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The self-reported causes of sleepiness in shift-working tram and truck drivers

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ABSTRACT

Identifying the causes of sleepiness in various safety-critical work environments is necessary for implementing more efficient fatigue management strategies. In transportation, little is known about drivers' own perceptions of these causes. Therefore, we instructed shift-working tram (n = 23) and long-haul truck drivers (n = 52) to report at the end of their shifts what made them sleepy if they felt so. These self-reports, measured on-duty sleepiness, and sleep amounts were recorded on every shift over a period of 2–3 weeks per driver. The causes of sleepiness were queried with smartphone applications and sleep logs. Sleepiness was measured with the Karolinska Sleepiness Scale (KSS) and sleep with wrist-worn actigraphs. Data were analyzed using generalized estimating equations. Sleep loss and insufficient rest breaks were commonly reported as causing sleepiness among the tram drivers, whereas time of day and sleep loss were the leading causes among the truck drivers. Other causes, such as traffic or cabin conditions, were not frequently mentioned. During morning, day, and evening shifts, the truck drivers were less likely to report insufficient rest breaks as causing sleepiness than the tram drivers. Similarly, during morning shifts, the truck drivers were less likely to attribute their sleepiness to sleep loss. In shifts with drives reporting severe sleepiness (KSS $\geq$ 7 at least once, 18–21% of shifts), sleep loss was significantly reported as causing sleepiness among both groups. Reporting insufficient rest breaks was associated with severe sleepiness among the tram drivers, whereas time of day showed the same among the truck drivers. The results highlight the need for addressing sleep-related fatigue in transportation and provide directions for future research with regard to secondary causes of sleepiness.

1. Introduction

Sleepiness and fatigue are safety risks in many work tasks. For example, sleepiness due to insufficient sleep or sleep pathology clearly increases the risk of traffic accidents (Connor et al., 2002; Philip & Åkerstedt, 2006; Williamson et al., 2011). This risk is especially high when driving at night or during the early morning hours (Folkard, 1997; Åkerstedt &

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Kecklund, 2001). A typical cause of sleepiness among e.g., professional drivers is shift work, where a driver is exposed to both working at an unfavorable time of day and sleep loss (Costa, 2015).

In research literature, the terms sleepiness and fatigue are sometimes used synonymously (Phillips, 2015). Sleepiness (or drowsiness) refers to difficulty staying awake, whereas fatigue may refer to difficulty maintaining the original level of performance in the present task (Brown, 1994). The former is closely linked to circadian regulation of sleep-wake rhythm and homeostatic sleep pressure (Gabehart & Van Dongen, 2017), whereas the latter is associated with task features such as duration, complexity, and pace.

May and Baldwin (2009) posit that fatigue may be caused either by sleep-related or task-related factors and stress the importance of identifying these factors in different working conditions. Previous research has identified determinants of sleepiness in driving simulator studies (Ahlström, Anund, Fors, & Åkerstedt, 2018a; Anund, Lahti, Fors, & Genell, 2015; Matthews & Desmond, 2002; Thiffault & Bergeron, 2003) and in the field of transportation (Adams-Guppy & Guppy, 2003; Brown, 1994; Miller, Filtness, Anund, Maynard, & Pilkington-Cheney, 2020; Taylor & Dorn, 2006). Arguably, mitigating sleep-related causes of fatigue is the top priority in preventing workplace safety hazards (Caldwell, Caldwell, Thompson, & Lieberman, 2019). However, designing occupation-specific efforts toward better fatigue management strategies is hampered by several factors. For example, several task-related factors may mask physiological sleepiness (Gabehart & Van Dongen, 2017). The work tasks in transportation are also variable by nature (Phillips, 2014). In urban transportation, the amount of traffic may be substantial, placing potentially high attentive demands to the driver. Unlike in long-distance operations, frequent stops are typical in urban transportation especially near the morning and afternoon travel peaks.

Arguably, drivers' own perceptions of what makes them sleepy at work would be valuable in increasing our understanding of the causes of sleepiness in transportation (Lal & Craig, 2001). Among urban bus drivers, time pressure, interaction with passengers, working overtime, insufficient sleep, other non-work commitments, lack of managerial support, cabin ergonomics, and long commute times have been reported as contributing to sleepiness (Biggs, Dingsdag, & Stenson, 2009; Maynard, Filtness, Miller, & Pilkington-Cheney, 2020; Tse, Flin, & Mearns, 2006). To date, very few studies have investigated the self-reported causes of sleepiness on a day-to-day basis in connection with different working time arrangements. In one study, Sallinen and colleagues (2021) found that the timing of the flight duty period and inadequate prior sleep were reported as the causes of sleepiness among airline pilots. However, the generalizability of the previous findings beyond aviation may be limited. For instance, airline pilots undergo fatigue management training and cover distances through different time zones. To the best of our knowledge, there is also no data to compare different occupational groups.

The key aim of this study was to find out professional drivers' perceptions of factors that make them sleepy and compare two driver groups, tram and long-haul truck drivers, in this regard. The association between self-reported causes of sleepiness and self-reported on-duty sleepiness was also investigated. In addition, we examined the association between sleep time prior to work shifts and sleep loss as a self-reported cause of sleepiness. We hypothesized that both driver groups emphasize sleep loss and unfavorable times of day as causes of sleepiness. To our knowledge, this is the first study to examine the differences in self-reported causes of driver sleepiness in different subgroups in transportation.

2. Methods

2.1. Participants

Participants were tram drivers (n = 23) working for Helsinki City Transport, and long-haul truck drivers (n = 52) working for four Finnish haulage companies operating in Finland. The tram drivers' working hours extended from 5:05 a.m. at the earliest to 2:25 a.m. at the latest. The truck drivers worked irregular shifts around the clock with no set shift schedule. The timing of shifts is illustrated in Fig. 1. The study period was three weeks (one full shift rotation) for the tram drivers and two weeks for the truck drivers. Earlier studies on the truck drivers (Onninen, Pylkkönen, Tolvanen, & Sallinen, 2021; Pylkkönen et al., 2015) provide information about the participants and their working hour arrangements as well as their sleep and sleepiness in more detail. Written consent was obtained from all participants. This study was approved by the Ethics Committee of the Finnish Institute of Occupational Health.

2.2. Procedures

2.2.1. Pre-measurement questionnaires

Prior to field studies, both groups of drivers completed a questionnaire covering basic demographic factors as well as sleep habits including habitual sleep need (Basic Nordic Sleep Questionnaire; Partinen & Gislason, 1995), and diurnal type (Torsvall & Åkerstedt, 1980).

