Finnish Institute of Occupational Health

Sleepiness and stress among long-haul truck drivers

AN EDUCATIONAL INTERVENTION TO PROMOTE SAFE AND ECONOMIC TRUCK DRIVING

Mia Pylkkönen
Mikael Sallinen
Pia Forsman
Axi Holmström
Hanna Kaisa Hyvärinen
Pertti Mutanen
Pradhapan Paruthi
Sampsa Puttonen
Maria Sihvola
Niilo Sirola
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www.ttl.fi

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TIIVISTELMÄ

Johdanto: Väsymyksen ja stressin tiedetään olevan keskeisiä ajamisen turvallisuuteen ja taloudellisuuteen vaikuttavia tekijöitä ammattikuljettajilla. Käsillä olevan hankkeen tavoitteena oli tutkia ammattikuljettajien ajonaikaista väsymystä ja stressiä erilaisissa työvuoroissa, ajonaikaisen väsymyksen ja stressin taustalla olevia tekijöitä sekä ajonaikaisen väsymyksen ja stressin yhteyttä kuljettajan ajotapaan. Lisäksi hankkeen tavoitteena oli selvittää vireydenhallintaa käsittelevän kertaluonteisen koulutusintervention vaikuttavuutta kuljettajien ajonaikaisen vireyden edistämisessä. **Menetelmät:** Satunnaistettuun kontrolloituun kenttätutkimukseen osallistui 52 yhdistelmäajoneuvon kuljettajaa (keski-ikä 38.1 vuotta) neljästä keskisuuresta kotimaisesta kuljetusyrityksestä. Neljästä viiteen kuukautta ennen ja jälkeen koulutusintervention kuljettajat osallistuivat kahden viikon mittausjaksoon, jonka aikana mitattiin heidän ajonaikaista vireyttä ja stressiä, vireydenhallintaan liittyvää käyttäytymistä sekä ajoneuvoon liittyviä suureita. Interventioryhmään arvotut 32 kuljettajaa osallistuivat pienryhmämuotoisena toteutettuun 3.5-tuntiseen koulutukseen. Koulutusta seurasi 4–5 kuukauden arviointi- ja palautejakso. Kontrolliryhmään arvotut 20 kuljettajaa jatkoivat työssään normaalisti. **Tulokset:** Kuljettajien väsymys kohosi hetkittäin tasolle, jolla saattaa olla vaikutuksia ajamisen turvallisuuteen. Kuljettajat arvioivat itsensä *voimakkaan väsyneiksi* 18.5 %:ssa kaikista työvuoroista. Yleisintä voimakas väsymys oli yövuorojakson alun ensimmäisissä yövuoroissa (37.8 %). Myös videoaineiston perusteella kuljettajilla oli havaittavissa hetkellisesti merkkejä voimakkaasta väsymyksestä 25.8 %:ssa aamu-/päivä-/iltavuoroista ja 28.6 %:ssa yövuoroista. Ajonaikaisen väsymyksen taustalla olivat erityisesti *yöaikaan ajaminen*, *työvuoroa edeltävän unen lyhyt kesto ja huono laatu*, *työvuoron pitkä kesto* sekä *runsas koettu vuorokautisen unen tarve*. Kuljettajat käyttivät erilaisia vireydenhallintakeinoja (esim. kofeiini, nokoset) erityisesti yövuoroissa. Itsearviointien ja sydämen syketaajuusmittausten perusteella ajonaikainen stressi ei ollut yhtä merkittävä ongelma kuin väsymys. Alustavat havainnot viittasivat siihen, että ajotyyli saattaa heiketä väsymyksen voimistuessa. Koulutusinterventioon liittyvät muutokset jäivät vähäisiksi. Unen kesto ennen ensimmäistä yövuoroa piteni, ja väsymyksen riski päivä- ja iltavuoroissa laski jonkin verran. Muita muutoksia ei havaittu. **Johtopäätökset:** Tulosten perusteella voidaan sanoa, että ajonaikainen voimakas väsymys on verraten yleinen pitkää matkaa ajavien raskaan ajoneuvon kuljettajien keskuudessa. Erityisen yleistä se on yövuorojakson alussa (ensimmäisessä yövuorossa). Lyhyt vireydenhallintaa käsittelevä koulutusinterventio ei näytä yksistään merkittävästi parantavan tilannetta käytännössä. Ammattikuljettajan ajonaikaisen väsymyksen vähentämiseen tarvitaan koulutuksen ohella myös muita, erityisesti työn kehittämiseen liittyviä, toimenpiteitä.

Asiasanat: ammattikuljettajat, väsymys, stressi, uni, vuorotyö, vireydenhallinta, interventio

ABSTRACT

Introduction: Driver sleepiness and stress are known to be issues among professional drivers as they compromise safe and economic driving. The current study examined driver sleepiness and stress in different types (morning, day/evening, night) of shifts, the factors underlying the phenomena, and the relationship between the phenomena and driving style. Furthermore, an attempt was made to evaluate the effectiveness of a brief, one-time educational intervention designed to improve driver alertness. **Methods:** 52 long-haul truck drivers (mean age 38.1 years) from four medium-sized domestic haulage companies volunteered to the field study conducted as a randomised controlled trial. Four to five months before and after the intervention all drivers underwent a 2-week measurement phase including subjective and objective measurements of sleepiness and stress at the wheel, sleep, alertness management behaviours, and vehicle-related parameters. Thirty-two drivers allocated to an intervention group received 3.5-hour educational intervention followed by a 4–5-month monitoring period. The remaining 20 drivers allocated to a control group continued working as usual. **Results:** The results showed that driver sleepiness momentarily reached levels that are likely to affect safe driving. In 18.5% of all shifts, the drivers rated themselves *severely sleepy* and this held true especially during the first nights of night shift spells (37.8%). In addition, on-the-road video recordings of the drivers revealed that occasional behavioural signs of severe sleepiness were observable in 28.6% of the night and in 25.8% of the non-night shifts. The main factors contributing to driver sleepiness were *night time driving*, *insufficient sleep prior to shift*, *long shift duration*, and *high perceived sleep need*. Sleepiness countermeasures (e.g., caffeine consumption, napping) were used most frequently during night shifts. On the basis of self-ratings and heart rate measurements, driver stress seemed to be a less notable issue compared to driver sleepiness. Preliminary findings suggested that driving style may be affected by sleepiness. Intervention-related improvements in driver sleepiness or alertness management remained minor. Only the sleep duration (main sleep period) prior to first night shifts and the risk of driver sleepiness during day and evening shifts showed some improvements. **Conclusions:** The results suggest that driver sleepiness is common among Finnish long-haul truck drivers, especially during the first nights of the night shift spells. A short, one-time group-based educational intervention on alertness management does not seem to significantly improve driver alertness. The latter finding calls for other – or additional – measures to be implemented to mitigate the problem of sleepiness among professional drivers. These measures include particularly amendments to the work itself.

Keywords: professional drivers, sleepiness, stress, sleep, shift work, alertness management, intervention

PROLOGUE

An educational intervention to promote safe and economic truck driving -project was an ambitious attempt to study professional truck drivers' sleepiness and stress on the road, and to examine whether driver sleepiness could be mitigated by means of driver education. Successful implementation of the study required flexibility and high motivation from all collaborators. Our main non-academic collaborations were, of course, the participating truck drivers and the four domestic medium-sized haulage companies they worked for at the time of the project. All the drivers and their employers deserve our warmest thanks for their invaluable contribution to the study.

The project group consisted of researchers representing various fields of expertise, such as psychology, medicine, and physical, technical, educational and nursing sciences. The members by institution were (in alphabetical order): **Finnish Institute of Occupational Health**: Gröhn Matti, Haapio Timo, Henelius Andreas, Hublin Christer (medical responsibility), Hyvärinen Hanna Kaisa, Jagadeesan Sharman, Karhula Kati, Lapveteläinen Nina, Mutanen Pertti, Pettersson Kati, Plaketti Pekka, Puttonen Sampsa, Pylkkönen Mia, Sallinen Mikael (principal investigator, also representing **Agora Center, University of Jyväskylä**), Sihvola Maria, Velin Riitta and Virkkala Jussi; **Tampere University of Technology**: Pradhapan Paruthi and Viik Jari**; University of Eastern Finland**: Tarvainen Mika; **Taipale Telematics**: Kuparinen Kai, Kuro Mika-Petteri, Köppä Sampsa, Laitsaari Juha, Rouhe Jarkko and Sirola Niilo; **Electronics Research Laboratory, Department of Physics, University of Helsinki**: Forsman Pia, Holmström Axi and Hæggström Edward. The research group collaborated with the following international and domestic actors: Gander Philippa (**Sleep/Wake Research Centre, Massey University's School of Public Health, New Zealand**), Kecklund Göran (**Stress Research Institute, Stockholm University, Sweden**), Anund Anna (**Swedish National Road and Transport Research Institute, Sweden**), Hanowski Rich and Olsson Rebecca (**Virginia Tech Transportation Institute, Virginia Tech and State University, United States**), and Summala Heikki (**Traffic Research Unit, University of Helsinki**). We would like to thank all our academic collaborators for their valuable contribution to the project. Last but not least we would like to thank the funder of the project, the **Finnish Work Environment Fund** who generously and patiently supported our work.

After two years of hard work and varying situations in the course of project implementation, our hope is that the results will help in finding effective and feasible remedies for professional drivers' sleepiness. Reporting the results will continue in individual papers, focusing on selected topics within the main topic of the project. We will be pleased to inform all our collaborators and the funder about these pieces of knowledge and continue the joint effort for making a difference in the real world.

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1 INTRODUCTION

1.1 Sleepiness in professional drivers

In professional driving, *driver sleepiness*, i.e. difficulty staying awake at the wheel has been found to be one of the major issues in terms of occupational and traffic safety. In a Finnish survey, 40% of long-haul and 21% of short-haul truck drivers reported having difficulties in maintaining wakefulness in at least one-fifth of their journeys (Häkkänen & Summala 2000). More than 20% of the long-haul truck drivers had fallen asleep at the wheel at least twice during their careers. In another study, 47% of long-haul truck drivers reported having fallen asleep at the wheel and for more than half of them this had happened in the preceding year (McCartt, Rohrbaugh, Hammer et al. 2000).

Sleepiness in professional driving have been shown to result from irregular working hours and night time driving, long distances, restricted time for sleep, sustained wakefulness, environmental monotony and potentially poor sleeping conditions (e.g., sleeping in the vehicle) (Mitler, Miller, Lipsitz et al. 1997; Härmä, Sallinen, Ranta et al. 2002; Carter, Ulfberg, Nyström et al. 2003).

The most serious consequences of driver sleepiness are, without a doubt, running off the road or colliding with an oncoming vehicle after falling asleep at the wheel, although driver behaviour shows impairments much before that. Driving capacity is enfeebled even as the driver feels sleepy or shows physiological or behavioural signs of sleepiness (Verwey & Zaidel 1999; Thiffault & Bergeron 2003; Dorrian, Hussey & Dawson 2007; Sandberg, Anund, Fors et al. 2011). In all, sleepiness has been suggested to be involved in up to 30% of fatal truck accidents in United States (Anund, Kecklund, Peters et al. 2008). In Finland every tenth fatal accident in 2005 was due to falling asleep at the wheel (VALT 2006).

Although the working conditions of professional drivers are known to be soporific and stressful in nature, research evidence of the impact of driver sleepiness and stress on driving style in real driving conditions is very limited. To date the body of research is also insufficient to assist with the selection and execution of the measures required to improve the situation on the ground.

Number of studies on driver sleepiness has recommend driver education as a mean to improve driver alertness (e.g., Brown 1997; Bunna, Slavova, Struttmann et al. 2005; Carter et al. 2003; Crummy, Cameron, Swann et al. 2008; Philip 2005). Popularity of the idea of driver education is easy to understand, since education is usually fairly inexpensive and cost-effective to execute and does not necessarily require reorganisation of the work itself.

However, to the best of our knowledge there is a little evidence of the effectiveness of educational interventions in combating driver sleepiness among professional drivers. One of the scarce experiments addressing this question comes from Gander, Marshall, Bolger et al. (2005) who developed and implemented an educational intervention (based on an alertness management education of Rosekind, Gander, Connell et al. (2001)) for professional heavy and light vehicle drivers. The intervention consisted of a two-hour live-presentation and a comprehensive compilation of training materials. The training materials were tailored for the participating drivers and they included examples of regulatory environments and working conditions. Pre- and post-intervention questionnaires assessing immediate knowledge transfer revealed a significant improvement in the participants' knowledge. According to a follow-up survey, about half of the participants reported changes in alertness management strategies they used at home and at work. No direct field measurements of sleepiness, use of alertness management strategies or driving were conducted.

