Impaired alertness and performance driving home from the night shift: a driving simulator study

TORBJÖRN ÅKERSTEDT, BJÖRN PETERS, ANNA ANUND and GÖRAN KECKLUND
Institute for Psychosocial Medicine, Karolinska Institutet, Stockholm, Sweden, Swedish Road and Transport Research Institute, Linköping, Sweden

SUMMARY Driving in the early morning is associated with increased accident risk affecting not only professional drivers but also those who commute to work. The present study used a driving simulator to investigate the effects of driving home from a night shift. Ten shift workers participated after a normal night shift and after a normal night sleep. The results showed that driving home from the night shift was associated with an increased number of incidents (two wheels outside the lane marking, from 2.4 to 7.6 times), decreased time to first accident, increased lateral deviation (from 18 to 43 cm), increased eye closure duration (0.102 to 0.143 s), and increased subjective sleepiness. The results indicate severe postnight shift effects on sleepiness and driving performance.

KEYWORDS accidents, commute, eye closure, lateral deviation, sleepiness

INTRODUCTION Night shift work is associated with increased reported sleepiness (Åkerstedt, 1998) and several studies have shown that train drivers (Torsvall and Åkerstedt, 1987), truck drivers (Kecklund and Åkerstedt, 1993), pilots (Samel et al., 1997), process operators (Torsvall et al., 1989), and others, show clear intrusions of sleep-like EEG patterns when working at night. There has also been reported an increased risk of road accidents driving home from a night shift (Gold et al., 1992; Ohayon et al., 2002; Stutts et al., 2003). These observations are also in line with the observations of a large increase in the risk of sleep-related accidents in the early morning (Horne and Reyner, 1995). Furthermore, the early morning hours are associated with a five- to sixfold increase in the risk of having a highway accident ( Åkerstedt et al., 2001) of any kind – sleep related or not.

Some of the early morning accident risk may be related to the commute home from the night shift as evidenced in several questionnaire studies (Gold et al., 1992; Ohayon et al., 2002; Stutts et al., 2003). However, this possibility does not seem to have been investigated in terms of actual driving performance. However, Horne and Reyner (1995) investigated the effect of caffeine on a morning simulator drive after a night spent awake and found that alertness and performance were clearly impaired. The participants were not night workers however.

The present study sought to investigate impairment during a simulated drive home from a regular night shift. Simulator parameters with a close link to real life driving may be, as suggested by Horne and Reyner (1995), the number of incidents and accidents. The latter were defined as two wheels and four wheels, respectively, outside the lane markings. As such measures are discrete also a more continuous measure of driving performance was added – the standard deviation of lateral position of the vehicle (Sdlat) (Arnedt et al., 2000; O’Hanlon and Kelly, 1974), as well as a measure of physiological sleepiness, eye closure duration (Wierwille and Ellsworth, 1994). In addition, ratings of subjective sleepiness were obtained every 5 min during the drive.

METHODS Five male and five female shift workers were recruited through advertisements in local companies employing night workers. Most came from a hospital, a newspaper and an energy plant. They had a mean age of 37 years (SD = 12 years), drove annually an average of 9500 km (SD = 6800 km) and had 5–9 years experience as shift workers. Three only worked at night while the rest alternated between night and day work/driving. They received a monetary compensation of approximately €110.

Correspondence: Torbjörn Åkerstedt, IPM/Karolinska Institute, Box 230, 17177 Stockholm, Sweden. Tel.: 46 8 52482041; fax: 46 8 320521; e-mail: torbjorn.akerstedt@ipm.ki.se
The subjects participated twice – one condition was preceded by a normal night sleep (baseline – night sleep) and one after a night of regular work (no sleep – night work), usually the first or second night shift. There was at least 3 days between drives. The subjects were instructed to maintain their normal work sleep pattern and behavior in connection with night and day work (no restrictions on coffee or napping). Before the study proper, the subjects had a practice drive in the simulator for 20 min and practice at using the rating scale, which had been sent out beforehand.