2.2.2. Field studies

Both groups of drivers underwent a period of field measurements to record their working hours, sleep, subjective sleepiness, and self-reported causes of sleepiness. An electronic diary was used to record working hours, sleep, and self-reported causes of sleepiness. Sleep was also measured using wrist-worn actigraphs (tram drivers: GENEActiv, Activinsights Ltd, UK; truck drivers: Actiwatch 7, CamNtech Ltd, Cambridgeshire, UK). Subjective sleepiness was measured with the Karolinska

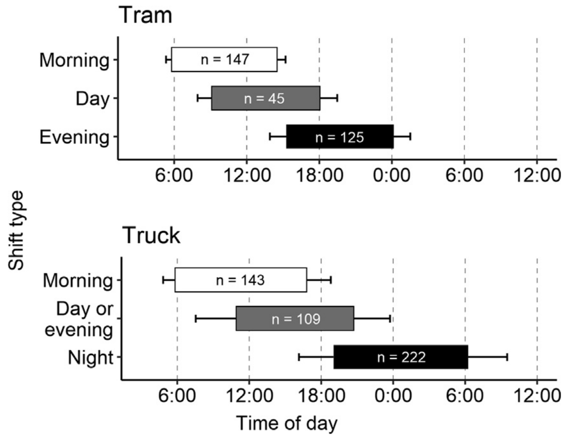

Fig. 1. Number and timing of work shifts (average start and end times) of the tram and truck drivers. Error bars denote standard deviations.

Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990). The tram drivers were instructed to report their sleepiness (KSS) with a smartphone at the beginning and end of each work shifts as well as before and after each rest break. The truck drivers were instructed to rate their sleepiness (KSS) once per hour with a smartphone attached to the dashboard. All drivers were instructed to report how sleepy they were feeling "within the last five minutes" (tram drivers) or "currently" (truck drivers). The field studies took place between November and May (tram drivers), and November and March (truck drivers).

2.3. Outcome measures

Main outcomes were the self-reported causes of sleepiness queried with a smartphone application (tram drivers) and a sleep diary (truck drivers) after each work shift (Table 1). The causes of sleepiness were compared based on the driver group by shift type and in matching work shifts (morning and day or evening shifts). Total sleep time (TST) as measured with actigraphy was compared within driver groups based on whether sleep loss was reported as a cause of sleepiness. The causes were also investigated separately for all shifts and those with severe subjective sleepiness. KSS $\geq$ 7 at least once during a shift was classified as severe sleepiness, since such levels correlate with physiological sleepiness (Åkerstedt & Gillberg, 1990). For the statistical analyses, the causes of sleepiness were categorized as follows: sleep loss, time of day, insufficient rest breaks, and other causes.

2.4. Statistical analyses

To account for the correlation between observations within individual drivers, logistic regression models were fitted using generalized estimating equations (GEEs; Liang & Zeger, 1986). For each GEE model fitted, the correlation structure was chosen a priori based on the quasi-likelihood under the independence model criterion (QIC; Pan, 2001). The GEE results are presented as adjusted odds ratios (OR) and their 95% confidence intervals with p values from F tests of term significance (Fay & Graubard, 2001). GEEs were used to analyze the differences between the driver groups to report different causes of sleepiness during morning and day or evening shifts. Since the duration of work shifts was on average nearly two hours longer among the truck drivers (10 h 49 min versus 8 h 50 min for the tram drivers), we added shift duration as a covariate in the first analyses. Because the driver groups differed in proportion of parents with children under 7 years of age and different diurnal types (Kruskal-Wallis tests, all $p < .05$), the analyses were also adjusted for these factors. Here, tram drivers acted as a reference group. GEEs were also used to analyze the association between severe sleepiness during shifts and the reported causes of sleepiness. In these analyses, shift type was included as a covariate. The statistical models are provided in detail in Appendix A. Analyses were carried out in R using packages *BCgee* (Lunardon & Scharfstein, 2017) and *saws* (Fay & Graubard, 2001), which reduce small-sample-related bias.

3. Results

The tram and truck drivers were on average 40.6 and 38.1 years old, respectively (Table 2). They had an average of 10.6–14.8 years of work experience. The gender composition of the tram driver group was well balanced, whereas the truck driver group included only one woman. The driver groups also differed in terms of diurnal type, with the tram drivers reporting less intermediate type and more evening type than the truck drivers.

Table 1
Driver group comparisons of data collected regarding self-reported causes of sleepiness.

	Tram drivers	Truck drivers
Question	"If you felt sleepy while driving, what do you think caused it?"	
Timing	After work shift, before bedtime	
Method	Smartphone application	Sleep diary
Response choices	Irregular/too little sleep	Irregular/too little/poor quality sleep
	Time of day (e.g. night)	Time of day (e.g. night)
	Long drive without a rest break	Long drive without a rest break
	Traffic*	Traffic (e.g. little traffic)†
	Condition of cabin*	Condition of cabin (e.g. temperature)†
	Visibility*	Visibility (e.g. darkness)†
	Condition of railways*	Condition of road (e.g. dry road)†
	Other*‡	Road type (e.g. straight and wide road)†

Note: Causes of sleepiness classified as "other causes" in tram (*) and truck drivers (†). Open-ended response choice (‡).

Table 2
Demographic and sleep-related characteristics of the drivers (mean ± standard deviation or %).

	Tram drivers	Truck drivers
Age, yr	40.6 ± 11.4	38.1 ± 10.5
Females, %	48	2
Body mass index, kg/m^2	26.5 ± 6.1	27.7 ± 4.4
Work experience, yr	10.6 ± 9.2	14.8 ± 10.0
Habitual sleep need, h:min*	7:35 ± 0:44	7:45 ± 1:00
Has children < 7 yr, %	30	18
Diurnal type, %†		
Morning	35	26
Intermediate	17	58
Evening	48	16

* Partinen and Gislason (1995).
† Torsvall and Åkerstedt (1980).

3.1. Self-reported causes of sleepiness by shift type

3.1.1. Tram drivers

Sleep loss was the most commonly self-reported cause of feeling sleepy among the tram drivers irrespective of shift type (Fig. 2). It was reported in 35.3% of all shifts. Insufficient rest breaks and, to a lesser extent, time of day were also commonly self-reported in all shift types (17.4 and 11.8%, respectively). All other causes of feeling sleepy were indicated in 12.0% of all shifts. Cabin conditions were reported in 22.2% of the evening shifts. Other causes reported by the tram drivers included personal issues, pain, low light, and boring route. At least once cause was reported in 69.1% of shifts. In shifts where at least one cause was reported, the average number of causes was 1.4 (±0.68).