In the current study, major emphasis will be placed on the accurate and comprehensive assessment of professional drivers' sleepiness in different shift types (morning shift, day/evening shift, night shift), factors contributing to driver sleepiness and the associations of sleepiness to driving style. In addition, an attempt will be made to assess the effectiveness of brief one-time alertness management training in reducing truck drivers' sleepiness at the wheel.

1.2 Stress in professional drivers

Compared to sleepiness, stress among professional drivers is a much less studied question. It may, however, play a role in occupational and traffic safety in this group of transportation workers. In a Finnish study, transportation sector workers had a high prevalence rate for burnout (Ahola, Honkonen, Kalimo et al. 2004). In another study, the prevalence of depression was clearly higher for truck drivers (13.6%) than for male adults in the general population (2–6%) (da Silva-Júnior, de Pinho, de Mello et al. 2009).

Work-related stress in professional drivers may result from a range of work and driving demands such as tight deadlines, traffic congestion, behaviours of other drivers, weather, ergonomic factors (e.g., noise, temperature), irregular and long working hours, solitary work and lack of social support (Vivoli, Bergomi, Rovesti et al. 1993; Orris, Hartman, Strauss et al. 1997; Salanne, Keskinen, Kärmeniemi et al. 2006).

The impact of *driver stress*, i.e. stress experienced at the wheel on driving performance can be indirect as it affects performance mainly by interfering with sleep. The association can, however, be also more direct. For example, daily hassles and situational stressors in general may put drivers at an elevated risk of aberrant driving and accident involvement in real driving conditions as well (Selzer & Vinokur 1974; Beirness 1993; Kontogiannis

2006; Rowden, Watson & Biggs 2006; Morton & White 2013). The risk of near miss and accident involvement for professional drivers suffering from severe stress-related conditions is akin to driving with a blood alcohol content of around 0.08% (Hilton, Staddon, Sheridan et al. 2009).

The current study aimed at an accurate and comprehensive assessment of driver stress in different shift types. It also strove to assess factors underlying driver stress and the association of driver stress to driving style.

2 OBJECTIVES

An overall aim of the study was to promote safe and economic driving among professional drivers by producing in-depth knowledge of three issues pertinent to driver sleepiness and stress. First, the study examined the levels of driver sleepiness and stress in different shift types (morning, day/evening, night) and the significance of these levels for driving style and thereby for fuel consumption and carbon emission. Second, the study produced knowledge of the most significant factors underlying driver sleepiness and stress. Third, the effectiveness of an educational intervention on alertness management was assessed by a wide range of measures of driver sleepiness.

The specified research questions were:

1. Do truck drivers' sleepiness and stress at the wheel reach levels that affect driving behaviour, fuel consumption, and carbon emissions?

2. What are the sources of elevated sleepiness and stress at the wheel in truck drivers?

3. Can truck drivers' sleepiness be mitigated by an educational intervention, and if yes, does it also improve driver behaviour and thus decrease fuel consumption and carbon emissions?

3 METHODS

3.1 Subjects

Sample size: Sample size suitable for the study was determined by power calculations (*SAS Power procedure*) by using *subjective sleepiness at the wheel* as an outcome measure. Subjective sleepiness was measured by a nine-graded *Karolinska Sleepiness Scale* (KSS) which correlates with electroencephalography (EEG) and behavioural indicators of sleepiness (Åkerstedt & Gillberg 1990; Reyner & Horne 1998; Kaida, Takahashi, Åkerstedt et al. 2006).

In the power calculations nominal power was 0.9 and alpha 0.05. The presumptions were:

a) The mean difference in subjective sleepiness between the pre- and post-intervention measurements is 1.3 rating points for the intervention group and 0.3 rating points for the control group.

b) The standard deviation of the difference between the pre- and post-intervention measurements is 0.8 for the intervention group and 0.2 for the control group.

c) The drop-out rate is 30%.

Due to the group differences in the estimate for standard deviation, the number of participants needed was greater for the intervention group (n=32) than for the control group (n=15). Since the possible drop-out rate was assumed to be slightly higher with the control group, the number of control group drivers was set at 20.

Selection of participants: Drivers had to be between 20 and 65 years of age, have at least two years of truck driving experience (to minimize learning effect between the study phases) and feel healthy enough[1] for the job. All volunteers had to be driving both day and night trips on a regular basis, and have sufficient Finnish language proficiency (intervention held in Finnish and some of the questionnaires validated only in Finnish).

Recruiting subjects: Fifty four voluntary long-haul truck drivers were recruited from four middle-sized domestic haulage companies. At the time of recruiting, the companies had a total of 677 long-haul truck drivers working for them. The companies were first given oral and written information about the project, and then asked to inquire after their drivers' interest in volunteering for the study (at first informing the drivers about the study e.g., via company's intranet). The companies were given two to three weeks to recruit drivers

[1] If drivers had reported not being healthy enough for the job, they would have been recommended to make a visit to their occupational physician for further examination. Also, if data collected during the course of the experiment had indicated a need for medical check-up, drivers in question would have been informed about the findings and recommended to visit their physicians.

interested in taking part in the study and meeting the above inclusion criterion. Each company delivered a list of volunteers who were then sent a consent form with an information letter. The information letter was designed to provide the participants with detailed information about the study (aim, stages, time schedule, advantages of the study, potential inconvenience for the participants, possibility to intermit the study at any point) and the research group conducting it. The information was revised with each participant individually over the phone. The participants were asked to sign and return the informed consent form to the FIOH before the initiation of data collection. For the inconvenience and effort, the participants received 150 euros for each completed two-week measurement period. They will also receive personal feedback of their measurements during spring 2013.

3.2 Study design and measurements

3.2.1 Group intervention under randomized controlled trial

The group intervention study was carried out as a randomized controlled trial (RCT), a study design typically used for evaluating the effectiveness of interventions within human populations. After being recruited, the participants were randomized to receive (intervention group, later referred to as "I") or not to receive (control group, later referred to as "C") the educational intervention. The design and measurement of the study are illustrated in **Figure 1**.

Study design and procedure: The pre-intervention measurements (later referred to as "Pre") were carried out 5 to 6 months before and the post-intervention measurements (later referred to as "Post") 4 to 5 months after the intervention. The measurement phases were conducted at the same time of the year (November to April) to control for seasonal effects.

The intervention between the measurement phases was implemented separately in the participating trucking companies, and the drivers were able to attend the training during their duty hours (agreed with their employers). One of the drivers was unable to take part in the training as scheduled and therefore an additional training session was held in one of the participating companies. All five training sessions were implemented between May and September in 2011. Subsequent to the post-intervention measurements (December 2012), the control group was also given an opportunity to participate in the same training.

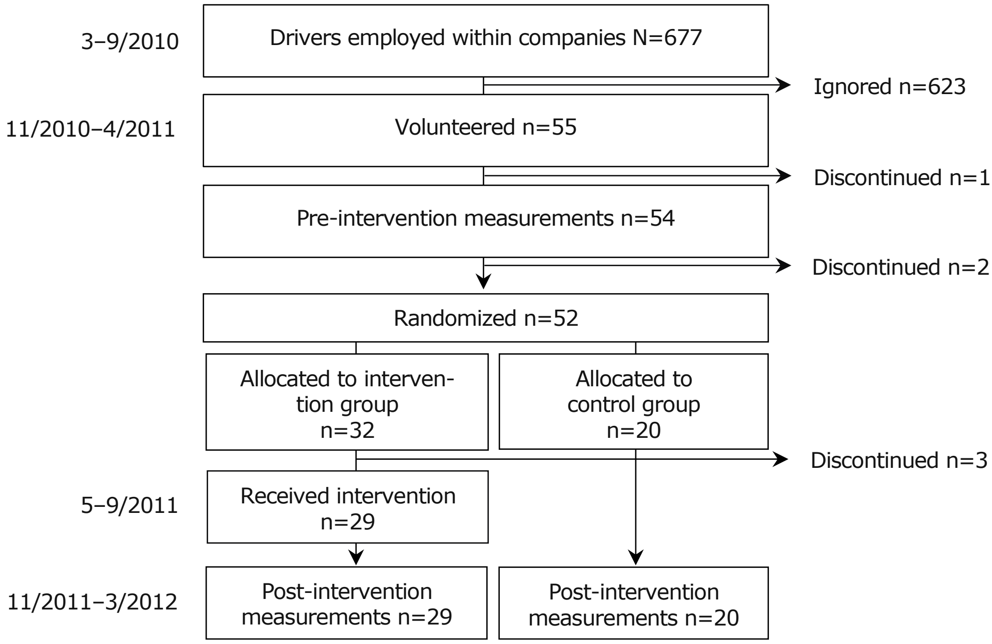

Figure 1. Participant flowchart.

3.2.2 Data collection

Data collection period and questionnaires preceding data collection: For each driver, both measurement phases covered a period of two weeks, including days on and off duty (***Table 1***).

The duty days contained driving during day and night time, and the routes operated during the two measurement phases were mainly the same. Both measurement phases were pre-scheduled prior to data collection in collaboration with the drivers and their employers.

Prior to the first measurement phase, the drivers were asked to complete a background questionnaire including questions on demographic and health characteristics. Prior to the second measurement phase, the questionnaires were complemented with the *Diurnal Type Questionnaire* (DTQ, Torsvall & Åkerstedt 1980) and the *FIOH Sleep Questionnaire* including the *Epworth Sleepiness Scale* (ESS, Johns 1991) and items measuring habitual sleep.

Table 1. A two-week measurement period with three intensive recording days.

			Measurement phase													
			WEEK 1							WEEK 2						
Measurement day *intensive recordings		0	1	2*	3	4	5	6*	7*	8	9	10	11	12	13	14
Shift schedule		-	off	non-night	non-night	non-night	off	off	night	night	night	night	night	night	off	off
Data-collection methods:	Background questionnaires	X														
	Sleep/work diary		→													
	Actigraph recording	→														
	KSS & STRESS															
	HRV recording (24 hrs)			1.				2.	3.							
	Video recording			1.					2.							
	Vehicle tracking															
	Fuel consumption, CO_2 emission monitoring															

Basic and intensive measurement days: The measurement phases contained both basic and intensive measurement days. The *basic measurement days* included measuring drivers' sleep/wake patterns using a wrist-worn actigraph device and a sleep/work diary (APPENDIX A). The drivers were asked to report their sleep/wake patterns (timing, duration, quality) and working hours in the sleep/work diary daily as the data collection proceeded. Due to its low invasiveness and ability to record continuously for 24 hours a day for several consecutive days, actigraphy is considered as a practical alternative for the traditionally used polysomnography (Ancoli-Israel, Cole, Alessi et al. 2003; Paquet, Kawinska & Carrier 2007). For duty days containing driving, the basic recordings were complemented by on-road self-report questionnaires measuring drivers' subjective sleepiness (KSS) and stress at the wheel (described in chapters 3.1 and 3.2.4).

In addition to the basic recordings, complementary data collection methods were used on three measurement days. These *intensive measurement days* covered two duty days (one with a night shift, other with an early morning, day or evening shift) and one day off on both measurement phases.

Data collection: The measurement devices and questionnaires were sent to participants few days prior to pre- and post-measurement phases. Both times the package included detailed written instructions for how to complete the measurements and the drivers were asked to get acquainted with them. To ensure the drivers were ready for the data collection, the instructions were revised (over the phone or face-to-face) with each driver individually before initiating the measurements. To minimize data loss, drivers were prompted by a text message reminder in the beginning and end of both measurement phases, and approximately 12 hours prior to each intensive recording day.

3.2.3 Measures for driver sleepiness

Basic measurement days: Driver sleepiness was measured each duty day that included driving using the KSS. To minimise driver distraction, the scale was presented in an auditory form with a touch screen phone (***Picture 1***) attached to the dashboard of a truck. Completing the questionnaire only took a few seconds. To give their ratings, drivers had to select and confirm a desired answer by touching the symbols on the screen (minus for smaller and plus for bigger rating, green circle for confirming the answer selected). Two sorts of KSS-based measures were used to assess driver sleepiness. First, the KSS ratings given within each shift type were used to calculate the mean levels of sleepiness during the first night shift, successive night shift, morning shift, and the day/evening shift. Second, the maximum rating of each shift type was used to assess whether sleepiness reached *elevated levels* within a given shift type. Three KSS-based criteria were used for defining the levels of elevated sleepiness: KSS rating > 5 ("moderate to extreme sleepiness"), KSS rating > 6 ("severe to extreme sleepiness"), and KSS rating > 7 ("extreme sleepiness").

Picture 1. A touch screen phone for administering on-road self-report questionnaires.

