Biological Psychology 89 (2012) 580–583

Contents lists available at SciVerse ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Driver sleepiness—Comparisons between young and older men during a monotonous afternoon simulated drive

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ARTICLE INFO

Article history:
Received 30 July 2011
Accepted 5 January 2012
Available online 20 January 2012

Keywords:
Sleepiness
Driving ability
Age effects
Road safety
Driving simulator

ABSTRACT

Young men figure prominently in sleep-related road crashes. Non-driving studies show them to be particularly vulnerable to sleep loss, compared with older men. We assessed the effect of a normal night's sleep vs. prior sleep restricted to 5 h, in a counterbalanced design, on prolonged (2 h) afternoon simulated driving in 20 younger (av. 23 y) and 19 older (av. 67 y) healthy men. Driving was monitored for sleepiness related lane deviations, EEGs were recorded continuously and subjective ratings of sleepiness taken every 200 s. Following normal sleep there were no differences between groups for any measure. After sleep restriction younger drivers showed significantly more sleepiness-related deviations and greater 4–11 Hz EEG power, indicative of sleepiness. There was a near significant increase in subjective sleepiness. Correlations between the EEG and subjective measures were highly significant for both groups, indicating good self-insight into increasing sleepiness. We confirm the greater vulnerability of younger drivers to sleep loss under prolonged afternoon driving.

1. Introduction

Fatal road crash statistics from around the world where the cause has been identified as the driver having fallen asleep at the wheel, show a predominance of young drivers being involved (e.g. USA – Langlois et al., 1985; Pack et al., 1995; Israel – Zomer and Lavie, 1990; UK – Horne and Reyner, 1995; Sweden – Åkerstedt and Kecklund, 2001). One reason may be that they are more vulnerable to sleep loss than older people, owing to a greater depth and intensity (more stage 4) of their sleep (cf. Adam et al., 2000; Klerman and Dijk, 2008; Dijk et al., 2010); thus sleep loss may be more profound in its effects. Whilst laboratory studies have confirmed this age effect, most have typically utilised simple performance indices, such as the psychomotor vigilance task (PVT) (Duffy et al., 2009; Philip et al., 2004; Adam et al., 2000).

More realistic driving situations have been undertaken by Campagne et al. (2004), Sagaspe et al. (2007) and Lowden et al. (2009). The former study monitored three age groups (20–30 y, 40–50 y and 60–70 y) driving for an average of 2 h 49 min, on a full-size simulator, and under monotonous conditions 'at night'. 'Run off the road' driving errors were more frequent in younger participants than either of the two older groups. Lowden et al. (2009) compared young (18–24 y) and older (55–64 y) participants driving a full-size car simulator for 45 min, between 02:30 and 04:00 h. Findings clearly showed the younger group to be sleepier, as determined by EEG and subjective responses using the Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990). Although lane drifting was similar for both participant groups, the authors noted that this drive duration was fairly short. Sagaspe et al. (2007) utilised real road driving at night, involving younger and older participants, with the main aim to compare two countermeasures to sleepiness: a nap and caffeine (with a placebo). Under the placebo condition, 75% of the older participants were able to maintain normal driving performance compared with only 25% of the younger group.

These latter three driving studies were conducted at night. However, it should be noted that younger drivers are more likely than older drivers to drive very early in the morning, which happens to be the most likely time of day for younger drivers to have a sleep related collision (e.g. Horne and Reyner, 1995; Maycock, 1997; Flatley et al., 2004). On the other hand, older (>50 y) drivers are more likely to have these collisions early afternoon, ostensibly during the bi-circadian 'dip' (Horne and Reyner, 1995). The aim of the present study is to compare the driving ability of both groups at this latter time of day which, hitherto, has not been investigated. This research may further address the issue whether the preponderance of young men being involved in early morning fall-asleep crashes is simply through their being more likely to be on the road at this time of day, and/or they have a greater vulnerability to sleep loss.

