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An on-road study of sleepiness in split shifts among city bus drivers

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ABSTRACT

Bus drivers often work irregular hours or split shifts and their work involves high levels of stress. These factors can lead to severe sleepiness and dangerous driving. This study examined how split shift working affects sleepiness and performance during afternoon driving. An experiment was conducted on a real road with a specially equipped regular bus driven by professional bus drivers. The study had a within-subject design and involved 18 professional bus drivers (9 males and 9 females) who drove on two afternoons; one on a day in which they had driven early in the morning (split shift situation) and one on a day when they had been off duty until the test (afternoon shift situation). The hypothesis tested was that split shifts contribute to sleepiness during afternoon, which can increase the safety risks. The overall results supported this hypothesis. In total, five of the 18 drivers reached levels of severe sleepiness (Karolinska Sleepiness Scale ≥ 8) with an average increase in KSS of 1.94 when driving in the afternoon after working a morning shift compared with being off duty in the morning. This increase corresponded to differences observed between shift workers starting and ending a night shift. The Psychomotor Vigilance Task showed significantly increased response time with split shift working (afternoon: 0.337 s; split shift 0.347 s), as did the EEG-based Karolinska Drowsiness Score mean/max. Blink duration also increased, although the difference was not significant. One driver fell asleep during the drive. In addition, 12 of the 18 bus drivers reported that in their daily work they have to fight to stay awake while driving at least 2–4 times per month. While there were strong individual differences, the study clearly showed that shift-working bus drivers struggle to stay awake and thus countermeasures are needed in order to guarantee safe driving with split shift schedules.

1. Introduction

Driver sleepiness is a well-known reason for crashes resulting in people being injured or killed and is considered to be a major contributor to approximately 15–30% of all crashes (Horne and Reyner 1995; Connor et al., 2002; Klauer et al., 2006; Williamson et al., 2011; Herman et al., 2013). Most previous sleepiness research has been performed on drivers of private cars (Sagaspe et al., 2008; Hallvig et al., 2013b; Åkerstedt et al., 2013) and trucks (Kecklund and Åkerstedt, 1993Mitler et al., 1997; Hanowski et al., 2003), while less is known about the situation for bus drivers (Tse et al., 2006).

All road transport involves a human driver and while the type of vehicle driven may differ, all humans are expected to be influenced by the same biological factors, namely time of the day, hours slept and hours awake (Åkerstedt et al., 2008). Other factors also contribute to driver fatigue, e.g. for professional drivers, long working hours have been proven to contribute to increased sleepiness and an increased risk of crashes (Robb et al., 2008). This is especially the case in combination with sleep loss, lack of breaks and difficult working conditions (Stevenson et al., 2014; Pylkkönen et al., 2015). Split shifts are a typical work hour characteristic for city bus drivers, and are associated with long working hours and insufficient sleep (Anund et al., 2016). This might be a major contributing factor to driver fatigue and a risk factor of crashes (Bohle et al., 2004). During a split shift a driver's work day is split into two or more parts, for example a first period between 05.00 and 09.00 h, followed by a long break, and then return to a second work period at 15.00 h and end the work day at 19.00 h. This is due to peak hours.

There are very few studies on sleepiness among bus drivers, and according to our knowledge, this is the first investigation of the impact of split shifts on sleepiness for city bus drivers. The overall performance of bus drivers, just like that of car and truck drivers, can be assumed to decrease under sleepiness and this issue needs to be investigated. The aim of this study was to evaluate how an early morning start affects bus

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drivers' level of sleepiness and performance during afternoon driving on the same day, a common situation when driving a split shift.

2. Method

2.1. Participants

The study involved 18 bus drivers (9 males, 9 females) normally working as public transport bus drivers in the area around Linköping, Sweden, who were recruited through contacts with four local bus companies operating in the area. The drivers received 3000 SEK in compensation for their participation. The study obtained ethical approval (Regional Ethical Review Board, Linköping EPN 2014/59-31).

The average age of the bus drivers was 48 years (standard deviation (SD) = 8) and they had been working as bus drivers for on average 14 years (SD 8.6 years). Two out of 18 drivers worked occasional split shifts in their current work hour schedules. The drivers had an average Body Mass Index (BMI) of 27.6 (SD 4.5; lowest 19.2, highest 35.2). They rated on average 9 (sd 5.04) on the Epworth Sleepiness Scale (ESS) (Johns 1991) with 27% reporting higher than 10. Of the 18 drivers, 56% reported that they do not exercise regularly, 50% reported that they take a nap once a day or more often and 11% reported poor sleep. No driver reported using sedatives or sleeping pills.

In total, 67% of the drivers (12/18) reported that they had to fight to stay awake while driving the bus at least 2–4 times per month or more frequently, and 22% indicated they had experienced at least one fatigue-related incident in the past 10 years.

