BUS DRIVERS WORKING HOURS AND
THE RELATIONSHIP TO DRIVER FATIGUE

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ABSTRACT

Bus drivers often have irregular working hours like split shifts and their work involve high levels of stress. These factors can lead to severe sleepiness and dangerous driving. The purpose of this study is to highlight how split shifts affect sleepiness and performance during afternoon drive. The study is an experiment on real road with an equipped bus driven by professional bus drivers. The study design is a within subject design and the 18 professional bus drivers (9 males and 9 females) drove twice during afternoon; once after a day with bus driving in the morning and once after a day when they had been off duty the whole day. The hypotheses was that split shifts contribute to sleepiness during afternoon, which together can result in increased safety risks. The overall results support this hypotheses. In total five out of 18 drivers reached levels of severe sleepiness (Karolinska Sleepiness Scale ≥ 8) with an average increase in KSS of 1,94 driving in the afternoon the day that preceded with bus driving in the morning compared to the day off duty in the morning, an increase corresponding to the levels of shift workers comparing start and end of a night shift. The Psychomotor Vigilance Task showed significant increased Response Time with split shift (afternoon: 0.337s; split shift 0.347s), so did also the EEG based KDS mean/max. Blink duration also increased, even though the difference was not significant. One driver fell asleep during the drive. In addition, 12 of the 18 bus drivers reported that they in their daily work had to fight to stay awake while driving the bus at least 2-4 times per month. Even though the study showed significant individual differences, it is clear that the bus drivers had to fight to stay awake and countermeasures are needed in order to guarantee safe driving under split shift schedules.
1. INTRODUCTION

Driver sleepiness is a well-known reason for crashes with people being injured or killed and it is considered to be a major contributor to approximately 15–30% of all crashes (Connor et al., 2002; Herman et al., 2013; Horne & Reyner, 1995; Klauer et al., 2006; Williamson et al., 2011).

Most of the research has been performed on drivers of passenger cars (Hallvig, Anund, Fors, Kecklund, Karlsson, Wande, et al., 2013; Sagaspe et al., 2008; T Åkerstedt et al., 2013) and truck drivers (Hanowski et al., 2003; Kecklund & Åkerstedt, 1993; Mitler et al., 1997) and less in know about bus drivers situation (Tse et al., 2006).

All transportation on road involve a human driver and even though the type of vehicle differ, humans are influenced by the same biological factors; time of the day, hours slept and hours being awake (T Åkerstedt et al., 2008). There are also other factors that contribute to driver fatigue and for professional drivers long working hours have been proven to contribute to increased sleepiness and an increased risk for crashes (Garefelt et al., 2014). This is especially the case in combination with sleep loss, lack of breaks and difficult working conditions (Kecklund et al., 2010). Since split-shift is a typical working schedule among bus drivers, it might be one major contributing factor to driver fatigue and an increased risk for crashes among drivers (Bohle et al., 2004).

To summarize, there are reasons to believe that bus drivers’ performance, just as for drivers of passenger cars and trucks is decreased under sleepiness and this needs to be further investigated. The aim with this study is to evaluate how early morning start effects the bus drivers’ level of sleepiness and performance during the afternoon drive the same day, a situation common when driving a split shift.

2. METHOD

2.1. Subjects

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

The bus drivers’ average age was 48 years (sd 8) and they had been working as bus drivers for 14 years (sd 8.6 years) in average. The drivers had an average BMI of 27.6 (sd 4.5), where the lowest was 19.2 and the highest was 35.2 and 56 percent reported that they do not exercise regularly. Among the drivers 50 percent reported that they every day or more often take a nap, and 11 percent reported poor sleep. No drivers used tranquilizers or sleeping drugs.

In total 67 percent of the drivers (12 out of 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 percent indicated they had experienced at least one fatigue related incident the last 10 years.