The phone was programmed to prompt drivers to give their ratings every 60 minutes, and they were asked to give a rating unprompted at the beginning and end of each driving session (i.e. at the beginning and end of each break they took from driving). The data was stored on a server, from where it was later collected for analysis. Drivers' were also asked to report their daily average level of arousal in the sleep/wake diary each measurement day, including days off.

Intensive measurement days: Besides the self-ratings described above, sleepiness at the wheel was measured during duty days with intensive recordings, by recording drivers' gestures, manoeuvres and facial expressions with a digital infrared video camera installed in the dashboard of a truck (***Picture 2***; see also Hanowski, Wierwille & Dingus 2003). The video recordings were stored on a 32 GB memory card (storage option included in the camera features) and drivers were asked to return the memory cards to the FIOH as a recorded delivery after each intense recording day.

Picture 2. A digital infrared video camera for recording drivers at the wheel.

The video data was analysed offline by three trained raters using the *Observer Rating of Drowsiness* (ORD) method developed by the Virginia Tech Transportation Institute (VTTI) (Wierwille & Ellsworth 1994; Verwey & Zaidel 2000; Schleicher, Galley, Briest et al. 2008; Wiegand, McClafferty, McDonald et al. 2009). The ORD method is based on an observer's subjective assessments of driver's level of drowsiness *at the wheel*, and the evaluations are made on the basis of his or her physical appearance (e.g., facial tone), behaviour and mannerisms. The rating scale (APPENDIX B) utilized in the method is an adaptation of the *Driver Drowsiness Continuum* originally developed by Wierwille and Ellsworth (1994). The scale is continuous, ranging from "not drowsy" (0) to "extremely drowsy" (100), and including three intermediate levels of drowsiness: "slightly drowsy" (scores 12.5–37.49), "moderately drowsy" (37.5–62.49), "very drowsy" (62.5–87.49) between the extremes. Each ORD rating is based on a review of a 60 seconds video segment and represents an overall or average level of drowsiness observed over that time period.

Prior to the ORD data analysis, the raters were given a three day intensive ORD training by the VTTI. In the end of the training, they all passed a proficiency test in which their ORD ratings of 24 unique 1 minute video clips representing the full range of sleepiness levels and a variety of drivers of different facial features, skin colour, etc. were compared with the ratings of an experienced ORD rater (Wiegand et al. 2009).

Before commencing the actual ORD ratings, the video data collected in the current study was reduced to 10% of its total amount. To do this selection in a way that made it possible to see possible alternations in sleepiness levels across a trip, every tenth 60-second video segment was analysed by the ORD. Because "different drivers within the same level of drowsiness may not display the same indicators" of drowsiness (Wiegand et al. 2009), the same rater assessed all the video recordings of one driver (max 4 drives per driver). To be better able to distinguish the signs of sleepiness and accurately differentiate between the levels of drowsiness, it was necessary for the raters to become familiar with the drivers' drowsy versus non-drowsy appearances, behaviours, and mannerisms. The ratings were delivered using computer software designed for the purpose.

3.2.4 Measures for driver stress

Basic measurement days: Driver stress was measured simultaneously with driver sleepiness with a questionnaire analogous to the KSS (instead of sleepiness, the questions were dealing with stress) (Dahlgren et al. 2005). Stress ratings (later referred to as "STRESS") were to be given each duty day including driving and at the same time points as the sleepiness ratings. The stress questionnaire was activated automatically after completing the KSS. To complement the hourly measures, the drivers were asked to report their daily average level of stress in the sleep/wake diary each measurement day, including days off. Two sorts of STRESS-based measures were used to assess driver stress. First, the STRESS ratings given within each shift type were used to calculate the mean levels of stress during the first night shift, successive night shift, morning shift and the day/evening shift. Second, the maximum rating of each shift type was used to assess whether stress reached *elevated levels* within a given shift type. Three STRESS-based criteria were used for defining the levels of elevated stress: STRESS rating > 5 ("moderate to extreme stress"), STRESS rating > 6 ("severe to extreme stress") and STRESS rating > 7 ("extreme stress").

Intensive measurement days: In addition to the hourly stress ratings, electrocardiogram was measured during duty days with intensive recordings using a *heartbeat measurement device* (attached to the driver's chest with two snap electrodes) to record R-R intervals from the drivers' electrocardiograph (ECG) (***Picture 3***). The heart rate variability[2] (HRV) was measured from the ECG recordings covering 24 consecutive hours for all three intensive recording days. Known as a non-invasive measure for cardiovascular autonomic regulation, the HRV provides information about the autonomic nervous system (ANS) offering opportunities to study associations between psychological processes and physiological reactions (Berntson, Bigger, Eckberg et al. 1997). The HRV analysis has also shown to be an effective method for studying work-related stressors (van Amelsvoort, Schouten, Maan et al. 2000; Ritvanen, Louhevaara, Helin et al. 2006).

Picture 3. A heartbeat measurement device for recording heart rate variability.

[2] An optimal level of variation in heart rate is associated with physiological resiliency, behavioural flexibility and a capacity for effectively adapting to stress and environmental demands. HRV has also been suggested to serve as a potential estimate for sleepiness-related decrements in driving performance (after total sleep deprivation) (Chua et al. 2012).

On duty days (one night shift and one non-night shift), the recordings started approximately one hour before the beginning of a shift. On days off, the recording started approximately one hour after waking up. The HRV recordings on the day off can be considered as a reference for comparison with the HRV acquired during the duty days, assuming that the drivers are under minimal physical stress during the rest period. To analyse the fluctuations in HRV during duty hours, the 24-hour ECG recordings for all drivers (on both duty days) were segmented using duty start and end time, as markers. The segmented files were then pre-processed to remove artefacts and analysed to generate several time and frequency domain HRV parameters for every ten minute intervals during the entire duty period. Although long-term analysis of HRV increases frequency resolution, frequent alterations in physical or mental state (Pagani, Rimoldi, Pizzinelli et al. 1991; Montano, Ruscone, Porta et al. 1994) and environmental changes (Pagani et al. 1991) may influence the results. Averaging the HRV parameters obtained from sequential ten minute intervals minimizes the error imposed by noisy data or external disturbances (Kuo, Lin, Yang et al. 1999).

In the present study, analysis was performed by identifying key parameters from time and frequency domain to successfully quantify the sympatho-vagal balance (Task Force… 1996; Thayer, Yamamoto & Brosschot 2009) of the ANS. Standard deviation of normal R-R intervals (SDNN), derived from time-domain analysis, is considered to emulate parasympathetic activity (Martin, Magid, Myers et al. 1987). The root mean square successive difference (RMSSD) between R-waves is a useful indicator of vagal activity (Task Force… 1996; Thayer, Yamamoto & Brosschot 2009). In the frequency domain, low frequency (LF: 0.04–0.15 Hz) power reflects both sympathetic and parasympathetic influences whereas high frequency (HF: 01.5–0.4 Hz) power is predominantly parasympathetic. Changes in the LF/HF ratio indicates a shift in the sympatho-vagal balance and is considered a key feature in short term analysis of HRV (Task Force… 1996).

3.2.5 Measures for driving style, fuel consumption, and carbon emission

Driving style: Driving style was measured using a mercantile vehicle tracking system (*Sensior*™ Driving Management) that measures the driving speed and accelerations of a vehicle in three dimensions with a sampling rate of 10 Hz. The vehicle tracking system was installed in the trucks prior to data collection.

The vehicle-based data obtained by the system was down-sampled to 0.02 Hz and stored on a server, from where it was downloaded retrospectively. To identify and sample the data, the drivers were asked to log onto the vehicle tracking system at the beginning of each drive using a personal identifier.

The identification of incidents and deviations (e.g., lane drifting) from normal driving was based on the accelerations and decelerations outside selected criteria (0.2g backward, forward, up or down, and 0.25g sideways; Hanowski, Hickman, Olson et al. 2009), and the length and severity of speeding over the legal speed limit of 80 kilometres per hour. The criteria were based on prior experience on the use of the same tracking system in truck driving and on the friction needed on an icy road (Onnettomuustutkintakeskus 2005). The measure of driving style, i.e. an *indriving index* combined data on accelerations and speed (variation and compliance with the posted speed limit, ***Figure 2***).

An algorithm was written (Electronics Research Laboratory, Department of Physics, University of Helsinki) to search for highway segments from the recorded driving speed. A median filter (window size 5) that smoothed transient variations in the speed was applied first. Segments where the filtered speed exceeded 70 kilometres per hour were identified. For each segment, the time intervals between adjacent data points was computed, and if a time interval exceeded 30 minutes the segment was split where this occurred. Next, if the recorded speed within a segment dropped below 20 kilometres per hour, the duration of the drop was computed. If the drop lasted longer than 20 minutes, the segment was split where this occurred. Finally, the remaining segments with duration longer than 30 minutes were identified as highway segments.

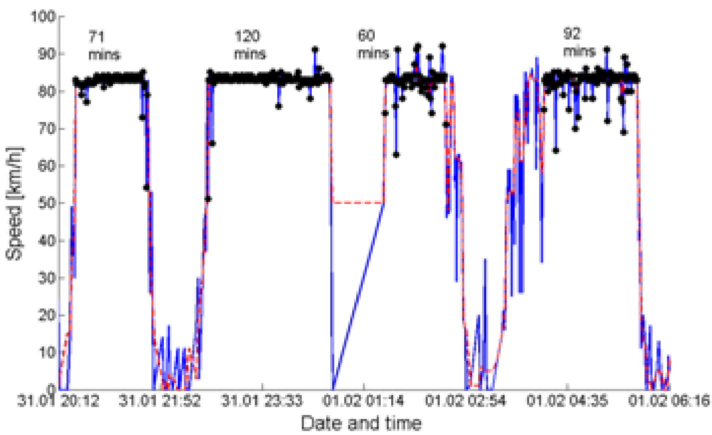

Figure 2. A graph showing driving speed as a function of time for one night-shift drive (solid line indicates recorded driving speed, dashed line represents filtered speed and identified highway segments are represented by dots). The duration of each segment is marked in minutes.

The drivers' were also asked to report all traffic-related incidents they would encounter while on duty during the pre- and post-intervention measurement phases. They were instructed to describe the potential incidents in the sleep/work diary each duty day.

Fuel consumption and CO_2 emission: Estimates of economic and environmental consequences of driver sleepiness and stress were based on fuel consumption measured from a vehicle CAN-bus of a truck (when available). Basic measures included the total distance travelled and the total amount of fuel consumed. After calculating fuel consumption in litres per 100 kilometres and fixing the fuel price at one euro per litre, the economic consequences of driving could be estimated and made comparable between the trips. Similarly, carbon emissions were calculated on the basis of fuel consumption. Consuming one litre of diesel generates 2.66 kg of CO_2 emission.

3.2.6 Measures for sleepiness countermeasures and sources of driver sleepiness and stress

Sources of sleepiness and stress at the wheel and strategies to cope with driver sleepiness were measured each duty day using the wrist-worn actigraph (described in chapter 3.2.2) and self-report questionnaire items incorporated into the sleep/work diary (Anund et al. 2008).

3.3 Educational intervention

The studied intervention aimed at promoting safe, economic and environmental-friendly driving among long-haul truck drivers by optimising their alertness at the wheel. This objective was pursued by *increasing* drivers' *knowledge* about the topic, and thus *motivating* them to become interested in their alertness at the wheel. Changes in drivers' knowledge and motivation were expected to result in *improved skills* to counteract driver sleepiness, and to become evident in drivers' behaviour.

The intervention was similar to the alertness management education of the *NASA Ames Fatigue Countermeasures Program* (Rosekind et al. 2001) studied and found beneficial in transportation industry by Gander et al. (2005, described in chapter 1.1). When the current intervention was designed, an emphasis was on the selection of behaviour change techniques (e.g., training and evaluation methods). To enable later exploitability, the training was designed to be time-efficient and cost-effective to execute as well as simple enough to be implemented without substantial prior knowledge on the topic (e.g., by occupational health care professionals).

Didactic model: The didactic models underlying the training were mainly founded on the *constructivist view of learning*, and the key didactic model was adapted from the *Problem based learning* (PBL, Barrows 1980; 1996), a method aiming at fostering learner's skills to apply theoretical knowledge efficiently into practise. Basic idea behind the method is that the utility value obtained for a learned material is greater if learning takes place while solving real-life problems instead of dealing with them solely theoretically. The real-life problems stemming from the every-day life of the learners and forming the basis for their learning process, are pre-planned by trainers whose role is to provide the learners with an active and flexible learning environment and to facilitate or guide the learning process.