3.1.2. Truck drivers

Among the truck drivers, time of day was the most commonly self-reported cause of feeling sleepy in night shifts, whereas sleep loss was commonly self-reported irrespective of shift type (Fig. 2). Sleep loss, time of day, insufficient rest breaks, and other causes were self-reported in 22.2, 19.2, 5.7, and 12.9% of all shifts, respectively. Traffic and visibility were most prominently reported in night shifts. At least one cause was reported in 51.1% of shifts. In shifts where at least one cause was reported, the average number of causes was 1.5 (±0.85).

3.2. Differences in self-reported causes of sleepiness between the driver groups during morning and day or evening shifts

Fig. 3 suggests that the tram drivers reported sleep loss more frequently than the truck drivers during morning shifts. In morning shifts, the truck drivers were less likely to self-report sleep loss as a cause of feeling sleepy (adjusted OR = 0.291 [95% confidence interval {CI} 0.111–0.766], p = .014) than the tram drivers (Fig. 4). This difference was not statistically significant for day or evening shifts in any of the models (all p > .05). In morning shifts, after adjusting for shift duration, the truck drivers were less likely to self-report time of day (adjusted OR = 0.059 [95% CI 0.004–0.857], p = .039), but not after further adjustments for individual factors (p = .144). Furthermore, the truck drivers reported insufficient rest breaks significantly less frequently than the tram drivers during both morning (adjusted OR = 0.065 [95% CI 0.015–0.280, p < .001) and day or evening shifts (adjusted OR = 0.124 [95% CI 0.026–0.579], p = .009). The truck drivers reported other causes less fre-

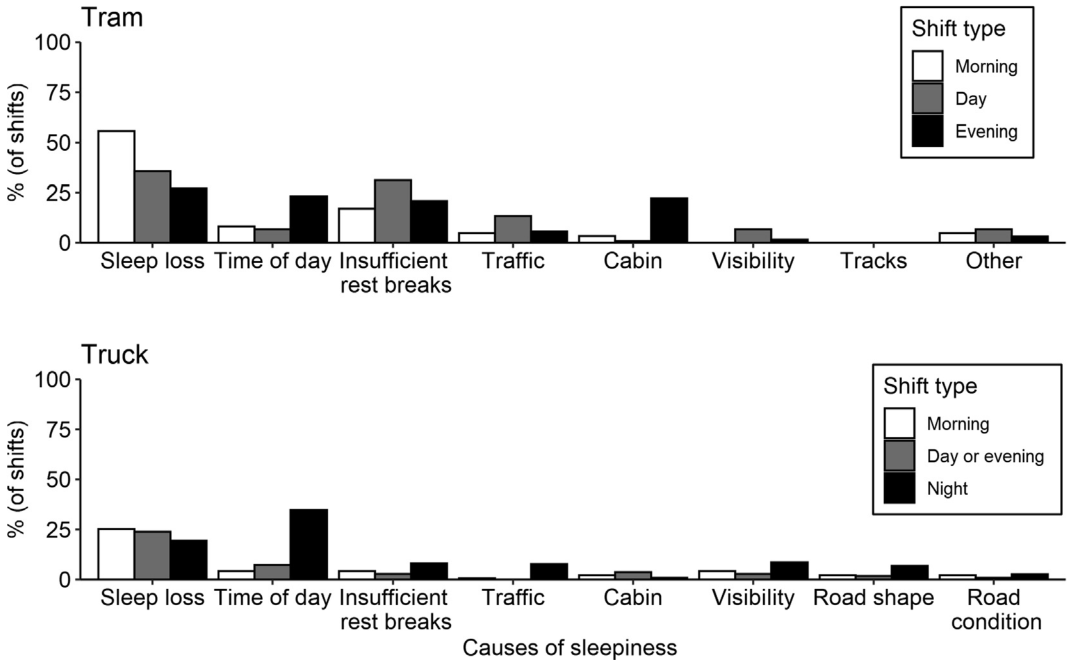

Fig. 2. Self-reported causes of sleepiness by shift type among the tram and truck drivers.

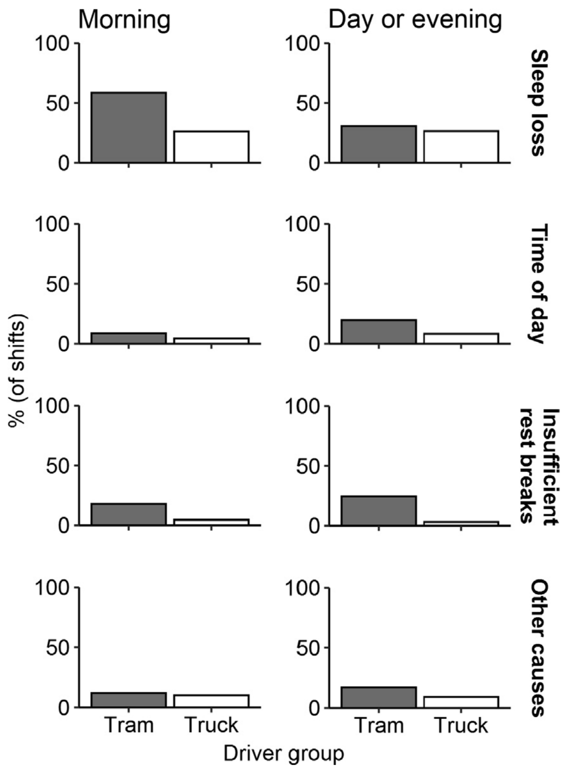

Fig. 3. The percentage of morning and day or evening shifts where different causes of sleepiness were reported by the tram and truck drivers.

quently than the tram drivers during day or evening shifts after adjusting for shift duration (adjusted OR = 0.236 [95% CI 0.067–0.840], p = .027), but not after further adjustments (p = .101). (For detailed analyses, see Appendix A, Table A1.)

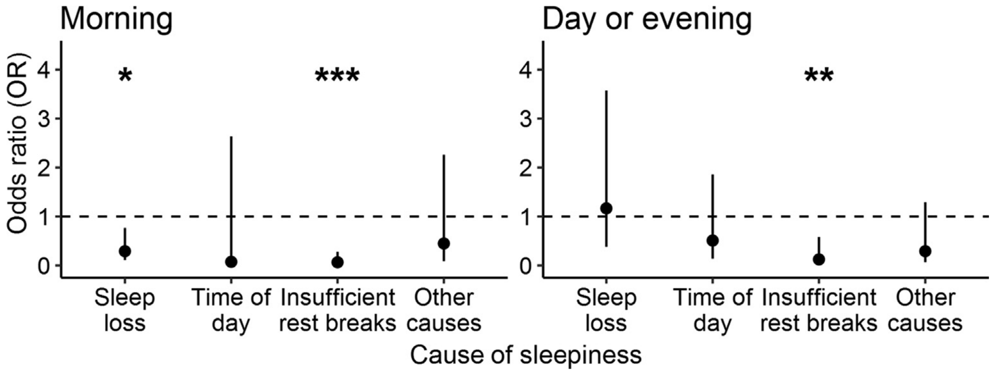

Fig. 4. Adjusted odds ratios (OR) with 95% confidence intervals for truck drivers to report different causes of sleepiness, compared to tram drivers, in morning and day or evening shifts. * = p < .05, ** = p < .01, *** = p < .001.