2.2. Design, procedures and test route

Each driver participated twice, both times during the afternoon between 14h and 20h. One drive was done one day when they had been driving a morning shift with start between 4-5h in the morning (simulating a split shift situation), and one drive was done a day after being of duty (simulating an afternoon shift). The order was balanced.
The bus drivers were asked to fill out sleep- and wake diaries and using Actiwatches for registration of sleep and not to drink alcohol 72 hours before arrival at the laboratory. At arrival they were informed about the experiment and the route to drive, they filled out informed consent were prepared with electrodes for physiological measurements. They were not aloud 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 ahead. Before starting a 10 minutes Psychomotor vigilance task (PVT) took place (M Basner & Dinges, 2012) and then the experiment started. The PVT test was done also after approximately 50 minutes’ drive and again in the end of the experiment. The drivers were seated in the bus at all three PVT tests.

The test route had a distance of 23 km and was driven three times (called laps) at each visit. There were four bus stops along the test route. At two of them the drivers were expected to stop to take on passengers. The passengers were simulated with passenger dummies. At two stops the drivers were expected to stop to let passengers off. The test leader pressed the button for stop. This was done at the same place each time. When the last lap was finalized the bus was driven to the laboratory directly and the final PVT took place while the driver was still seated in the bus.

During the driving the bus drivers self-reported their sleepiness once each 5 minutes using the Karolinska Sleepiness Scale (KSS) (T Åkerstedt & Gillberg, 1990). The test leader, seated behind the driver, reminded the drivers to report KSS verbally by saying “sleepiness?” This was the only conversation they were aloud to do, except that the test leader were permitted to answer questions about the route during the first lap in case the drivers had problems to find the way.

After the 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 from Temec Instruments BV was used for electrophysiological measurements. The sampling frequency was set to 256 Hz for EEG and 512 Hz for EOG. The EOG was DC-recorded and disposable electrodes were used. The EOG data were processed for analysis of blink duration using MATLAB program which determines the blink duration based on the midslope (50-50) of the triangular EOG pattern typical for a blink pattern (James et al., 2008). The EEG signals were manually cleaned from artefacts and Karolinska Drowsiness Score (KDS) was calculated. The classification was performed in two-second epochs that yield continuous measurements (0-100%, in steps of 10%, out of each 20-second or 30-second epoch) (Anund et al., 2008; Gillberg et al., 1996; Lowden et al., 2004).
The bus was a normal bus used for public transportation, a 13 meters long of the brand Zetra with an automatic gearbox. The automatic gearbox. The bus was equipped with a Vbox\(^1\) for automatically registration of speed and GPS-position, video position, video cameras directed at the driver and at the road in front, see Figure 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 to 100 km/h. The route passed through some small villages with a speed reduction of 30 or 50 km/h.

2.3. Preparation of data and statistical analysis
Data describing KDS, KSS and Blink duration were aggregated and average per 5 minute was calculated. The first lap was not included in the analysis, since some drivers were unsure of the route and asked the test leader of the way to drive, and therefore consider being confounded. The dataset used for the analysis included 20 minutes’ drive on the 2nd lap and 20 minutes drive on the 3rd lap, for both types of simulated shifts (afternoon and split shift).

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 on KSS, Blink duration, KDS mean and KDS max a Mixed Model Anova was used with participant as a random factor and time on task and type of shift as fixed factors.

All statistical analysis conducted when 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 are presented, here it corresponds to a difference between afternoon shift and split shift average for a specific indicator.

\(^1\) https://www.vboxautomotive.co.uk/index.php/en/
3. RESULTS
The participants reported significant higher level of sleepiness (KSS) the “split shift” day (5.799; sd 0.226) compared to the “afternoon shift” day (3.860; sd 0.228), see Table 1. In total 5 out of 18 drivers reached KSS levels of 8 or higher and 9 drivers reached KSS 7 or higher.