Structure and methods of the training: The structure and methods of the training are illustrated in ***Figure 3***. Content of the training was designed to encompass the basics of circadian rhythms, sleep, sleepiness and sleepiness countermeasures, which were discussed in relation to shift work (e.g., irregular working hours, working during early morning and night time hours) and driving. The relevant theoretical information was offered in a form of a *lecture*. The approximately 90-minute lecture served as an introduction to a 2-hour *workshop* in which the pre-planned problem, i.e. driver sleepiness was defined, explained, examined, and finally solved.

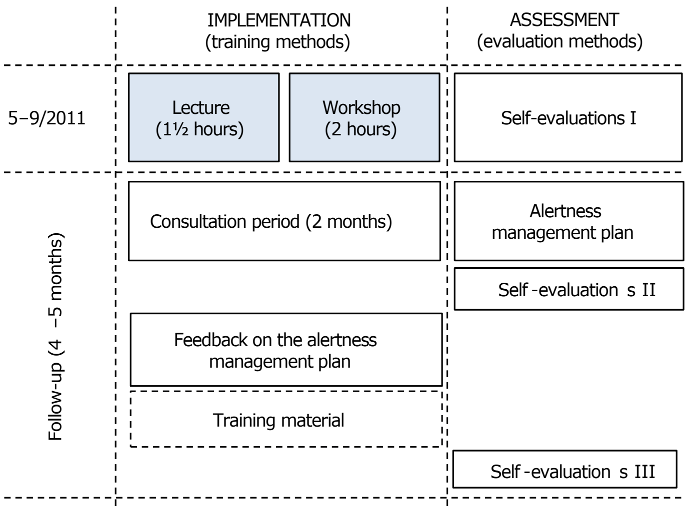

Figure 3. Structure and methods of the educational intervention.

Both the lecture and the workshop were divided into two distinct parts. The first part of the lecture introduced the current state of knowledge about the physiological mechanisms underlying sleepiness in general, and at the wheel in particular. During the first part of the workshop the participants reviewed, discussed, and broadened the topic based on their prior knowledge and practical experience. The second part of the lecture focused on the factors mitigating driver arousal. Some widely held misconceptions were brought up and corrected, and recommendations and "tips" of effective ways to optimize driver arousal were given. During the second part of the workshop, participants searched for eligible solutions to the problem (driver sleepiness).

Both parts of the workshop were preceded by an orienting *solo work* (exercises comprising self-evaluations). At the beginning of the workshops, participants were instructed to work in pairs or small groups to prepare for a *brainstorming session*, and then represent the emerged ideas in another brainstorm held among the whole trainee group. The brainstorm in the first part of the workshop focused on factors causing driver sleepiness, and the brainstorm in the second part aimed at finding solutions for the problem. Participants were encouraged to present questions and take initiative to evoke *reflective discussions* at any point during the training.

To bring the training closer to practice, the participants were provided with a personal computer-based estimation demonstrating how their alertness would alter during their typical shift spells and working hours. The estimations were made using a software implementation of a mathematical model of human sleep-wake cycle and recuperating system (Åkerstedt and Folkard 1995). To demonstrate how the acquired knowledge could be applied to practise, the estimations were complemented with recommendations of effective measures and strategies to counteract driver sleepiness during different types of shift schedules.

Assessment of learning: To assess whether the educational objectives set for the training were achieved, the participants were asked to apply the newly acquired knowledge to complete a written assignment (***Fig.3***: *Alertness management plan*). Changes in trainees' motivation were evaluated in three phases using a questionnaire adapted from Brian Little's (1983) *Personal Projects Analysis* (***Fig.3***: *Self-evaluations I–III* at the end and two months after the training, and prior to the post-intervention measurements). The first self-evaluation included goal-setting by the trainees who were asked to set personal goals related to improving their alertness at the wheel.

To assess the expected behaviour changes, the participants were asked to report their stage of change in the beginning and two months after the training, and prior to the post-intervention measurements (***Fig.3***: *Self-evaluations I–III*) using a questionnaire adapted from Prochaska and DiClemente's (1982) *Stages of Change Model*.

The trainees were provided with personal feedback on their alertness management plan after the two-month consultation period. In addition, *lecture material* based on previous literature (e.g., Hakola et al. 2007; Härmä et al. 2008; Härmä & Sallinen 2004) was offered in readable form for potential subsequent self-education, and the trainees were given an opportunity (and were encouraged) to consult the trainers (by e-mail or phone) for a period of two months after the intervention. The learning outcomes will be assessed more elaborately during the upcoming spring 2013.

3.4 Statistical methods

To study the main factors underlying self-rated sleepiness and stress while driving we conducted mainly two kinds of statistical analyses. In case of a dichotomous outcome variable, the associations of the factors included in the model to the outcome variable were examined by logistic regression analyses. In case of a continuous outcome variable, the same associations were studies by mixed model analyses. Before these analyses, the explanatory factors included in the statistical models were selected by examining each explanatory factor’s crude association with the outcome variable and by studying the correlations among the explanatory factors that showed a strong association with the outcome variable. If there was a high correlation between two explanatory factors, only one of them was included in the final statistical model. The age of the driver was always included in the statistical models to control for this basic individual factor.

To study the effects of the educational intervention, we conducted multi-factorial logistic regression and mixed model analyses to test whether the intervention and control groups differed from each other in terms of self-rated sleepiness and stress while driving in the post-intervention phase of the study. The data of the pre-intervention phase were used to confirm that the two groups did not differ from each other before the intervention in relation to the outcome variables.

4 RESULTS

4.1 Demographics and health characteristics of the drivers

Background questionnaires: *Table 2* shows the demographics and health characteristics of the drivers. The majority of the participants (98.1%) were male, with an average age of 38.1 years (min 22.5, max 58.3). At the beginning of data collection, 44.9% of the drivers had under-aged children, and for 18.4% the children were under school-age.

Based on the DTQ, there were more morning types than evening types among the drivers (26% vs. 16%). None of the drivers had a strong preference for either extreme morningness or eveningness (diurnal type index of 1 or 4, respectively), and 58% of the drivers were classified as "intermediate type" (not clearly morning or evening type).

Table 2. Descriptive statistics of volunteers participating in the study (mean±SD).

Individual factors	Intervention group	Control group	Both groups
Age (yrs)	38.2±11.3	37.9±9.4	38.1±10.5
BMI[1]	27.7±5.0	27.4±3.8	27.5±4.6
Diurnal type[2]			
Morning type (%)	20.0	35.0	26.0
Evening type (%)	16.7	15.0	16.0
Intermediate type (%)	63.3	50.0	58.0
Sleep need (hrs)	7:56±1:05	7:27±0:49	7:45±1:00
ESS score[3]	6.9±4.01	6.5±4.02	6.8±3.97
Children <7 yrs (%)	20.7	15.0	18.4
Children <18 yrs (%)	41.4	50.0	44.9
Trucking experience (yrs)	15.03±9.94	14.89±10.43	14.98±10.02
Nature of contract			
Employment contract (%)	90.0	95.0	92.0
Subcontractor (%)	10.0	5.0	8.0
Wage basis			
Payment by the hour (%)	86.7	75.0	82.0
Piecework pay (%)	6.7	20.0	12.0
Both (%)	6.7	5.0	6.0

[1] body mass index: normal body weight 18.5–24.9; [2] diurnal type index (1–4): morning type (3.1–4), evening type (1–2), intermediate type (2.1–3); [3] ESS score (0–24)

According to the FIOH sleep questionnaire, the drivers needed 7 hours 45 minutes of sleep per day. The daily sleep need varied from 5 to 10 hours. The intervention group drivers needed approximately half an hour more sleep than the controls.

The drivers' trucking experience ranged from 3 to 39 years. On average, they had been working as professional drivers for 14.98 years. 92.0% of the drivers had an employment contract, and 8.0%were working as subcontractors in one of the four participating companies. Payment by the hour was the most common wage basis for both study groups. Piecework pay was somewhat more common wage basis among control group drivers (20.0%) than among those in the intervention group (6.7%). For a small portion (6.0%) of drivers the wage basis was comprised of both, the payment by the hour and the piecework pay.

4.2 Working hours of the drivers

Shift types and shift system: The drivers' working hours were similar in the two study groups in both pre- and post-intervention phases (***Figures 4*** and ***5***). The intervention group started the day/evening shifts 2 hours 8 minutes and ended 1 hour 9 minutes earlier than the control group in the pre-intervention phase. The intervention group started 38 minutes and ended 1 hour and 23 minutes earlier than the control group in the post-intervention phase. Of the shift types, the night shift was the longest one, averaging almost 11.5 hours. The first and successive night shifts were very similar in terms of their timing and duration in both groups and measurement periods.

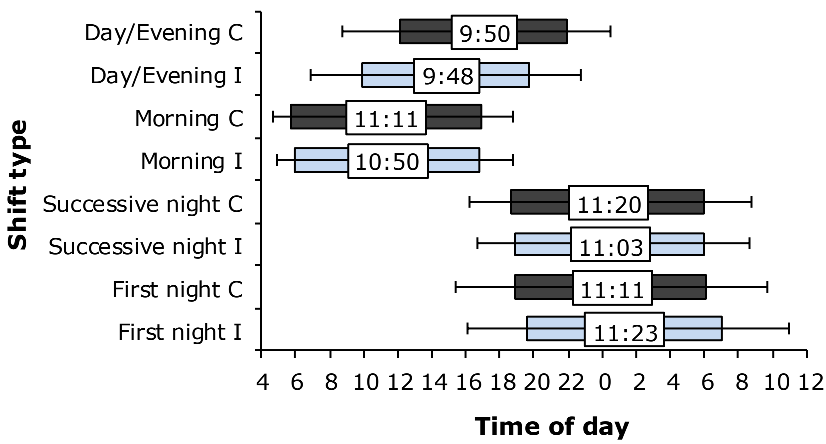

Figure 4. Schematic illustration of the duration and timing of different shift types in the intervention (I) and control (C) groups before the intervention. The horizontal bars denote standard deviations.

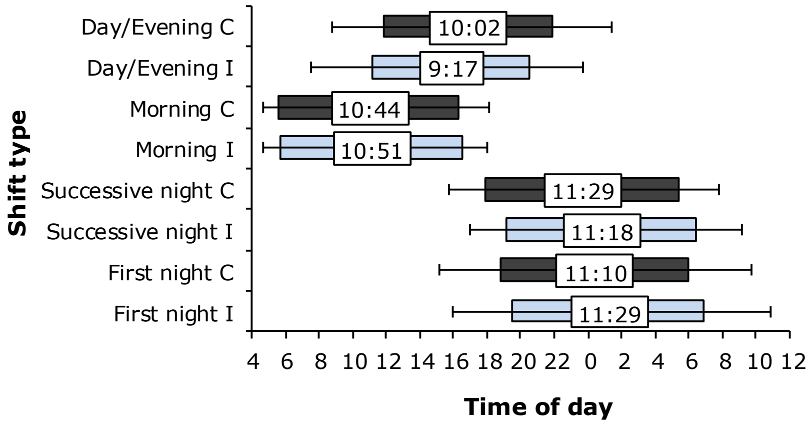

Figure 5. Schematic illustration of the duration and timing of different shift types in the intervention (I) and control (C) groups after the intervention. Horizontal bars denote standard deviations.

4.3 Driver sleepiness and stress before the intervention

4.3.1 Levels and underlying factors of driver sleepiness

4.3.1.1 Self-rated sleepiness and its association with driving style

Mean levels of self-rated sleepiness: Depending on the shift type, an average self-rated sleepiness varied from 3.0 to 3.9 across all KSS ratings of a shift type (***Table 3***). These values fell between "alert" and "neither alert nor sleepy" (values 3 and 5, respectively, on the 9-point KSS). When only maximum value of each shift type was used to estimate sleepiness, the level altered between 4.2 and 5.7, depending on the shift type. These values indicate that the drivers were "neither alert nor sleepy" (value 5 on the 9-point KSS). When only minimum value of each shift was used, the level was between 2.2–2.5 indicating good alertness.

Table 3. Self-rated sleepiness in different shift types (mean±SD).

KSS score	**First night** (n=93)	**Successive night** (n=129)	**Morning** (n=143)	**Day/Evening** (n=109)
Mean per shift	3.9±1.3	3.3±1.2	3.0±1.2	3.5±1.3
Maximum per shift	5.7±1.9	4.8±1.9	4.2±1.8	4.6±1.8
Minimum per shift	2.5±1.1	2.3±1.0	2.2±1.1	2.5±1.2

Mixed model analyses revealed that all KSS outcomes including either all ratings or maximum ratings were significantly affected by the shift type only (KSS mean per shift: $F(3,322)=17.8$, $p<0.001$; KSS maximum per shift: $F(3,322)=25.2$, $p<0.0001$. Both indexes showed greater sleepiness for the first night shift than for the non-night shifts (KSS mean per shift: $t(322)=$ 3.5–6.4, $p<0.001$; KSS maximum per shift: $t(322)=$3.14–7.83, $p<0.001$)).