3.3. Sleep prior to work shifts and sleep loss as a self-reported cause of sleepiness

TST prior to work shift appeared shorter for the shifts where sleep loss was self-reported as causing sleepiness than for the shifts where it was not (Fig. 5). This difference was observed in all shift types but appeared more pronounced among the truck drivers. Among the tram drivers, the differences in mean TST in morning, day, and evening shifts was roughly 34, 76, and 22 min, respectively. Among the truck drivers, the difference in morning, day or evening, and night shifts was roughly 58, 75, and 51 min, respectively.

3.4. Self-reported causes of sleepiness in shifts with severe sleepiness by driver group

3.4.1. Tram drivers

Among the tram drivers, severe sleepiness was reported in 20.8% of all shifts. Sleep loss was self-reported as a cause of sleepiness in 68.2% of the shifts with severe sleepiness. Time of day and insufficient rest breaks were reported in 22.7% and 40.9% of such shifts, respectively. Sleep loss was particularly commonly reported during morning shifts (Fig. 6). Cabin conditions were reported in 42.9% (n = 3) of the day shifts with severe sleepiness. At least one cause was reported in 92.4% of all shifts with severe sleepiness. Both sleep loss and time of day were reported in 17.1% of morning and 20.8% of evening shifts, but in none of the day shifts (6.3% of all shifts). Sleep loss and insufficient rest breaks together were reported in 8.5% of all shifts.

3.4.2. Truck drivers

Among the truck drivers, severe sleepiness was reported in 17.9% of all shifts. Time of day was the most commonly self-reported cause of sleepiness among those shifts (58.8% of the shifts). Insufficient sleep was reported in 45.9% of such shifts. Time of day was clearly reported during night shifts, whereas sleep loss was most frequently reported during morning shifts (Fig. 6). 92.9% of all shifts with severe sleepiness included at least one reported cause. Both sleep loss and time of day were

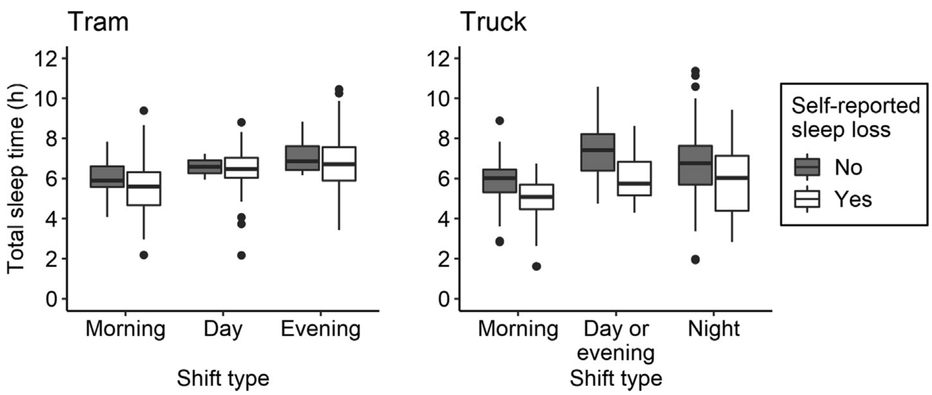

Fig. 5. Total sleep time (h) prior to different work shifts based on whether sleep loss was not (grey) or was self-reported (white bars) as a cause of sleepiness among the tram and truck drivers.

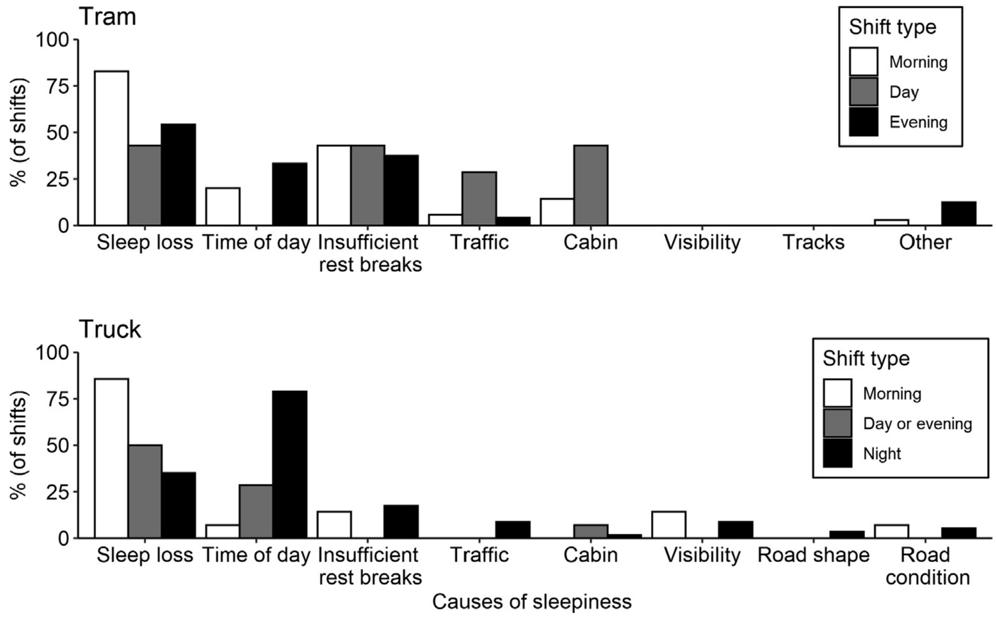

Fig. 6. The causes of sleepiness in work shifts with severe sleepiness (Karolinska Sleepiness Scale ≥ 7 at least once) among the tram and truck drivers.

reported in 29.8% of night, 7.1% of morning, and 14.3% of day or evening shifts (12% of all non-night shifts). Both sleep loss and insufficient rest breaks together were reported in 5.9% of all shifts with severe sleepiness.

3.5. Association between self-reported causes of sleepiness and severe on-duty sleepiness by driver group

3.5.1. Tram drivers

Among the tram drivers, the self-reports of sleep loss and insufficient rest breaks as causes of feeling sleepy were significantly associated with severe on-duty sleepiness (Fig. 7). The adjusted odds of severe sleepiness were over threefold for shifts with sleep loss (adjusted OR = 3.65 [95% CI 1.25–10.64], p = .020) and insufficient rest breaks reported (adjusted OR = 3.52 [95% CI 1.53–7.45], p = .005). Time of day or the other causes were not associated with severe on-duty sleepiness (p > .05). There were no significant differences between the crude and adjusted GEE models.