KDS mean was significantly higher during the “split shift” day (0.648; sd 0.101) compared to the “afternoon shift” day (0.463; sd 0.101). KDS Max was higher during “split shift” days (7.014; sd 0.807) compared to “afternoon shift” (4.861; sd 0.807). In addition, blink durations were longer the “split shift” day (0.113 sd 0.004) compared to the “afternoon shift” day (0.112 sd 0.004), however the difference was not significant, see Table 1 and Figure 2. For all indicators there were significant differences between participants see Table 1 and Figure 3. There were no significant interactions.

Table 1 Mixed Model Anova. Factors: Type of shift (Split shift, Afternoon shift); Minute (40, 45, 50, 55, 60, 65, 70, 75); Interaction on 2-level. Significant effects in bold, p in brackets, and df.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Type of shift</th>
<th>Minute</th>
<th>Type of shift*Minute</th>
<th>Participants (Wald Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSS</td>
<td>243.245 (&lt;0.01) (df 1, 249)</td>
<td>1.904 (0.069) (df 7, 248)</td>
<td>0.133 (0.133) (df 7, 248)</td>
<td>2.688 (&lt;0.01)</td>
</tr>
<tr>
<td>Blink duration</td>
<td>0.554 (0.457) (df 1, 255)</td>
<td>0.516 (0.822) (df 7, 255)</td>
<td>0.973 (0.452) (df 7, 255)</td>
<td>2.818 (&lt;0.01)</td>
</tr>
<tr>
<td>KDS mean</td>
<td>5.114 (0.025) (df 1, 255)</td>
<td>0.979 (0.447) (df 7, 255)</td>
<td>0.526 (0.815) (df 7, 255)</td>
<td>2.340 (0.02)</td>
</tr>
<tr>
<td>KDS max</td>
<td>8.960 (&lt;0.01) (df 1, 255)</td>
<td>0.894 (0.512) (df 7, 255)</td>
<td>0.499 (0.512) (df 7, 255)</td>
<td>2.188 (0.03)</td>
</tr>
</tbody>
</table>
Figure 2 Driver sleepiness indicators KSS, Blink duration, KDS max and KDS mean. Minute correspond to minutes driven from start, error bars represent Confidence Interval (CI).
The drivers had significantly longer response times performing PVT test when driving the split shift (0.346; sd 0.009) compare to afternoon shift (0.335; sd0.09) (F(1, 66) 5.142; p=0.027), see Figure 4. There was no significant difference between the three tests during the day of visit (F(2, 66) 2.896; p=0.062) and there was no significant interaction.

The PVT lapses (%) increased comparing the split shift (4.650; sd 1.047) to afternoon shift (2.337; sd 1.069), but the difference was not significant (F(1, 67) 2.582; p=0.113). In addition there was no significant difference between the three tests a day (F(2, 67) 1.326; p=0.272) and there was no significant interaction.

Figure 3 Individual differences in KSS, blink duration and KDS mean
Figure 4 PVT response time and PVT lapses for afternoon shift and split shift situation, performed three times (before start, after lap 2, after lap 3). Error bars represent Confidence Interval (CI).

Also for PVT response time (s) and lapses (%) there was major individual differences. The majority of the subjects showed an increased response time and increased frequency of lapses, but there was also some individuals that behaved differently, see Figure 5.

Figure 5 PVT response time and PVT lapses for afternoon shift and split shift situation, performed three times (before start, after lap 2, after lap 3). Error bars represent Confidence Interval (CI).
4. DISCUSSION
Driving a bus in the afternoon during a split shift situation was shown to be related to higher levels of self-reported sleepiness (KSS), higher levels of physiological sleepiness (KDS) and increased response times (PVT), compared to an afternoon shift. The absolute levels of KDS was still rather low, even though some of the subjects reach high levels on KDS, also the case for KSS and PVT.