The hourly mean KSS ratings across successive working hours showed that the highest level of sleepiness (5.0) was reached after 9 consecutive hours of work during first night shift (**Figure 6**). Of the four shift types, morning shift was the only shift type which did not show elevated levels of sleepiness towards the end of a shift.

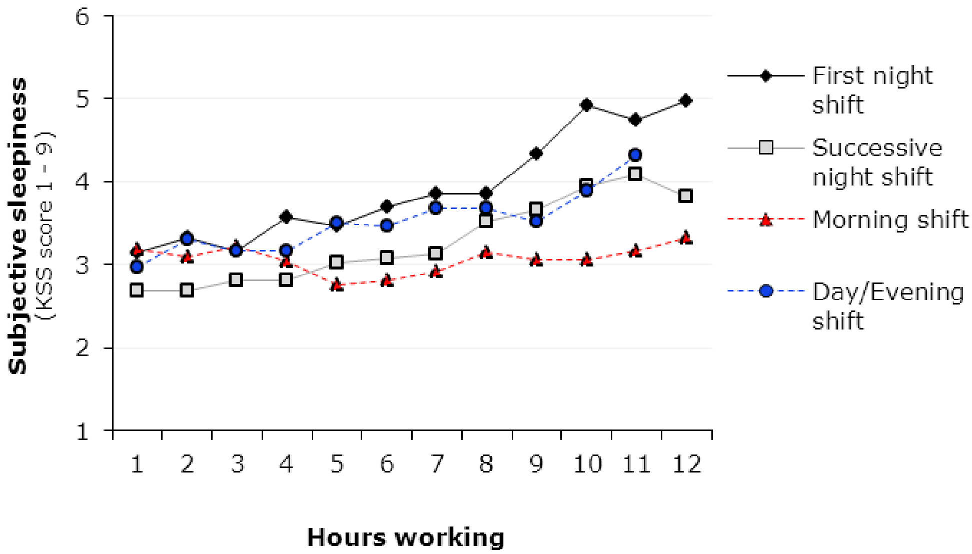

Figure 6. Mean hourly levels of self-rated sleepiness (KSS ratings) across successive hours working in different shift types.

Occurrence of elevated levels of driver sleepiness*: Figure 7* shows that during the first night shifts 20.7% of the KSS scores were 5 or higher, whereas among the other shift types the proportion of the KSS>5 ratings was only 9.4%–12.6%. When the criterion for elevated sleepiness was tightened to KSS>6 the proportion of ratings indicative of elevated sleepiness reduced at least by half compared to the more loose sleepiness criterion of KSS>5. KSS ratings indicating extreme sleepiness (KSS>7) were rare, ranging from 0.4% during the morning shifts to 3.6% during the first night shifts.

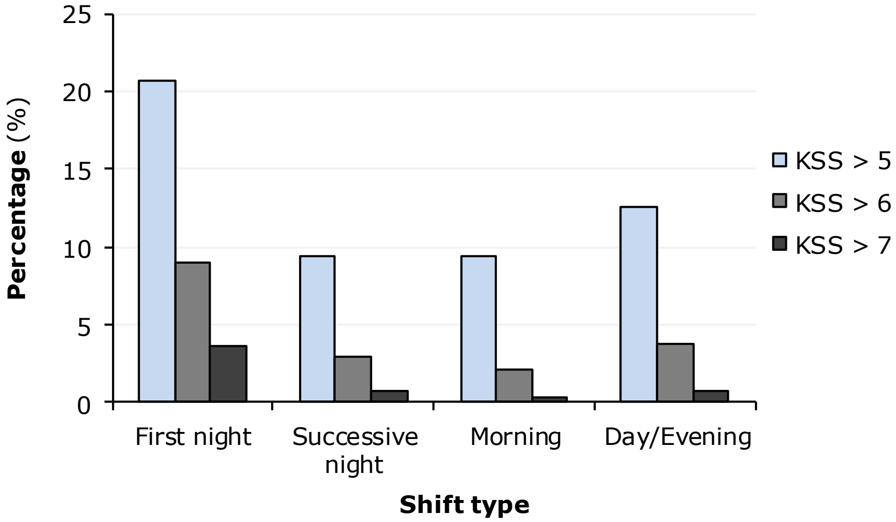

Figure 7. Proportion of sleepiness in different shift types. Sleepiness index was based on self-rated sleepiness (KSS>5, KSS>6, or KSS>7). The total number of ratings was 1057 in the first night shifts, 1332 in the successive night shifts, 1365 in the morning shifts, and 864 in the day/evening shifts.

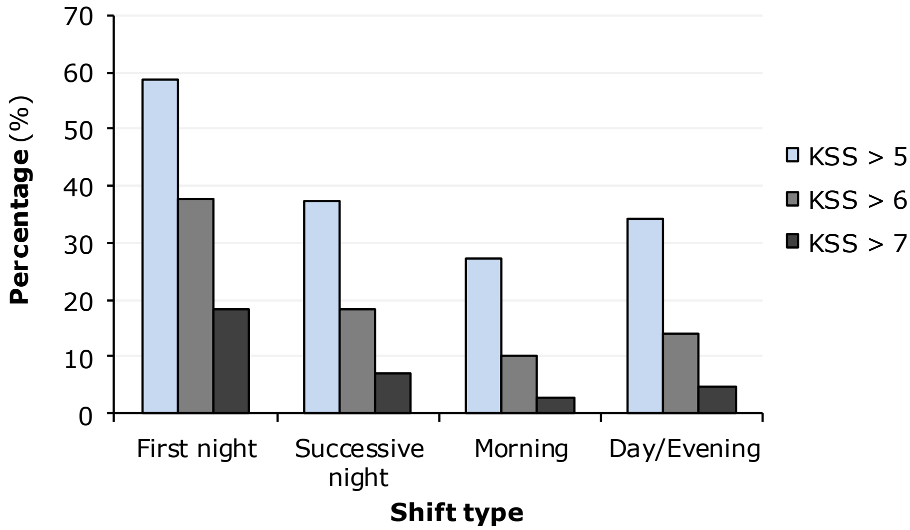

Figure 8. Proportion of shifts including at least one self-rating indicative of elevated sleepiness in different shift types. Elevated sleepiness was defined as "moderately to extremely sleepy" (KSS>5), "severely to extremely sleepy" (KSS>6), and "extremely sleepy" (KSS>7).

Figure 8 shows the proportion of shifts during which the drivers rated themselves sleepy at least once. Regardless of the KSS threshold, the highest proportion of shifts including elevated sleepiness was found in the first night shift (58.9%–18.3%, depending on the criterion), whereas the rest of the shift types showed lower proportions (37.3%–2.8%, depending on the criterion). The drivers rated themselves extremely sleepy at least once in almost one-fifth of the first night shifts (18.3%).

Association of self-rated sleepiness with driving style and fuel consumption: *Figure 9* shows that the mean driving style (measured as indriving index) across the highway driving segments was above 85 during those shifts the drivers never rated being extremely sleepy. During shifts including ratings indicative of the extreme sleepiness the mean driving style was 81.4 (SD 16.6). Unfortunately, the number of shifts with extreme sleepiness (n=23) was too low to conduct any statistical comparison.

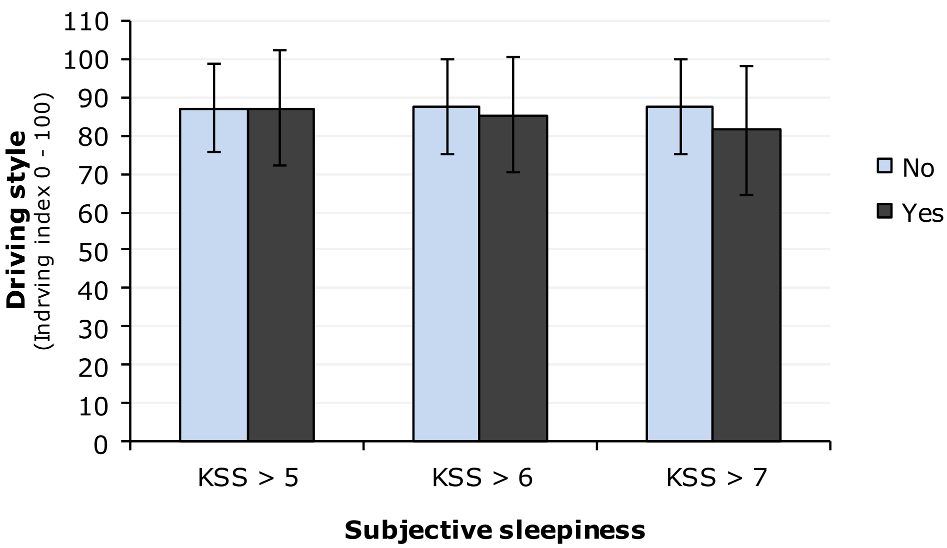

Figure 9. Vehicle data based driving style (indriving index) as a function of the occurrence of elevated subjective sleepiness at the wheel (self-rating on the KSS >5, >6, or >7 at least once a shift). The vertical bars denote standard deviations.

The number of shifts including reliable data on fuel consumption remained very low and consequently no clear results can be presented. The mean fuel consumption for the highway segments varied little between the shifts (successive night shift: 36 litres per 100 kilometres (n=2); morning shift: 35 litres per 100 kilometres (n=7); day or evening shift: 37 litres per 100 kilometres).

4.3.1.2 Observer-rated sleepiness

Video-based levels of driver sleepiness during the night and non-night shifts are illustrated in ***Figure 10***. The ORD outcome comprises all ORD scores of all shifts including indications of slight sleepiness independent of the shift type. The ORD outcome including only the minimum score per shift indicated good alertness and the outcome consisting of only the maximum score per shift moderate sleepiness. These findings applied to both shift types. For all ORD outcomes, the scores were slightly higher during the night shifts than during the non-night shifts, but the difference was fewer than 10 on the 100 step scale. Unfortunately the number of observations was too low for testing the effect of the shift type statistically.

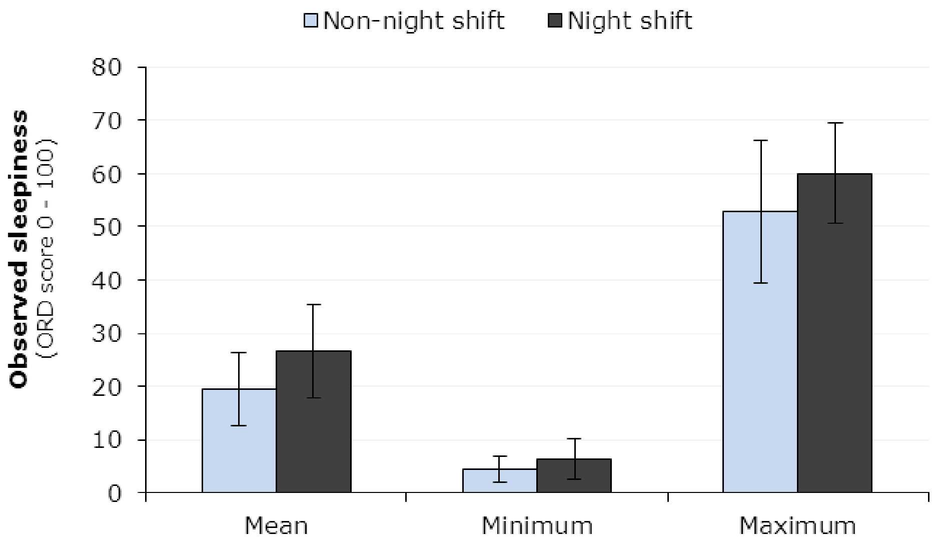

Figure 10. Mean levels of observed sleepiness in non-night and night shifts analysed by Observer Rating of Drowsiness (ORD) method. "Mean" indicates mean of all ORD values per shift, "Minimum" represents minimum ORD value for each shift, and "Maximum" denotes maximum ORD value for each shift. The data included 32 drivers, 31 non-night shifts, and 28 night shifts. The vertical bars denote standard deviations.

Figure 11 shows the ORD scores as a function of time into shift, with one-hour precision across the night and non-night shifts. The mean hourly ORD scores varied from 20.9 (SD 12.6) to 30.2 (SD 14.3) during the night shifts and from 15.9 (SD 9.6) to 21.7 (SD 9.5) during the non-night shifts, indicating slight sleepiness in both cases. The development of sleepiness over successive work hours differed between the two shift types. For the night shift, sleepiness increased over the first four hours after which the build-up of sleepiness levelled out until the last two work hours during which there was a decrease in sleepiness. For the non-night shift, sleepiness was quite even over the work hours and showed no clearly recognisable trend.

