. *2002 Sleep in America Poll.* National Sleep Foundation, Washington, 2002.

Pack, A. I., Pack, A. M., Rodgman, E., Cucchiara, A., Dinges, D. F. and Schwab, C. W. Characteristics of crashes attributed to the driver having fallen asleep. *Accid. Anal. Prev.*, 1995, 27: 769–775.

Philip, P. and Åkerstedt, T. Transport and industrial safety, how are they affected by sleepiness and sleep restriction? *Sleep Med. Rev.*, 2006, 10: 347–356.

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

Philip, P., Vervaille, F., Le Breton, P., Taillard, J. and Horne, J. A. Fatigue, alcohol, and serious road crashes in France: factorial study on national data. *BMJ*, 2001, 322: 829–830.

Powell, N. B., Schechtman, K. B., Riley, R. W., Guilleminault, C., Chiang, R. P. and Weaver, E. M. Sleepy driver near-misses may predict accident risks. *Sleep*, 2007, 30: 331–342.

Ramaekers, J. G. Antidepressants and driver impairment: empirical evidence from a standard on-the-road test. *J. Clin. Psychiatry*, 2003, 64: 20–29.

Rosekind, M. R. Underestimating the societal costs of impaired alertness: safety, health and productivity risks. *Sleep Med.*, 2005, 6(Suppl. 1): S21–S25.

Sagaspe, P., Taillard, J., Åkerstedt, T. *et al.* Extended driving impairs nocturnal driving performances. *PLoS ONE*, 2008, 3: e3493. doi: 10.1371/journal.pone.0003493

Verster, J. C., Pandi-Perumal, S. R., Ramaekers, J. H. G. and De Gier, J. J. (Eds) *Drugs, Driving and Traffic Safety.* Springer, Birkhäuser, Basel, 2009.