In a review about KSS and its sensitivity as indicator of insufficient sleep and impaired waking function it was shown that KSS levels above 6 is related to increased number of incidents (T. Åkerstedt et al., 2014). The authors conclude an effect size of KSS between day and night time driving on real road of 2.6 ± 0.10; and between start and end of shift at 1.87 ± 0.40. In the present study the effect size was 1.94, which means higher than for night shift, but lower than real road driving at night. The observed effect size should be considered as rather high for a day time situation at ordinary work. As always, there were major individual difference in the reporting of KSS. In fact 5 out of 18 drivers reported severe sleepiness (KSS ≥8), this needs to be considered as critical since several studies on real roads have shown an increased risk for involuntary line crossings at such levels (Sandberg et al., 2010; T Åkerstedt et al., 2013).

Even though there are significant differences in KDS mean and max, between afternoon shift and split shift, the absolute levels are rather low. In general, driving simulator studies show an increase in KDS during night time driving, leading to significant increased variability in lateral position at KDS 20% and an increased risk for line crossings at KDS 30% (Anund et al., 2008). Comparing how drivers react in simulators versus real road driving show differences in both sensitive indicators and their thresholds (Hallvig, Anund, Fors, Kecklund, Karlsson, Wahde et al., 2013; Philip et al., 2005).

In simulator studies there are normally significant effects on KDS, in opposite it seem to be less sensitive when driving on real roads (Hallvig et al., 2013). The reason for this is not know, but might be related to the more realistic situation with real risks and the need to fight to stay awake. Therefor it was not really expected to see significant differences in KDS for the split shift situation at daytime driving and even though the absolute levels of KDS mean and max are rather low it is clear that the split shift situation provide more alfa activity and slow eye movements in the EEG for the majority of the drivers. Micro sleeps are at risk to occur at high levels of KDS, a situation that is correlated with increased cognitive capability and hence an increased risk for incidents or crashes.

Psychomotor Vigilance Test (PVT) is commonly used to measure behavioural alertness and is proven to be sensitive to the effects of sleep loss and circadian misalignment (Mathias Basner & Dinges, 2011; Dinges & Kribs, 1991; Dinges & Powell, 1985; Van Dongen & Dinges, 2005). In this study the drivers performed the PVT test three times at each experimental day (at arrival, after 2 laps, after lap 3). There was no significant difference in response time for the three tests, but there was a significant delay for the split shift day compared to the afternoon shift day with an overall response time divergence of 0.011s or 0.095s expressed as Response time speed (1/RT). There was also significant differences between the individuals. The results are in line with studies looking into effects on PVT under for example partial sleep deprivation (M Basner et al., 2011).

This study suffers from several limitations. One is related to the real road situation and to the fact that simulating the ordinary work as a bus driver, includes driving in both urban and sub-urban environments with a rather flexible surrounding. From an experimental point of view there will be problems with confounding with especially external factors like; prevalence of unprotected road users
or other car drivers. This comes with realistic designs and is difficult to adjusted for. The real road situation also cause a higher degree of artefacts in physiological signals. The reason for this is not fully know, it might be an effect of the fight to stay awake, but also the fact that you are moving a lot more then in a laboratory. In any case it is important to find a solution in order to in a more clear way identify risky driving behaviour due to driver sleepiness. A limitation is also that the results is not proven to be valid for other type of bus routes, like long haul transports. The situations for them, most truly, do not only included an effect of time of the day, hours being awake or hours slept the last 24 hours, but also an effect related to the task. The driving situation might cause them cognitive underload or overload, depending on the route to go and the level of stress. Just as for other groups of drivers, promising countermeasures needs to be adjusted depending on the reason for driver fatigue (May & Baldwin, 2009). Future studies are rated as important in order to understand when, why and how driver fatigue appear among bus drivers and how it influence their safe driving. Not only the relationship to type of shifts needs to be considered, but also the environment they drive in, driver ergonomic aspects, the drivers’ health, stress and coping strategies.

5.  AKNOWLEDGEMENT
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REFERENCES