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doi:10.1016/j.biopsycho.2012.01.002

Another aspect of this study is to compare the extent to which sleepy drivers are aware of their own sleepiness when driving. In the UK this issue has medico-legal implications for driver responsibility, as drivers have a legal duty of care to ensure that they are fit to drive; that is, if drivers know they are very sleepy they are obliged to cease driving. For this reason, it has also been a focus of our previous research as well as that of others. Although close associations between subjective and EEG measures of sleepiness in young drivers have been reported previously (e.g. Horne and Baulk, 2003; Anund and Åkerstedt, 2010), to the extent that they are aware of increasing EEG determined sleepiness, less is known about older drivers in this respect.

A recent driving study of ours, focussing on older men with obstructive sleep apnoea (Filtness et al., 2011), included a control group of 20 age-matched healthy men. In the present report we compare the control group from Filtness et al. (2011) with data for young drivers. Data for younger participants comprises that of 12 participants previously published in Horne et al. (2003) and 8 others from an unpublished study. In all cases identical protocols and the same real car simulator were used. All participants drove for 2 h during the early afternoon 'dip', under conditions of a normal prior night's sleep vs. sleep restricted to 5 h (designed to worsen the dip). Measurements comprise lane drifting, EEG and subjective sleepiness.

2. Methods

2.1. Participants

In the UK, men are responsible for the majority (90%) of sleep related collisions (Horne and Reyner, 1995; Flatley et al., 2004), and for this reason our participants were men. Two groups of healthy male drivers were recruited via local advert and were initially screened by postal questionnaire and phone. Initial screening excluded those with estimated BMIs > 28, who drove for <3 h per week or lived further than 40 km of our research centre. Remaining potential participants were invited for an interview, which covered illnesses (especially heavy snoring and other signs of obstructive sleep apnoea), medications liable to affect sleep, habitual sleep characteristics, and to establish low coffee and alcohol consumption. BMIs were confirmed by measurements and all had BMIs in the range 20–27 kg/m^2. 20 older men (mean age 66.6 y to 52–74 y) and 20 younger men (mean age 22.7 y to 20–26 y were recruited. All were good sleepers, although the younger group had a (not significantly) longer average usual sleep duration (by actigraphy) of 503 min compared with 468 min for the older group. All were healthy, medication-free and scored <10 on the Epworth Sleepiness Scale (ESS – Johns, 1991). They were experienced drivers (having driven for over 2 y, for more than 3 h per week). A 30 min familiarisation drive in the simulator was completed by all participants prior to the experimental days. The procedures were fully explained and all signed consent forms. For participating, they received either a gift voucher or were paid the equivalent value on completion of the study. During both experimental phases, all participants were collected from and returned to their home by taxi. The investigation had full approval of the University's Ethical Committee.

2.2. Design and procedure

Our standard experimental protocol undertaken by both groups, was as follows. Participants underwent a 2 h simulator drive following two experimental sleep conditions: (i) normal sleep and (ii) sleep restriction to 5 h by delayed bed-time. Test days were completed in a counterbalanced design, with each condition 1–2 weeks apart. To ensure compliance with sleep instructions, participants wore wrist actimeters (Cambridge Neurotechnology, UK) for three nights prior to each experimental day, when they kept daily logs of estimated sleep onset, and morning wakening and rising times. No alcohol was consumed 36 h prior to each test session, and nil caffeine after 18:00 h the evening before. Participants refrained from eating after 10:00 h on the morning of the drive. On arrival at the laboratory, at 13:00 h, they were given a light lunch. Actimeters were downloaded to verify that they had complied with the previous night's sleep requirements; all had done so. At 13:15 h electrodes were applied and they went to the simulator at 13:50 h, to be given 10 min to settle into the car. The 2 h continuous drive began at 14:00 h. A 2 h drive was chosen because UK road safety organisations recommend that this should be the limit before a break from driving.