2.2. Design, procedures and test route

Each driver participated twice, both times during the afternoon. One of these afternoon drives was on a day when the driver had worked an early morning shift starting between 04.00 and 05.00 h (representing a split shift situation), and one was on a day when the driver was off duty until the test (simulating an afternoon shift). The order was balanced. For practical reasons two drivers each day participated. The first participant arrived at 14 h, preparations such as fitting electrodes for the physiological recordings were done and the driving lasted between approximately 15.30–17 h. The second participant arrived at 16 h, preparations were done and the driving lasted approximately between 17 and 18.30 h.

The bus drivers were asked to fill out sleep and wake diaries, to use Actiwatches (which monitors wrist activity) to record sleep and not to drink alcohol 72 h before arrival at the laboratory. On arrival, they were informed about the experiment and the driving route, signed informed consent forms and were fitted with electrodes for physiological measurements. They were not allowed to drink caffeine from arrival at the laboratory. The bus drivers drove a practice drive from the laboratory to the start of the test route 5 km away. They completed a 10-min psychomotor vigilance task (PVT) (Basner and Dinges 2012) before the experiment started, after approximately 50 min of driving and at the end of the experiment. The drivers were seated in the bus during all three PVT tests.

The test route was on a real road, 23 km long corresponding to a typical real city bus route in Sweden. It was driven three times (called laps) per visit. There were four bus stops along the test route. At two of these, the drivers were expected to stop to take on passengers. The passengers were simulated using dummies. At two stops the drivers were expected to stop to let passengers off. The test leader pressed the stop button, at the same place each time. When the last lap was completed, the bus was driven directly to the laboratory and the final PVT took place in the bus.

During the drive, the bus drivers self-reported their sleepiness once every 5 min using the Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990). The test leader, seated behind the driver, reminded the drivers to report KSS verbally by saying "Sleepiness?". This was the only remark the test leader was permitted to make, but they were permitted to answer questions about the route during the first lap if the driver had problems finding the way.

After driving the participants filled out a questionnaire about their experience and finally the electrodes were removed and the participants went home.

A portable recording system called Vitaport 2 (Temec Instruments BV) was used for electrophysiological measurements. The sampling frequency was set to 256 Hz for Electroencephalography (EEG) and 512 Hz for Electrooculography (EOG). The EOG was DC-recorded using disposable electrodes. The EOG data were processed for analysis of blink duration using the MATLAB programme, which determines the blink duration based on the midslope (50–50) of the triangular EOG pattern typical of a blink movement (James et al., 2008). The EEG signals were manually cleared of artefacts and Karolinska Drowsiness Score (KDS) was calculated. The classification was performed in 2-s intervals that yielded continuous measurements, those were then clustered into 20 s interval and the percentage of KDS (0–100%) in steps of 10% was identified. (Gillberg et al., 1996; Lowden et al., 2004; Anund et al., 2008).

The bus was a normal bus used for public transportation, a 13 m long Zetra model with an automatic gearbox. It was equipped with a Vbox[1] for automatic recording of speed and GPS position and with video cameras directed at the driver and at the road in front (Fig. 1).

The test route consisted of mostly two-lane rural roads and a collision-free road with 2 + 1 lanes. The speed limit varied between 70 and 100 km/h. The route passed through some small villages with a speed limit of 30 or 50 km/h.

2.3. Preparation of data and statistical analysis

Data describing KDS, KSS and blink duration were aggregated and an average value per 5 min was calculated. The first lap was not included in the analysis, since some drivers were unsure of the route and asked the test leader for route instructions, and it was therefore considered as confounded. The dataset used for the analysis included 20 min of driving on the 2nd lap and 20 min of driving on the 3rd lap for both types of simulated shifts (afternoon and split).

The PVT analysis was based on the average response time for correct responses (≤ 500 ms) and the percentage of lapses (≥ 500 ms). To evaluate the effect of split shift working on KSS, blink duration, KDS mean and KDS max, a Mixed Model Anova was used with participant as random factor and minute driven and type of shift as fixed factors.

All statistical analysis were conducted using IBM SPSS 22.0 statistical software (IBM Corp., Armonk, NY, USA). An alpha level of 0.05 was used to determine statistical significance. In some cases effect size is presented as the difference between afternoon shift and split shift averages for a specific indicator.

3. Results

The participants reported significantly higher levels of sleepiness (KSS) during the split shift day drives (5.799; SD 0.226) than during the afternoon shift day drives (3.860; SD 0.228) (Table 1). In total, five of the 18 drivers reached KSS levels of 8 or higher and nine drivers reached KSS 7 or higher. All KSS ratings at level 7 (35/378) was done during split shift situation, except for one rating. In addition, all reported KSS values at level 8 and 9 (27/378) was made during the split shift situation.

The mean KDS value was significantly higher on the split shift day (0.648; SD 0.101) than the afternoon shift day (0.463; SD 0.101). Moreover, KDS max was higher on split shift days (7.014; SD 0.807) than afternoon shift days (4.861; SD 0.807). There was no significant

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[1] https://www.vboxautomotive.co.uk/index.php/en/.