Figure 12 shows the proportion of night and non-night shifts where the drivers' ORD scores indicated of either "moderate to severe sleepiness" (ORD 37.5–87.49) or "severe sleepiness" (ORD 62.5–87.49) at least once during a shift. During all night shifts and almost all non-night shifts, the drivers showed signs of at least "moderate sleepiness". Severe sleepiness was found in approximately one-fourth of the shifts independent of the shift type. No signs of "extreme sleepiness" (ORD 87.5–100) were found in any of the shifts.

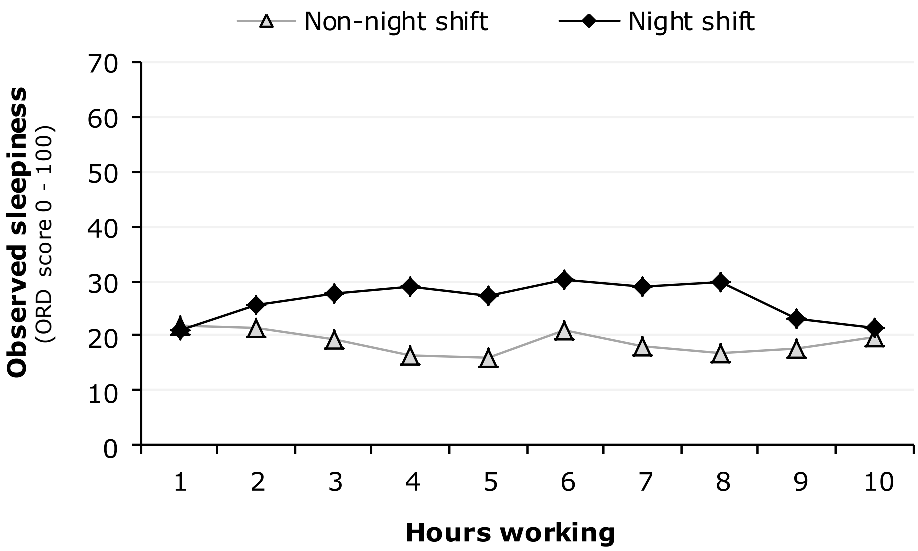

Figure 11. Mean hourly levels of observed sleepiness analysed by Observer Rating of Drowsiness (ORD) method across successive hours working during night and non-night shifts.

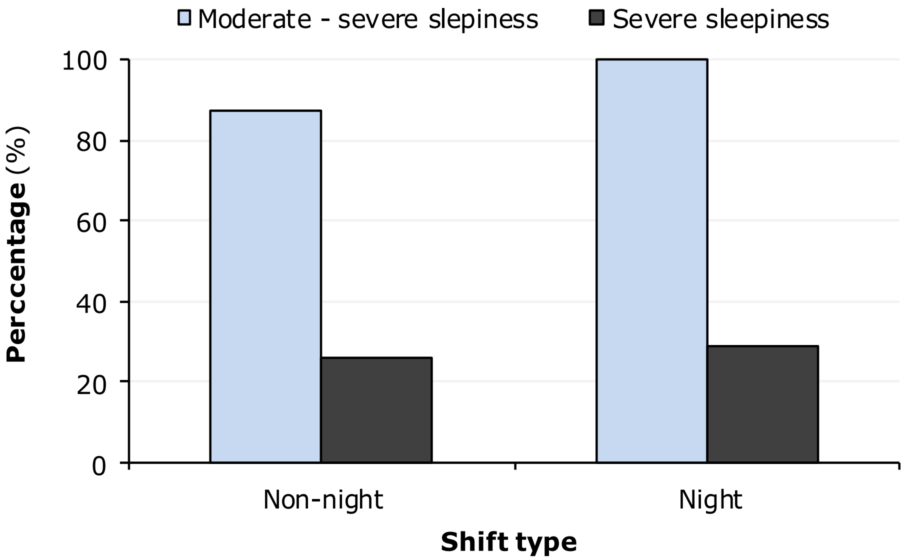

Figure 12. Proportion of observed sleepiness (including either moderate to severe or severe sleepiness) in non-night and night shifts analysed by Observer Rating of Drowsiness (ORD) method. "Moderate to severe sleepiness" refers to ORD ratings ranging from 37.5 to 87.49, and "severe sleepiness" to ORD ratings ranging from 62.5 to 87.49.

4.3.1.3 Factors underlying driver sleepiness

Sleep: The results on sleep in connection with different shift types are presented in ***Table 4***. Actigraph-based sleep duration was shortest (6 hours) prior to successive night and morning shifts, and longest (7 hours) prior to first night shifts. On days off, the drivers obtained similar amounts of sleep compared to the first night shifts. Short main sleep (<6 hours) preceded 18.8% of the first night shifts, 49.6% of the successive night shifts, 55.6% of the morning shifts, and 28.4% of the day or evening shifts.

Sleep quality – based on actigraph (sleep efficiency, fragmentation index) and diary (wake after sleep onset, subjective alertness upon awakening, estimated sleep quality) data – was very comparable among the four shift types and days off. The proportion of shifts that were followed by a nap was clearly highest for the first and successive night shifts (29.3% and 14.0%, respectively).

Table 4. Diary- and actigraph-based results for sleep in relation to different shift types, recovery days, and days off (mean±SD).

Sleep outcomes	**First night shift** (n=93)	**Successive night shift** (n=129)	**Morning shift** (n=143)	**Day/Evening shift** (n=109)	**Recovery day** (n=57)	**First day off** (n=124)	**Successive day off** (n=119)
Bedtime (h:min)	23:57±2:53	7:22±3:08	22:23±1:15	23:57±2:24	6:56±2:57	00:08±1:41	00:37±1:56
Get up time (h:min)	8:21±3:50	14:17±2:55	4:52±0:58	7:47±2:08	12:48±2:35	8:59±1:55	9:16±1:57
Actigraph-based measures							
TIB[1] (h:min)	8:24±2:24	6:54±1:28	6:30±1:07	7:53±1:32	5:53±1:51	8:53±1:40	8:38±1:26
TST[2] (h:min)	7:21±2:07	6:03±1:17	5:43±1:07	6:53±1:26	5:08±1:38	7:47±1:29	7:36±1:14
Sleep efficiency[3] (%)	87.5±5.4	87.8±5.6	87.7±7.3	87.3±5.7	87.3±4.9	87.8±5.5	88.3±6.1
Fragmentation index[4]	28.0±12.50	28.2±13.2	25.1±12.1	29.2±12.7	28.0±12.3	28.7±14.0	27.5±13.3
Diary-based measures							
TST[2] (h:min)	8:13±2:02	6:36±1:19	6:06±1:16	7:39±1:33	5:58±1:53	8:32±1:42	8:25±1:21
Sleep latency (min)	15.1±11.9	12.9±14.3	18.9±26.0	13.8±14.4	14.9±19.9	13.2±14.1	14.8±19.6
Wake bouts (no.)	1.3±1.5	1.1±1.1	1.0±1.3	1.0±1.1	0.5±0.7	1.1±1.6	1.0±1.1
WASO[5] (min)	16.4±37.9	14.6±28.9	8.2±19.5	6.7±14.4	4.4±8.6	12.2±32.6	12.8±18.6
Alertness[6]	2.76±0.9	2.66±0.7	2.54±0.8	2.71±0.8	2.32±0.9	2.67±0.9	2.78±0.8
Sleep quality[7]	3.08±0.8	3.13±0.8	2.84±0.9	3.10±0.8	2.88±0.9	3.07±0.8	3.16±0.8
Slept home (%)	100	98.1	99.0	93.3	100	97.8	94.0
Napping off duty[8] (%)	29.3	14.0	2.1	1.8	3.5	8.9	9.2
Alcohol[9] (%)	32.6	2.6	23.1	37.5	26.3	67.6	73.9

[1] time in bed; [2] total sleep time; [3] actigraph-based measure (TST/TIB) indicating sleep quality; [4] actigraph-based measure indicating sleep quality; [5] wake after sleep onset; [6] subjective alertness upon awakening (0–4); [7] estimated (subjective) sleep quality (0–4); [8] yes/no; [9] yes/no

Factors associated with self-rated sleepiness at the wheel: ***Table 5*** shows the associations between selected individual-, sleep-, and work- related factors and the occurrence of elevated sleepiness at the wheel (KSS>5 at least once a shift). The results revealed that especially the shift- and sleep-related factors were associated with elevated sleepiness at the wheel. Of these factors sleep duration, sleep efficiency, time in bed, napping off duty and time since awakening were significant. The shift type and shift duration of the shift-related factors and self-assessed (perceived) daily sleep need of the individual factors all reached significance.

Table 5. Factors associated with driver sleepiness (KSS>5 at least once a shift).

	DF	Chi Sq	Prob. Chi Sq
Individual factors			
Age	1	0.03	0.8713
Diurnal type index[1]	1	0.13	0.7208
Sleep need[2]	1	8.01	0.0047
ESS score[3]	1	0.95	0.3308
Trucking experience	1	0.86	0.3527
Children <7 yrs	1	0.17	0.6773
Children <18 yrs	1	0.06	0.8030
Sleep-related factors			
TST[4]	1	6.72	0.0095
Sleep efficiency[5]	1	4.73	0.0296
Fragmentation index[6]	1	1.81	0.1781
TIB[7]	1	5.45	0.0195
Napping off duty[8]	1	7.29	0.0069
Time since awakening[9]	1	19.31	<0.0001
Shift-related factors			
Shift type[10]	3	20.10	<0.0001
Shift duration	1	8.39	0.0038
Free time between shifts[11]	1	2.72	0.0990
Work-related factors			
Contract (SC vs. EC)[12]	1	0.75	0.3878
Wage basis (PBH vs. PWP)[13]	2	3.91	0.1418

[1] diurnal type index (1–4): morning type (3.1–4), evening type (1–2), intermediate type (2.1–3); [2] self-assessed (subjective) daily sleep need; [3] ESS score (0–24); [4] total sleep time; [5] actigraph-based measure (TST/TIB) indicating sleep quality; [6] actigraph-based measure indicating sleep quality; [7] time in bed; [8] yes/no; [9] time elapsed from waking up till the end of a shift; [10] first night shift, successive night shift, morning shift, day/evening shift; [11] time off between two consecutive duty days; [12] SC=subcontractor, EC=employment contract; [13] PBH=payment by the hour, PWP=piecework pay

A logistic regression analysis showed that a one-hour increase in sleep need more than doubled the risk (OR 2.32) for elevated sleepiness during a shift (***Table 6***). The shift type contributed to elevated sleepiness at the wheel as well. The risk for elevated sleepiness was on average OR 3.85–8.33 fold greater during first night shifts than it was during the other shift types. A one-hour increase in shift duration was associated with a 1.13 fold increase in the risk of elevated sleepiness. In addition, a one-hour decrease in sleep duration was associated with a 1.33 fold risk of elevated sleepiness. In case of sleep efficiency, a one-per cent decrease in actigraph-based sleep efficiency was associated with a 1.04 fold risk of elevated sleepiness. Age was not significantly associated with the risk of elevated sleepiness in the model including multiple explanatory factors.

Table 6. Logistic regression analysis (GEE) of the variables predicting a risk (odds ratio, OR) of elevated driver sleepiness (KSS>5 at least once a shift).

Explanatory variable	**Level 1**	**OR**	**95%**	**Confidence limit**	**Prob.**
Intercept		0.22	0.00	1.21	0.0619
Age		0.99	0.95	1.02	0.5699
Sleep need[1]		2.42	1.57	3.75	<0.001
Shift type	First night	1.0	1.0	1.0	
	Successive night	0.26	0.12	0.56	0.0005
	Morning	0.12	0.06	0.24	<0.0001
	Day/Evening	0.15	0.06	0.35	<0.0001
Shift duration		1.13	1.01	1.27	0.0342
TIB[2]		0.75	0.66	0.87	<0.0001
Sleep efficiency[3]		0.96	0.93	1.00	0.0375

[1] self-assessed (subjective) daily sleep need; [2] time in bed; [3] actigraph-based measure (TST/TIB) indicating sleep quality

Self-reported sources of driver sleepiness: *Figure 13* shows the self-assessed sources of sleepiness at the wheel. In 43.2% of the shifts, the drivers reported at least one source of sleepiness. The reports of these sources were given most frequently during the first night shifts (58.1%) and least frequently during the morning shifts (32.9%). Of several alternatives, *time of day* (for night shifts) and *insufficient sleep* (across all the shift types) stood out. Time of day was reported to underlie sleepiness in 35% of the night shifts and in 6% of the non-night shifts. Insufficient sleep was reported to cause sleepiness in approximately one-fourth of the shifts, except for the successive night shift, for which the proportion was only 15%.