The subjects arrived at approximately 07:00-07:30 h in the morning directly after night work or after rising. The EOG electrodes were applied and the subjects were taken directly to the simulator after filling out a questionnaire on background factors and sleep pattern for the previous day. The drive started at 08:00 h and was scheduled to last for 2 h. After the drive the subjects were debriefed and sent home. In the night work condition the drivers were brought to the test and back by taxi.

A dynamic, high fidelity, moving base driving simulator was used. The car cab was a Volvo 850 and the system simulated acceleration in three dimensions through roll, pitch and linear lateral motion. The visual system presented the scenario on a 120° wide screen 2.5 m in front of the driver. The sound system generated noise and infrasound that resembles the internal environment in a modern passenger car. The vibration system simulated the sensations the driver experiences from the contact between the road surface and the vehicle. The driving scenario was a rural two-lane road with lanes 3.6 m wide and with a 0.5 m hard shoulder. The conditions were “summer” with a slightly hazy sky. Signed speed limit was 90 km h\(^{-1}\) and there was sparse oncoming traffic and cars to follow or pass.

The measures provided by the system were speed (mean and SD), lateral position (mean and SD), time to line crossing (TLC), steering wheel angle (mean and SD). Driving behavior was recorded at a frequency of 12.5 Hz. From the many parameters recorded those selected for the present purpose were 5-min epochs with four wheels outside the left or right lane marking (accident) and two wheels outside the lane markings (incident). After driving off the road the car was automatically and gently brought back on the road again. In addition, the Sdlat was selected, as previous studies suggested that this may be the most sleepiness sensitive continuous performance measure (Arnedt et al., 2000; O’Hanlon and Kelly, 1974).

An EOG recording using horizontal and vertical derivations was carried out using a Vitaport recorder and vertical electrodes above and below the right eye. Data were obtained with a sampling rate of 128 Hz with a bandpass filter set at 0.3–25 Hz. Raw data were analyzed with a modified MATLAB program developed by the Center for Applied and Environmental Physiology (Dr A Muzet, CEPA, Strasbourg, France). It essentially involves using a low-pass filter to obtain a stable baseline for the signal, and then establishing a threshold that has to be exceeded to score a blink (done visually), with definition of the start/end of the blink based on slope and with computation of blink duration at midslope. To reduce problems with concurrence of eye movements and eye blinks blink durations were calculated by finding the half amplitude of the upswing and downswing of each blink and computing the time elapsed between the two.

Sleepiness was rated every 5 min prompted by an instruction displayed on the windshield, with the response given orally, using the scale pasted to the steering wheel. The scale used was the Karolinska Sleepiness scale (KSS) ranging from 1 to 9 where 1 = very alert, 5 = neither sleepy nor alert, 7 = sleepy but no effort to remain awake, and 9 = very sleepy, an effort to stay awake, fighting sleep (Åkerstedt and Gillberg, 1990). The scale was modified to have labels also on intermediate steps (Reynier and Horne, 1998). Before the drive the subjects filled out a questionnaire on prior work and sleep pattern.

Differences across time and between conditions were analyzed using a repeated measures ANOVA, with Huyhn–Feldt corrections for sphericity. For comparisons of accidents and incidents between conditions Wilcoxon’s non-parametric test was used because of skewed distributions. For other comparisons, paired \(t\)-tests were used.

RESULTS

In the baseline condition the subjects rose at 06:51 h ± 13 min and slept for 7.6 ± 0.32 h. In the night work condition the subjects finished work around 07:25 h ± 17 min in the morning and obtained 2.2 ± 0.8 h of sleep, mainly during the prior morning or afternoon.