2.3. Apparatus

2.3.1. Car simulator

This comprised an immobile car with a full-size, interactive, computer generated road projection of a dull monotonous dual carriageway; each having two lanes. The image was projected onto a 2.0 m × 1.5 m screen, located 2.3 m from the car windscreen. The road had a hard shoulder and simulated auditory 'rumble strips' (incorporated into white lane markings) either side of the carriageway, with long straight sections followed by gradual bends. 'Crash barriers' were located either side, beyond the rumble strips. Slow moving vehicles were met occasionally, that require overtaking (to avoid collision). Participants drove in the left hand lane (unless overtaking), according to UK road rules, at a speed appropriate for the road and to enable full control of the vehicle. During the drive the investigator was in the room at all times, but there was no communication between investigator and participant once the drive had begun.

2.3.2. Driving incidents

Lane drifting is the most common manifestation of sleepy driving. When all four wheels came out of the driving lane (lane departure) this was identified as a driving 'incident'. Split-screen video footage of the road and driver's face (filmed by an unobtrusive infrared camera) were scrutinised and enabled the cause of the incident to be determined. Those caused by sleepiness (e.g. eye closure, eyes rolling upwards or vacant staring ahead) were logged as 'sleep-related'. As a further check for the latter, the EEG and electrooculogram (EOG) were examined respectively for alpha/theta intrusions and confirmation of any 'eye rolling'. Non-sleep related incidents (driver distraction, fidgeting or looking around) were excluded; therefore all results refer to sleep related incidents only.

2.3.3. Subjective sleepiness

Every 200 s during the drive, participants were verbally prompted by the computer system ('*sleep-check*') to report their subjective sleepiness on the 9-point KSS: 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, and 9 = very sleepy, great effort to keep awake, fighting sleep. The scale was located on the car's dashboard and permanently visible to the participant; this prompting and its response quickly became routine. Results are reported as absolute values at each 'sleep check'.

2.3.4. EEG and EOG

Electrodes were attached for two channels of EEG, with inter-electrode distances maintained using the '10-20 EEG montage' (main channel C_3-A_1, backup channel C_4-A_2). There were two EOG channels (electrodes 1 cm lateral to and below left outer canthus and 1 cm lateral to and above right outer canthus; both referred to the centre of the forehead). EEGs and EOGs were recorded using "Embla" (Flaga Medica Devices, Iceland) and spectrally analysed using "Somnologica" (Flaga) in 4 s epochs. EEG low and high band-pass filtering at >20 Hz and <4 Hz removed slow eye movements and muscle artefact. In these circumstances, greater EEG power in the alpha (8–11 Hz) and theta (4–7 Hz) ranges reflect increased sleepiness. Power in the combined range (4–11 Hz) was averaged in 1 min epochs. To accommodate for individual differences, and to allow comparisons between conditions, each individual's power in these ranges was standardised, by taking the difference between each minute's epoch and the individual's mean value over the first 30 min of baseline data, which was then divided by the standard deviation around the mean of that 30 min of data (cf. Reyner and Horne, 1997).

2.4. Statistical analysis

Mixed model, repeated measures analysis of variance (ANOVA) were utilised, with one between-subject (nested as groups) and two within subject factors: (i) condition – two levels: normal sleep and sleep restriction; (ii) duration of drive – four levels: 0–30 min, 30–60 min, 60–90 min and 90–120 min. Huynh–Feldt (ε) adjustments were used if the assumption of sphericity was not met. Where appropriate square root transformations corrected for skewed driving incident raw data. For all measures, data was collapsed into 30 min epochs for statistical analysis.

3. Results

3.1. Driving incidents (Fig. 1)

There was a significant main effect for sleep condition on the number of driving incidents, with both groups having more incidents following sleep restriction [$F(1,38) = 27.67$, $p = 0.000$, $\varepsilon = 1$]. A significant condition by group interaction showed the younger participants were more impaired by sleep restriction [$F(1,38) = 9.92$, $p = 0.003$, $\varepsilon = 1$]. There was also a significant time effect, with number of incidents increasing for both groups with time on task [$F(2.6, 99.0) = 4.8$, $p = 0.005$, $\varepsilon = 0.87$]. Although Fig. 1 indicates a greater