When inquired for their own views on the importance of alertness at the wheel, the drivers considered being alert at the wheel fairly important (mean 84, SD10; 100="very important" and 0="not at all important"), and they also expressed being somewhat worried about their alertness at the wheel (mean 55, SD 25; 100="very worried" and 0="not at all worried").

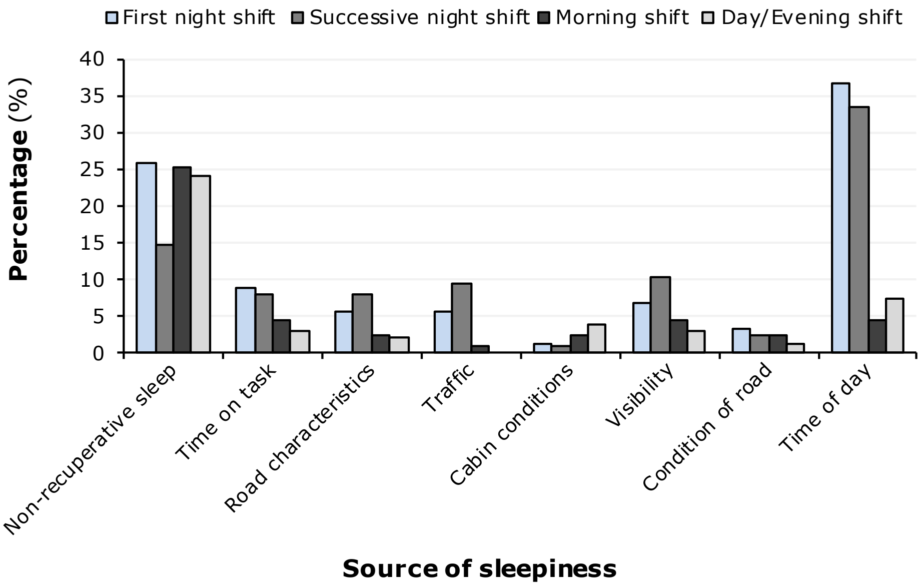

Figure 13. Self-reported sources of driver sleepiness in different shift types.

Use of sleepiness countermeasures: *Caffeine* was the most common sleepiness countermeasure the drivers used while on duty (***Figures 14*** and ***15***). The drivers consumed caffeine frequently during their prescribed rest breaks across the different shift types (range 63.9%–77.5%). Outside the prescribed rest breaks caffeine was used as a sleepiness countermeasure twice as frequently during the night shifts (range 36.5%–38.4%) as during the morning or day/evening shifts (range 16.8%–18.3%). A chi-square test revealed that caffeine consumption was significantly affected by the shift type (χ^2_3=27.01, p<0.0001). Using nicotine (ranging from 20.4% to 33.3% among the shift types) and talking to someone, i.e. socializing (ranging from 15.7% to 35.7% among the shift types) were used frequently during and outside prescribed rest breaks (ranges 10.1%–17.8% and 8.3%–23.3%, respectively). The same held true for eating light meals or snacks during prescribed rest breaks (range 51.6%–66%). Napping was an infrequent sleepiness countermeasure outside prescribed rest breaks (range 0.9%–6.5%), yet relatively frequent during the night shifts (20.4% of the first night shifts and 10.1% of the successive night shifts). A chi-square test showed that napping during a prescribed rest break was significantly affected by the shift type (χ^2_3=24.72, p<0.0001).

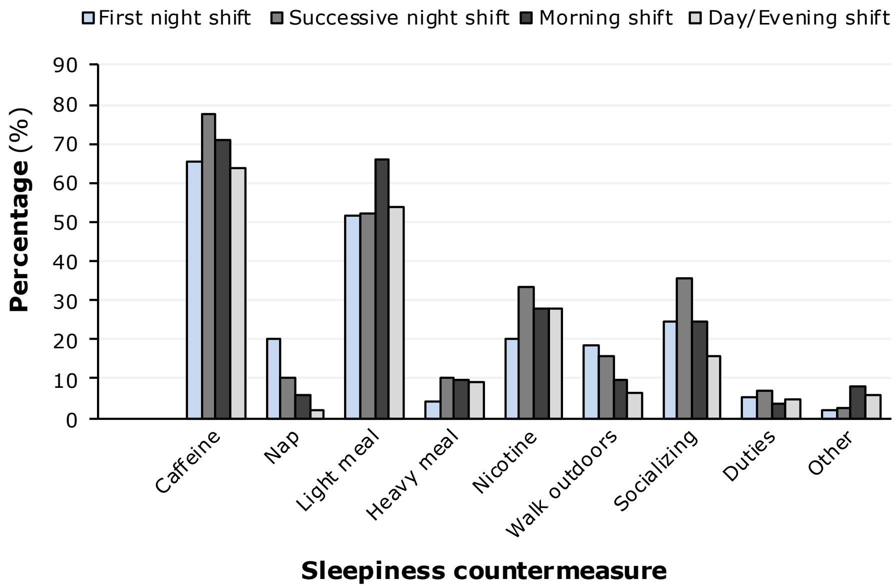

Figure 14. Self-reported activities during prescribed rest breaks in different shift types.

Figure 14 shows that many sleepiness countermeasures were used more frequently during the night shifts than during the other shifts when feeling tired at the wheel. Such countermeasures included drinking coffee (night shifts 33.7% vs. non-night shifts 15.6%), eating sweets (7.9% vs. 3.0%), drinking soft drinks (13.8% vs. 0.4%), having a nap break (3.7% vs. 1.5%), having a break to walk outdoors (7.4% vs. 2.7%), adjusting cabin temperature (6.0% vs. 1.5%), turning up a radio/stereo (9.2% vs. 2.1%), singing/whistling/talking (9.2% vs. 4.3%) and talking with someone, i.e. socializing (20.3% vs. 9.4%). In all cases the countermeasures were used at least twice as often during the night shifts as during the non-night shifts. Body movements while driving were often used as a way to maintain alertness, especially during the first night shifts. The differences between the usage of sleepiness countermeasures during the night and non-night shifts reflected in the mean number of different countermeasures used during a shift. For the night shifts, the mean number was 2.7 (SD 1.9, range 1–8) and for the other shifts 2.0 (SD 1.0, range 1–5). The drivers reported using at least one sleepiness countermeasure in 61.7% of the night shifts and in 38.9% of the non-night shifts.

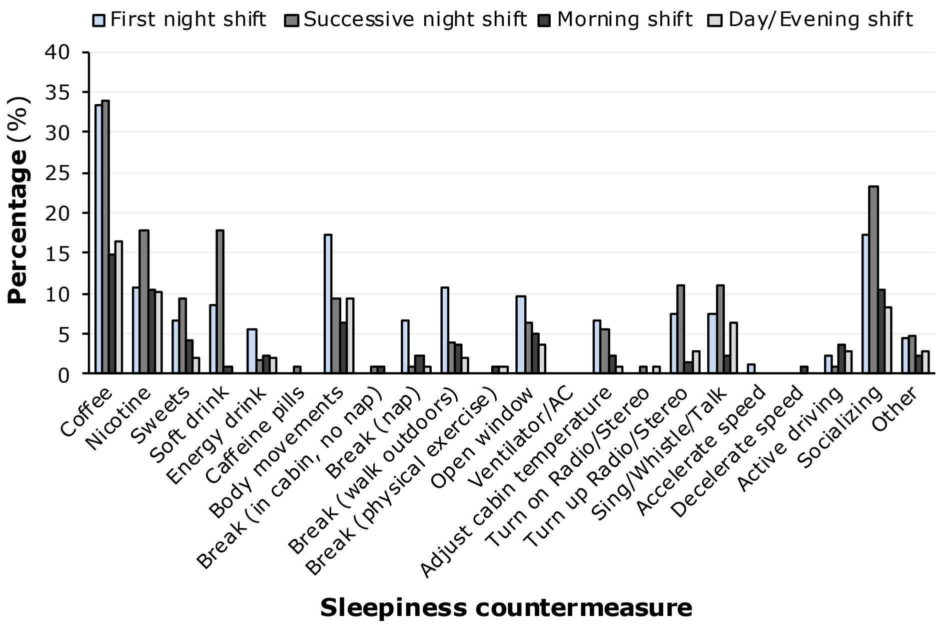

Figure 15. Self-reported use of sleepiness countermeasures outside prescribed rest breaks (when feeling sleepy at the wheel) in different shift types.

4.3.2 Levels and underlying factors of driver stress

4.3.2.1 Self-rated stress and its association with driving style

Mean levels of self-rated stress: *Figure 16* shows that the mean levels of self-rated driver stress were low, reaching the maximum value of 3.0 (SD 1.2) during first night and day/evening shifts, and the minimum value 2.7 (SD 1.2) during successive night shifts. For morning shifts the value was 2.8 (SD 1.3).

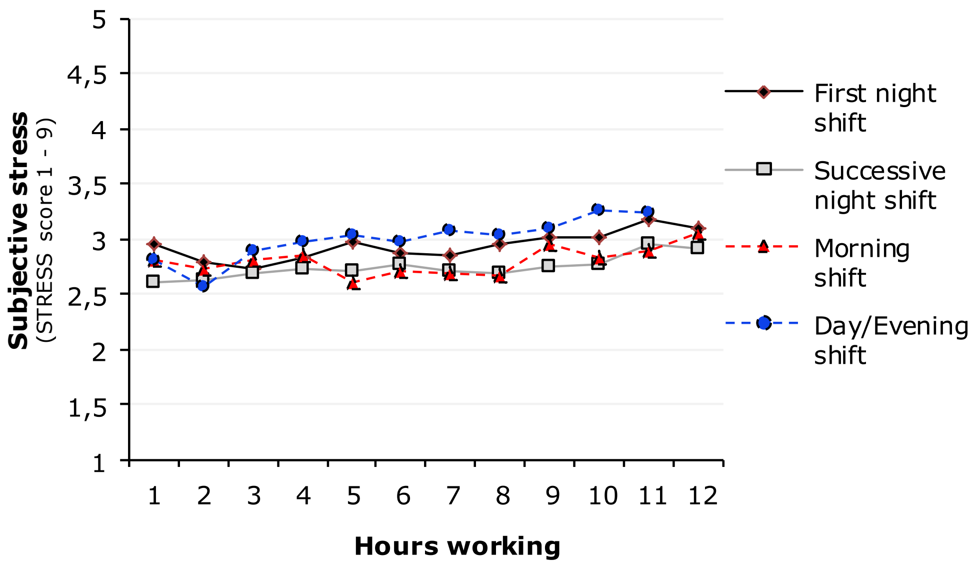

Figure 16. Mean hourly levels of self-rated stress across successive hours working in different shift types. The higher the rating on the 9-point stress scale, the higher the level of stress.

Occurrence of elevated levels of driver stress: *Figure 17* shows the proportion of ratings indicative of elevated stress in the four shift types. Depending on the shift type, 3.7%–5.4% of the rated values were higher than 5 on the 9-point stress scale. When the criterion was tightened (STRESS>6) the proportion of the ratings indicative of elevated stress reduced to 0.7%–1.25%. Ratings indicative of extreme stress (STRESS>7) were virtually absent. The highest proportions were found for the morning (0.2%) and successive night shifts (0.2%).

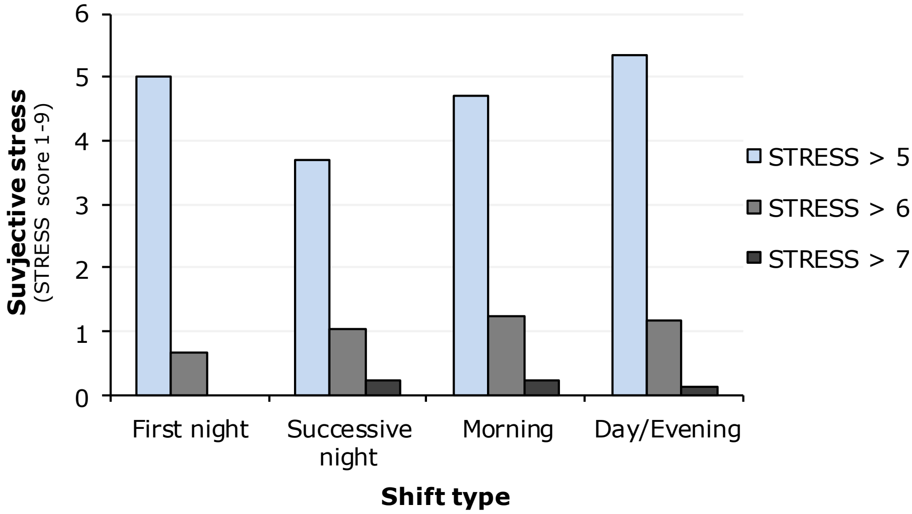

Figure 17. Proportion of driver stress (STRESS>5, >6, or >7 at least once a shift) in different shift types. The total number of STRESS ratings in the four shift types was as follows – first night shifts: 1057; successive night shifts: 1332; morning shifts: 1365; day/evening shifts: 864.