3.5.2. Truck drivers

Among the truck drivers, the adjusted odds of severe sleepiness were five- to sevenfold for shifts with sleep loss (adjusted OR = 5.31 [95% CI 2.68–10.52], p < .001) and time of day (adjusted OR = 7.07 [95% CI 3.68–13.56], p = .020) as self-reported causes of feeling sleepy (Fig. 7). Insufficient rest breaks or the other causes were not associated with severe on-duty sleepiness (p > .05). There were no significant differences between the crude and adjusted GEE models. (For detailed analyses, see Appendix A, Table A2.)

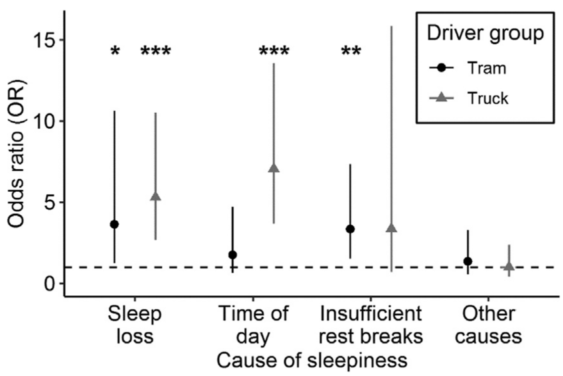

Fig. 7. Adjusted odds ratios (OR) of severe sleepiness (Karolinska Sleepiness Scale ≥ 7 at least once) associated with different self-reported causes of sleepiness. ORs with 95% confidence intervals are shown for the tram and truck drivers separately.

4. Discussion

Here, we examined factors that tram and long-haul truck drivers perceive as making them sleepy during different work shifts. As expected, sleep loss was a common cause of sleepiness in both driver groups. Time of day and long driving bouts with insufficient rest breaks were also frequently identified by the drivers. For the most part, other factors, such as traffic, the conditions or the nature of the route or cabin were seldom reported as inducing sleepiness. Self-reports of sleep loss were generally associated with severe on-duty sleepiness.

Sleep loss was the single most commonly specified cause across all work shifts in both driver groups. This was expected, since these drivers frequently obtain less sleep than generally recommended (Pylkkönen et al., 2015), and since subjective sleepiness is a hallmark of insufficient sleep (Åkerstedt, Anund, Axelsson, & Kecklund, 2014). The truck drivers were less likely to report sleep loss as the cause of sleepiness in morning shifts but not in day or evening shifts. Since the statistical models were adjusted for shift duration and diurnal type, the observed difference cannot be attributed to these factors. Instead, it could be partly explained by individual differences in sleep need. Self-reported sleep loss appeared to be associated with shortened sleep prior to work shifts, as measured with actigraphy, although the size of the difference was rather small especially in connection with early and late shifts.

The drivers studied here perceived time of day as making them sleepy in 12–19% of all shifts. It was the leading cause of sleepiness in night shifts among the truck drivers. This is consistent with substantial scientific evidence linking night work and sleepiness (Åkerstedt et al., 2014). Although morning, day, and evening shifts were not statistically tested for differences in this regard, the drivers appeared to report time of day as a cause of sleepiness least in day shifts, again corresponding to previous research (Åkerstedt et al., 2014).

Long driving bouts with insufficient rest breaks were perceived as causing sleepiness in 6–17% of all shifts among all drivers. Here, both timing and frequency of rest breaks probably matter. In Europe, truck drivers are ensured a single break of at least 45 min for every 4.5 h of driving. The break may be divided into a single 15-minute break and a 30-minute break. The rest breaks of the tram drivers in Finland are governed by collective agreements that limit the maximum continuous driving time to 5.5 h, although 4 h is usually closer to what is actualized. However, public transport drivers have less autonomy in timing their rest breaks due to the nature of their work task. The alertness-enhancing effect of rest breaks may last for no more than 25 min (Neri et al., 2002). Because the periods of driving between rest breaks are markedly longer in both driver groups, it was predictable that the drivers consider their rest breaks inadequate. This is true especially for the tram drivers for whom on-duty naps are unfeasible.

The other causes of sleepiness were implicated by the drivers in one eighth of all shifts. Traffic was infrequently reported in both driver groups. Unfortunately, the questionnaires used here did not contain an option to specify whether traffic as a source of sleepiness was related to high or low traffic density. Such indications would have been interesting to interpret as signs of cognitive load (Desmond & Hancock, 2001). Cabin conditions were implicated in the tram drivers' evening shifts. Limited previous research suggests that exposure to heat and glare may be sleepiness-inducing factors in the cabin (Biggs et al., 2009). Visibility appeared slightly more common as a cause of sleepiness among the truck drivers. This is possibly due to group-wise differences in the drivers' exposure to light (Ahlström, Anund, Fors, & Åkerstedt, 2018b; Phipps-Nelson, Redman, Schlangen, & Rajaratnam, 2009; Taillard et al., 2012). Furthermore, the truck drivers perceived visibility as causing sleepiness particularly during night shifts. This finding is in accordance with the notion that poor visibility increases task-related sleepiness (May & Baldwin, 2009).

Reporting sleep loss and time of day were positively associated with the occurrence of severe sleepiness during work shifts. This was expected, since the two factors are the primary determinants of sleep propensity (Borbély, Daan, Wirz-Justice, & Deboer, 2016). Although not statistically verified, reporting both sleep loss and time of day reached its maximum during night shifts and its minimum during day shifts.

The tram drivers studied here appeared to indicate insufficient rest breaks as a cause of sleepiness especially in shifts where they also experienced severe sleepiness. This is consistent with a recent survey of London bus drivers showing that the perception of insufficient rest breaks (as well as poor sleep) is one of the strongest predictors of driver sleepiness (Miller et al., 2020). The finding is also consistent with previous research showing that extended periods of driving induces sleepiness, inattentiveness and/or fatigue (Brown, 1994; Larue et al., 2011; Schmidt et al., 2009, Åkerstedt et al., 2010) and that rest breaks may be effective in alleviating driver sleepiness (Eriksen, Åkerstedt, Kecklund, & Åkerstedt, 2005; Otmani et al., 2005; Phipps-Nelson, Redman, & Rajaratnam, 2011; Tucker et al., 2003). Furthermore, the time-on-task effect on fatigue has been shown to be escalated when the driver's sleep is restricted (Otmani et al., 2005). Similarly, in a driving simulator study, Phipps-Nelson et al. (2011) showed that this effect is amplified under conditions of high sleepiness. Additionally, sleep loss and insufficient rest breaks together were reported in roughly 6–9% of all shifts with severe sleepiness. This rather small portion suggests that the tram drivers were susceptible to severe sleepiness due to long continuous driving even when they were not affected by sleep loss.