The two conditions differed significantly with respect to number of incidents with 2.40 ± 1.1 for the baseline condition and 7.6 ± 2.1 for the night work condition (Wilcoxon \(z = 2.80, P < 0.01\)). In this analysis four subjects who terminated their night work condition prematurely because of excessive sleepiness only contributed data from the corresponding time period in the baseline condition.

The number of accidents was 2 in the baseline condition and 18 in the night work condition. To test this while accounting for the premature termination of the four individuals, time to first accident or to premature termination was used as a dependent variable. This yielded 83 ± 11.5 min versus 116.5 ± 3.0 min (Wilcoxon \(z = 2.20, P < 0.05\)), respectively. The time to the first report of sleepiness at level 9 was 49.5 ± 9.5 versus 113.0 ± 5.0 min (\(t = 5.6, P < 0.001\)), respectively.

The results from the comparisons between conditions across time are presented in Fig. 1. Only 65 min are presented as this represents the longest period of time for which data were available from all subjects.

The F- and P-values (after Huyhn–Feldt correction) for blink duration were \(F = 7.2 (P < .05)\) for condition, \(F = 9.1 (P < .001)\) for time, and \(F = 1.1 (ns)\) for interaction. Blink duration was higher after the night shift and increased over the drive.

For the Sdlat the values were \(F = 6.0 (P < .05)\) for condition, \(F = 3.7 (P < .01)\) for time and \(F = 1.4 (ns)\) for interaction. Sdlat was higher after the night shift and increased over the drive.
For subjective sleepiness (KSS) the results were $F = 60.1$ ($P < .001$) for condition, $F = 38.2$ ($P < .001$) for time, and $F = 2.1$ ($P < .05$) for interaction. Thus, sleepiness was higher after the night shift, increased across time and increased faster after night sleep. In all analyses the degrees of freedom were 1/9, 12/108, and 12/108, respectively.

DISCUSSION

The present study showed that simulated commuting back from night shift work clearly caused incidents, decreased time to accidents, increased variability in lateral position, increased eye closure durations as well as increased subjective sleepiness. Reyner and Horne (1999) simulated a night shift and found a similar increase in number of accidents and incidents, although risk or lateral deviation was not computed. They also reported increased subjective sleepiness as well as sleep intrusions in the EEG. Similar observations have been made in many studies of sleep loss and lateral deviation (Arnedt et al., 2000) or eye closure duration (Wierwille and Ellsworth, 1994).

The sleepiness effects during the morning commute are in line with the epidemiological studies that have demonstrated an increased accident risk in shift workers traveling home after a night shift (Gold et al., 1992; Ohayon et al., 2002; Stutts et al., 2003). They are also in line with a number of studies that demonstrate increased risks of road accidents in connection with early morning driving (Åkerstedt et al., 2001; Connor et al., 2002).

The reason for the accident risk associated with the postnight shift commute is, most likely, the combination of the circadian low and an extended time awake (only 2.2 h of sleep during the preceding 24 h) as has been demonstrated in several studies of forced desynchronization (Dijk and Czeisler, 1995). Work at the circadian trough and extended wakefulness are inherent in night shift work but countermeasures may ameliorate the effects. One such countermeasure is taking a nap during the night shift (Bonnefond et al., 2001) or phase-delaying the circadian low through light treatment during the night shift (Eastman and Martin, 1999). However, field evaluations of accident risk have not been carried out.
It should be emphasized that the present data were obtained in a driving simulator, with the weaknesses of such an approach. Whereas a simulator comes rather close to real life driving in some ways (Törnros et al., 1998) it is likely that the fatigue-inducing effects may be greater in the simulator, but this aspect does not seem to have been studied before. It seems, however, a reasonable assumption that impairment and sleepiness in on-the-road driving situations would be less pronounced due to the higher level of stimulation in the latter situation. True levels of performance impairment need to be determined in driving with instrumented cars in real-life situations.

In summary, the present study has demonstrated that driving a simulator after a night shift is associated with pronounced impairment of alertness and driving performance.

REFERENCES