Finally, we found that within both driver groups, reports of sleep loss as causing sleepiness were over threefold higher in work shifts affected by severe sleepiness, compared to shifts where severe sleepiness was not reported. Insufficient rest breaks were associated with severe sleepiness among the tram drivers. Interestingly, this factor appeared to be reported independent of sleep loss. Time of day was linked to severe sleepiness among the truck drivers. The properties of the KSS are such that sleepiness ratings above the cut-off point (i.e., 7 or higher) best correspond to physiological sleepiness

(Åkerstedt & Gillberg, 1990). Therefore, these results are in line with the notion that sleep-related causes of fatigue are the most important to consider in preventing on-duty sleepiness (Caldwell et al., 2019). Additionally, since the tram drivers seldom reported both sleep loss and insufficient rest breaks as causing sleepiness, it could be argued that task-related factors are an independent cause of severe sleepiness. Although other factors such as cabin conditions and environmental factors were not associated with severe sleepiness, it has been suggested that these could interact with physiological sleepiness (Gabehart & Van Dongen, 2017; May & Baldwin, 2009). However, this effect is probably rather small.

Taken together, our findings show that both driver groups frequently attribute on-duty sleepiness to sleep-related causes, namely lack of or poor-quality sleep. When sleep loss was self-reported as causing sleepiness, sleep prior to work shift did appear shortened. Tram drivers are also possibly vulnerable to secondary causes related to the nature of the task (May & Baldwin, 2009). However, more research is needed to solve whether this task-related sleepiness is due to cognitive underload or overload, or ultimately related to underlying, latent physiological sleepiness (Goel, Abe, Braun, & Dinges, 2014; Yang, Lin, & Spielman, 2004; Åkerstedt, Kecklund, & Axelsson, 2008; Åkerstedt et al., 2014). Since introducing more rest breaks in tightly scheduled urban public transportation systems may not be feasible, alleviating time-on-task-related sleepiness may be achieved otherwise, e.g., via reducing auxiliary tasks and introducing automation or gamification (May & Baldwin, 2009; Phillips, Kecklund, Anund, & Sallinen, 2017; Ralph, Onderwater, & Thomson, 2016; Steinberger, Schroeter, & Watling, 2017). Truck drivers reported time of day as inducing sleepiness, which was expected since they regularly worked night shifts. The drivers appear to report at least one cause in most shifts where severe sleepiness is manifest. Interestingly, the self-reported causes are mostly in line with studies employing objective causes of sleepiness even though the drivers studied here do not routinely undergo fatigue management training, unlike airline pilots.

Several considerations are warranted as for the generalizability of these results. The participants were recruited via convenience sampling. Although the sampling rate with regard to different causes of sleepiness is a strength, they were queried in retrospect, and it is uncertain whether this delay influenced the self-ratings. Since individual factors affect sleep loss related performance impairment, sleepiness, or self-assessments thereof (Biggs et al., 2007; Caldwell, Caldwell, & Schmidt, 2008; Hudson, Van Dongen, & Honn, 2020; Lal & Craig, 2001), it is probable that inter-individual variation exists in the self-ratings of sleepiness as well. Moreover, employees' own perceptions of sleepiness may be obscured by other subjective states, such as anxiety or stress (Phillips, 2015; Taylor & Dorn, 2006). Severe sleepiness in some shifts, e.g., the tram drivers' day shifts, was observed so infrequently that the results are inconclusive. Our study did not elaborate on possible gender differences or various other causes associated with on-duty sleepiness, e.g., driver health or other personal factors (Biggs et al., 2009; Miller et al., 2020). The truck drivers in this study may have underestimated their on-duty sleepiness (Sallinen, Pylkkönen, Puttonen, Sihvola, & Åkerstedt, 2020).

5. Conclusions

Both tram and long-haul truck drivers frequently perceive sleep loss as making them sleepy on duty, which was expected based on previous findings that it is not uncommon for these drivers to obtain less sleep than generally recommended (Hirshkowitz et al., 2015). Insufficient rest breaks and inopportune working hours are also common self-assessed causes. The former is evident especially among tram drivers while the latter is pronounced among long-haul truck drivers in night shifts. Reports of sleep loss, prolonged driving periods with inadequate rest, and circadian influence are evident in shifts with severe sleepiness. These findings provide preliminary directions for planning more efficient occupation-specific fatigue management in the field of transportation. Namely, focusing on ensuring sufficient sleep and minimizing variation in sleep timing with more stable shift schedules is justifiable. Additionally, drivers in urban public transportation might benefit from countermeasures aimed at task-related sleepiness. Future research should seek to identify the specific factors in the work tasks of urban public transport operators that might contribute to on-duty sleepiness. More research is needed to substantiate these findings in related subsectors of transportation, in different working time arrangements, and in consideration of individual factors.

CRediT authorship contribution statement

Jussi Onninen: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing - original draft, Writing - review & editing, Visualization, Funding acquisition. **Mia Pylkkönen:** Methodology, Investigation, Writing - review & editing. **Tarja Hakola:** Methodology, Investigation, Writing - review & editing. **Sampsa Puttonen:** Conceptualization, Methodology, Writing - review & editing. **Jussi Virkkala:** Methodology, Investigation, Writing - review & editing. **Asko Tolvanen:** Formal analysis, Writing - review & editing. **Mikael Sallinen:** Conceptualization, Methodology, Investigation, Resources, Data curation, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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References

Adams-Guppy, J., & Guppy, A. (2003). Truck driver fatigue risk assessment and management: A multinational survey. *Ergonomics, 46*(8), 763–779. https://doi.org/10.1080/0014013021000056980.

Ahlström, C., Anund, A., Fors, C., & Åkerstedt, T. (2018a). Effects of the road environment on the development of driver sleepiness in young male drivers. *Accident Analysis and Prevention, 112*, 127–134. https://doi.org/10.1016/j.aap.2018.01.012.

Ahlström, C., Anund, A., Fors, C., & Åkerstedt, T. (2018b). The effect of daylight versus darkness on driver sleepiness: A driving simulator study. *Journal of Sleep Research, 27*(3). https://doi.org/10.1111/jsr.12642.

Anund, A., Lahti, E., Fors, C., & Genell, A. (2015). The effect of low-frequency road noise on driver sleepiness and performance. *PLoS ONE, 10*(4). https://doi.org/10.1371/journal.pone.0123835.

Biggs, S. N., Smith, A., Dorrian, J., Reid, K., Dawson, D., van den Heuvel, C., & Baulk, S. (2007). Perception of simulated driving performance after sleep restriction and caffeine. *Journal of Psychosomatic Research, 63*(6), 573–577. https://doi.org/10.1016/j.jpsychores.2007.06.017.

Biggs, H. C., Dingsdag, D., & Stenson, N. (2009). Fatigue factors affecting metropolitan bus drivers: A qualitative investigation. *Work, 32*(1), 5–10. https://doi.org/10.3233/WOR-2009-0810.

Borbély, A. A., Daan, S., Wirz-Justice, A., & Deboer, T. (2016). The two-process model of sleep regulation: A reappraisal. *Journal of Sleep Research, 25*(2), 131–143. https://doi.org/10.1111/jsr.12371.

Brown, I. D. (1994). Driver fatigue. *Human Factors, 36*(2), 298–314. https://doi.org/10.1177/001872089403600210.

Caldwell, J. A., Caldwell, J. L., & Schmidt, R. M. (2008). Alertness management strategies for operational contexts. *Sleep Medicine Reviews, 12*(4), 257–273. https://doi.org/10.1016/j.smrv.2008.01.002.

Caldwell, J. A., Caldwell, J. L., Thompson, L. A., & Lieberman, H. R. (2019). Fatigue and its management in the workplace. *Neuroscience & Biobehavioral Reviews, 96*, 272–289. https://doi.org/10.1016/j.neubiorev.2018.10.024.

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., ... Jackson, R. (2002). Driver sleepiness and risk of serious injury to car occupants: Population based case control study. *BMJ, 324*(7346), 1125–1128. https://doi.org/10.1136/bmj.324.7346.1125.

Costa, G. (2015). Sleep deprivation due to shift work. *Handbook of Clinical Neurology, 131*, 437–446. https://doi.org/10.1016/B978-0-444-62627-1.00023-8.

Desmond, P. A., & Hancock, P. A. (2001). Active and passive fatigue states. In P. A. Hancock & P. A. Desmond (Eds.), *Stress, workload and fatigue* (pp. 455–465). Mahwah, NJ: Lawrence Erlbaum Associates.

Eriksen, C. A., Åkerstedt, T., Kecklund, G., & Åkerstedt, A. (2005). Comment on short-term variation in subjective sleepiness. *Perceptual and Motor Skills, 101*(3), 943–948. https://doi.org/10.2466/pms.101.3.943-948.

Fay, M. P., & Graubard, B. I. (2001). Small-sample adjustments for Wald-type tests using sandwich estimators. *Biometrics, 57*(4), 1198–1206. https://doi.org/10.1111/j.0006-341X.2001.01198.x.

Folkard, S. (1997). Black times: Temporal determinants of transport safety. *Accident Analysis and Prevention, 29*(4), 417–430. https://doi.org/10.1016/s0001-4575(97)00021.

Gabehart, R. J., & Van Dongen, H. P. A. (2017). Circadian Rhythms in Sleepiness, Alertness, and Performance. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and Practice of Sleep Medicine* (6th ed., pp. 388–395). Philadelphia, PA: Elsevier. https://doi.org/10.1016/b978-0-323-24288-2.00037-4.

Goel, N., Abe, T., Braun, M. E., & Dinges, D. F. (2014). Cognitive workload and sleep restriction interact to influence sleep homeostatic responses. *Sleep, 37*(11), 1745–1756. https://doi.org/10.5665/sleep.4164.

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., ... Adams Hillard, P. J. (2015). National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Health, 1*(1), 40–43. https://doi.org/10.1016/j.sleh.2014.12.010.

Hudson, A. N., Van Dongen, H. P. A., & Honn, K. A. (2020). Sleep deprivation, vigilant attention, and brain function: A review. *Neuropsychopharmacology, 45*, 21–30. https://doi.org/10.1038/s41386-019-0432-6.

Lal, S. K. L., & Craig, A. (2001). A critical review of the psychophysiology of driver fatigue. *Biological Psychology, 55*(3), 173–194. https://doi.org/10.1016/S0301-0511(00)00085-5-3.

Larue, G. S., Rakotonirainy, A., & Pettitt, A. N. (2011). Driving performance impairments due to hypovigilance on monotonous roads. *Accident Analysis and Prevention, 43*(6), 2037–2046. https://doi.org/10.1016/j.aap.2011.05.023.

Liang, K.-Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika, 73*(1), 13–22. https://doi.org/10.1093/biomet/73.1.13.

Lunardon, N., & Scharfstein, D. (2017). Comment on 'Small sample GEE estimation of regression parameters for longitudinal data'. *Statistics in Medicine, 36*(22), 3596–3600. https://doi.org/10.1002/sim.7366.

Matthews, G., & Desmond, P. A. (2002). Task-induced fatigue states and simulated driving performance. *Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology, 55*(2), 659–686. https://doi.org/10.1080/02724980143000505.

May, J. F., & Baldwin, C. L. (2009). Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. *Transportation Research Part F: Traffic Psychology and Behaviour, 12*(3), 218–224. https://doi.org/10.1016/j.trf.2008.11.005.

Maynard, S., Filtness, A., Miller, K., & Pilkington-Cheney, F. (2020). Bus driver fatigue: A qualitative study of drivers in London. *Applied Ergonomics, 92*. https://doi.org/10.1016/j.apergo.2020.103309 103309.

Miller, K. A., Filtness, A. J., Anund, A., Maynard, S. E., & Pilkington-Cheney, F. (2020). Contributory factors to sleepiness amongst London bus drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 73*, 415–424. https://doi.org/10.1016/j.trf.2020.07.012.

Neri, D. F., Oyung, R. L., Colletti, L. M., Mallis, M. M., Tam, P. Y., & Dinges, D. F. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. *Aviation, Space and Environmental Medicine, 73*(7), 654–664.

Onninen, J., Pylkkönen, M., Tolvanen, A., & Sallinen, M. (2021). Accumulation of sleep loss among shift-working truck drivers (submitted for publication).

Otmani, S., Pebayle, T., Roge, J., & Muzet, A. (2005). Effect of driving duration and partial sleep deprivation on subsequent alertness and performance of car drivers. *Physiology & Behavior, 84*(5), 715–724. https://doi.org/10.1016/j.physbeh.2005.02.021.

Pan, W. (2001). Akaike's information criterion in generalized estimating equations. *Biometrics, 57*(1), 120–125. https://doi.org/10.1111/j.0006-341X.2001.00120.x.

Partinen, M., & Gislason, T. (1995). Basic Nordic Sleep Questionnaire (BNSQ): A quantitated measure of subjective sleep complaints. *Journal of Sleep Research, 4*(S1), 150–155. https://doi.org/10.1111/j.1365-2869.1995.tb00205.x.

Phillips, R. O. (2014). What is fatigue and how does it affect the safety performance of human transport operators? Institute of Transport Economics (TØI). https://www.toi.no/getfile.php?mmfileid=38953.

Phillips, R. O. (2015). A review of definitions of fatigue—And a step towards a whole definition. *Transportation Research Part F: Traffic Psychology and Behaviour, 29*, 48–56. https://doi.org/10.1016/j.trf.2015.01.003.

Phillips, R. O., Kecklund, G., Anund, A., & Sallinen, M. (2017). Fatigue in transport: A review of exposure, risks, checks and controls. *Transport Reviews, 37*(6), 742–766. https://doi.org/10.1080/01441647.2017.1349844.

Philip, P., & Åkerstedt, T. (2006). Transport and industrial safety, how are they affected by sleepiness and sleep restriction?. *Sleep Medicine Reviews, 10*(5), 347–356. https://doi.org/10.1016/j.smrv.2006.04.002.

Phipps-Nelson, J., Redman, J. R., Schlangen, L. J. M., & Rajaratnam, S. M. W. (2009). Blue light exposure reduces objective measures of sleepiness during prolonged nighttime performance testing. *Chronobiology International, 26*(5), 891–912. https://doi.org/10.1080/07420520903044364.

Phipps-Nelson, J., Redman, J. R., & Rajaratnam, S. M. W. (2011). Temporal profile of prolonged, night-time driving performance: Breaks from driving temporarily reduce time-on-task fatigue but not sleepiness. *Journal of Sleep Research, 20*(3), 404–415. https://doi.org/10.1111/j.1365-2869.2010.00900.x.

Pylkkönen, M., Sihvola, M., Hyvärinen, H. K., Puttonen, S., Hublin, C., & Sallinen, M. (2015). Sleepiness, sleep, and use of sleepiness countermeasures in shift-working long-haul truck drivers. *Accident Analysis and Prevention, 80*, 201–210. https://doi.org/10.1016/j.aap.2015.03.031.

Ralph, B. C. W., Onderwater, K., Thomson, D. R., & Smilek, D. (2016). Disrupting monotony while increasing demand: Benefits of rest and intervening tasks on vigilance. *Psychological Research, 81*(2), 432–444. https://doi.org/10.1007/s00426-016-0752-7.

Sallinen, M., Onninen, J., Ketola, K., Puttonen, S., Tuori, A., Virkkala, J., & Åkerstedt, T. (2021). Self-reported reasons for on-duty sleepiness among commercial airline pilots (submitted for publication).

Sallinen, M., Pylkkönen, M., Puttonen, S., Sihvola, M., & Åkerstedt, T. (2020). Are long-haul truck drivers unusually alert? A comparison with long-haul airline pilots. *Accident Analysis and Prevention, 137*. https://doi.org/10.1016/j.aap.2020.105442.

Schmidt, E. A., Schrauf, M., Simon, M., Fritzsche, M., Buchner, A., & Kincses, W. E. (2009). Drivers' misjudgement of vigilance state during prolonged monotonous daytime driving. *Accident Analysis and Prevention, 41*(5), 1087–1093. https://doi.org/10.1016/j.aap.2009.06.007.

Steinberger, F., Schroeter, R., & Watling, C. N. (2017). From road distraction to safe driving: Evaluating the effects of boredom and gamification on driving behaviour, physiological arousal, and subjective experience. *Computers in Human Behavior, 75*, 714–726. https://doi.org/10.1016/j.chb.2017.06.019.

Taillard, J., Capelli, A., Sagaspe, P., Anund, A., Åkerstedt, T., & Philip, P. (2012). In-Car Nocturnal Blue Light Exposure Improves Motorway Driving: A Randomized Controlled Trial. *PLoS ONE, 7*(10). https://doi.org/10.1371/journal.pone.0046750.

Thiffault, P., & Bergeron, J. (2003). Monotony of road environment and driver fatigue: A simulator study. *Accident Analysis and Prevention, 35*(3), 381–391. https://doi.org/10.1016/S0001-4575(02)00014-3.

Torsvall, L., & Åkerstedt, T. (1980). A diurnal type scale. Construction consistency and validation in shift work. *Scandinavian Journal of Work, Environment & Health, 6*(4), 283–290. https://doi.org/10.5271/sjweh.2608.

Tse, J. L. M., Flin, R., & Mearns, K. (2006). Bus driver well-being review: 50 years of research. *Transportation Research Part F: Traffic Psychology and Behaviour, 9*(2), 89–114. https://doi.org/10.1016/j.trf.2005.10.002.

Tucker, P., Folkard, S., & Macdonald, I. (2003). Rest breaks and accident risk. *Lancet, 361*(9358), 680. https://doi.org/10.1016/S0140-6736(03)12566-4.

Williamson, A., Lombardi, D. A., Folkard, S., Stutts, J., Courtney, T. K., & Connor, J. L. (2011). The link between fatigue and safety. *Accident Analysis and Prevention, 43*(2), 498–515. https://doi.org/10.1016/j.aap.2009.11.011.

Yang, C. M., Lin, F. W., & Spielman, A. J. (2004). A standard procedure enhances the correlation between subjective and objective measures of sleepiness. *Sleep, 27*(2), 329–332. https://doi.org/10.1093/sleep/27.2.329.

Åkerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience, 52*(1–2), 29–37. https://doi.org/10.3109/00207459008994241.

Åkerstedt, T., & Kecklund, G. (2001). Age, gender and early morning highway accidents. *Journal of Sleep Research, 10*(2), 105–110. https://doi.org/10.1046/j.1365-2869.2001.00248.x.

Åkerstedt, T., Kecklund, G., & Axelsson, J. (2008). Effects of context on sleepiness self-ratings during repeated partial sleep deprivation. *Chronobiology International, 25*, 271–278. https://doi.org/10.1080/07420520802110589.

Åkerstedt, T., Ingre, M., Kecklund, G., Anund, A., Sandberg, D., Wahde, M., ... Kronberg, P. (2010). Reaction of sleepiness indicators to partial sleep deprivation, time of day and time on task in a driving simulator – The DROWSI project. *Journal of Sleep Research, 19*(2), 298–309. https://doi.org/10.1111/j.1365-2869.2009.00796.x.

Åkerstedt, T., Anund, A., Axelsson, J., & Kecklund, G. (2014). Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. *Journal of Sleep Research, 23*(3), 242–254. https://doi.org/10.1111/jsr.12158.

Taylor, A. H., & Dorn, L. (2006). Effects of physical inactivity on stress, fatigue, health and risk of at-work road traffic accidents. *Annual Review of Public Health, 27*, 371–391. https://doi.org/10.1146/annurev.publhealth.27.021405.102117.

Glossary

KSS: Karolinska Sleepiness Scale