Figure 18 shows the proportion of shifts during which the drivers rated being stressed at least once. Approximately one-fifth of the shifts included at least one self-rating indicative of elevated stress (STRESS>5). The proportion of shifts including at least one self-rating indicative of severe stress (STRESS>6) were quite rare (7.1%–9.3%, depending on the shift type). Shifts during which the drivers rated being extremely stressed were infrequent (0.0%–2.4%, depending on the shift type).

Association of self-rated stress with driving style: *Figure 19* depicts driving style during highway segments based on vehicle data. Independent of the criterion for elevated stress, the driving style index was marginally lower for the shifts with elevated stress. The number of observations was, however, low for the shifts including elevated stress (n=5–69) and consequently no statistical tests were conducted to study differences between the shift types (stress vs. no stress).

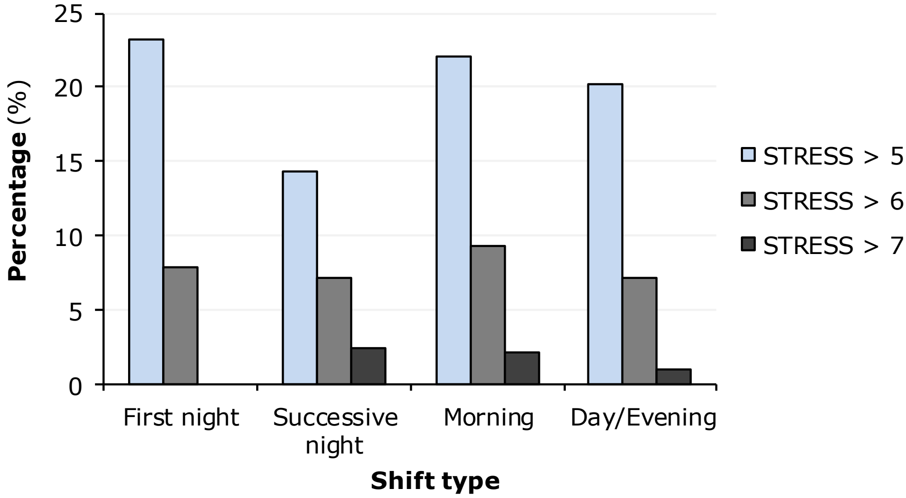

Figure 18. Proportion of shifts including at least one self-rating indicative of elevated stress in different shift types. Elevated stress was defined as "moderate to extreme stress" (STRESS>5), "severe to extreme stress" (STRESS>6), and "extreme stress" (STRESS>7).

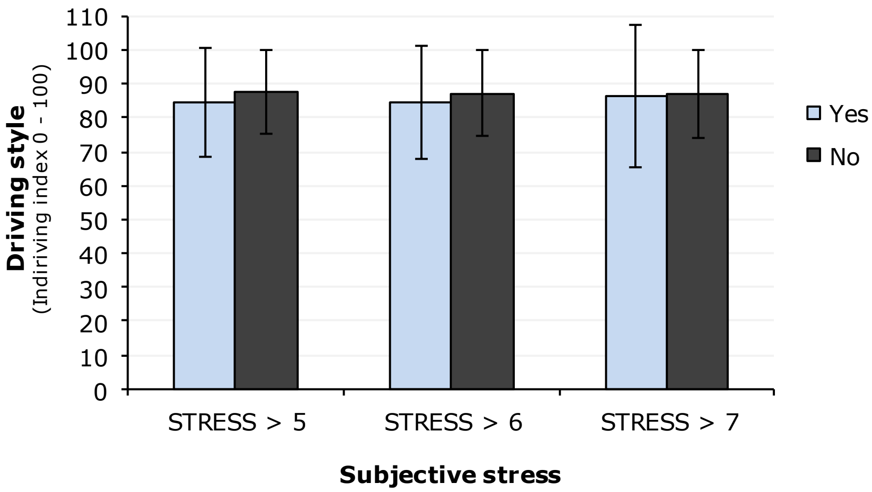

Figure 19. Vehicle data based driving style (indriving index) as a function of the occurrence of elevated subjective stress at the wheel (STRESS rating >5, >6, or >7 at least once a shift). The vertical bars denote standard deviations.

4.3.2.2 Stress levels based on heart rate variability

Figure 20 shows four HR-based outcome metrics across night and non-night shifts. The mean HR and SDNN varied significantly, suggesting a decrease in vagal modulation during the non-night shifts as compared to the night shifts (HR: $p<0.001$; SDNN: $p=0.018$). The difference in RMSSD between the shift types approached statistical significance ($p=0.0546$). The mean levels of LF/HF ratio did not differ between the shift types.

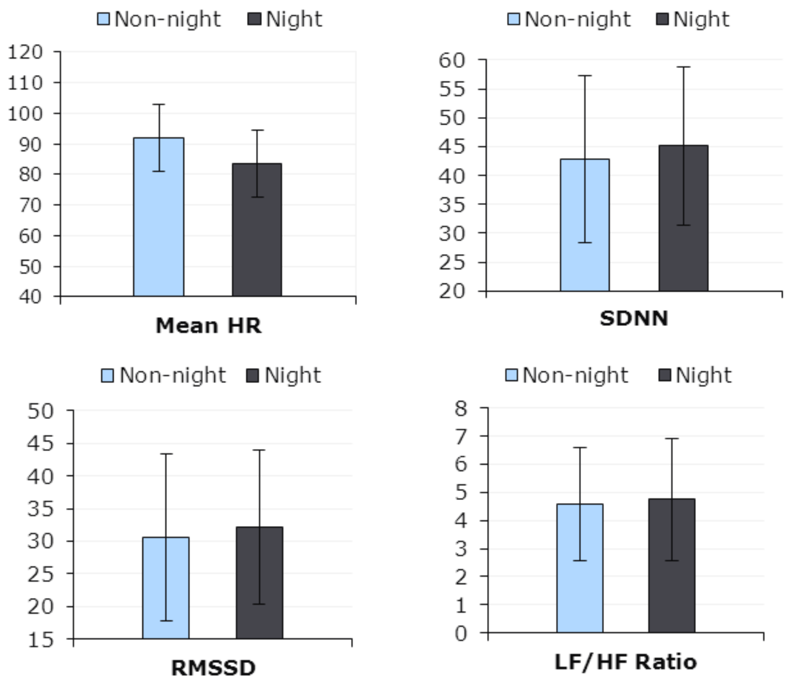

Figure 20. Mean levels of four heart rate based measures of driver stress during non-night and night shifts. The number of shifts included in the analyses was 31 for the non-night shifts and 28 for the night shifts.

Figure 21 illustrates the course of the selected four heart rate based measures of stress across successive work hours during the non-night and night shifts. The HR, SDNN and RMSSD measures of stress indicated that the shift type-related difference was not present in the beginning of the shifts but developed especially during the latter half of the shifts.

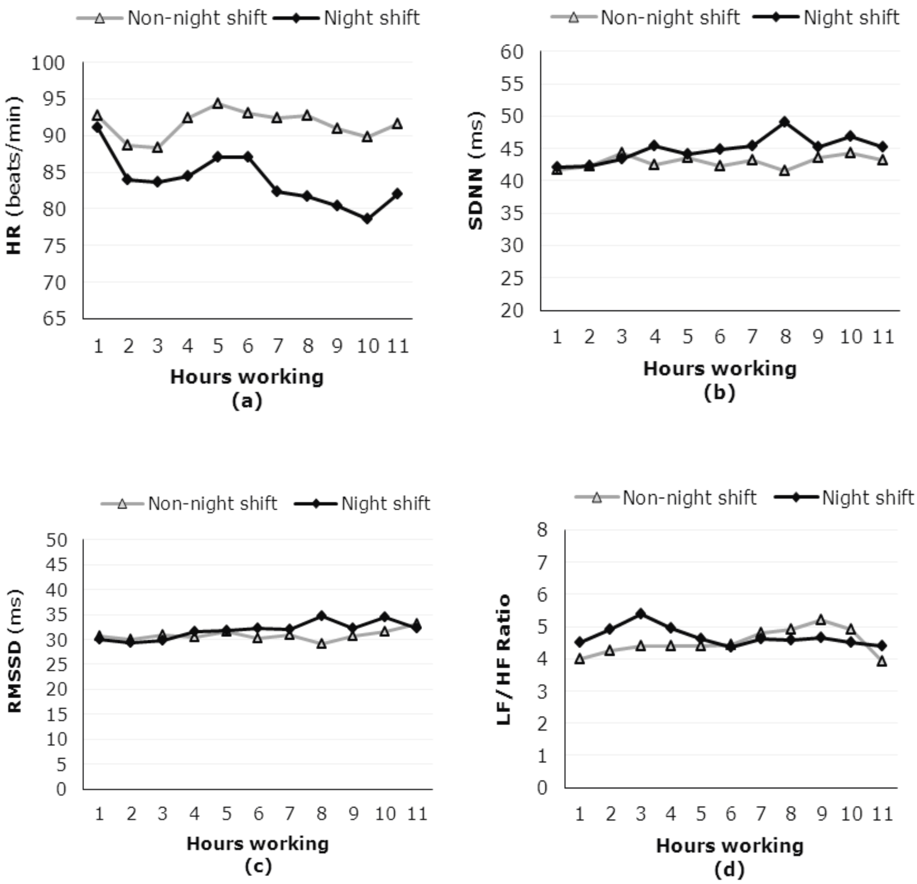

Figure 21. Mean hourly levels of four hear rate based measures of driver stress across successive hours working during non-night and night shifts [(a) Mean HR, (b) SDNN, (c) RMSSD and (d) LF/HF Ratio].

4.3.2.3 Factors underlying driver stress

Self-reported sources of driver stress: The sources of stress the drivers reported during different types of shifts are demonstrated in ***Figure 22***. At least one source of stress was reported for 42.8% of the shifts. The proportion was highest for the day or evening shifts (51.4%) and lowest (i.e. the least stressors per shift) for the successive night shifts (38.0%).

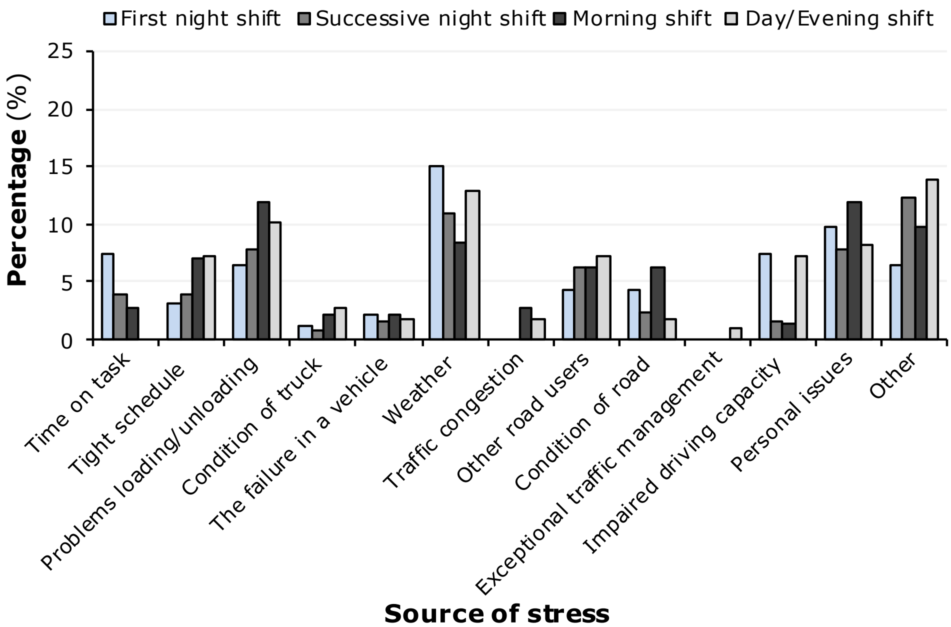

Figure 22. Self-reported sources of stress at work in different shift types.

The most frequently reported causes for driver stress included *problems loading/unloading a truck*, *poor weather*, and *personal issues*. Impaired driving capacity was considered causing stress in 7% of the first night and day/evening shifts, while only in 1% of the morning and successive night shifts.

Factors associated with self-rated stress at the wheel: *Table 7* shows the connection between individual-, sleep-, and work-related factors and the occurrence of elevated stress levels (STRESS>5 at least once during a shift). Of all individual- and sleep-related and other factors, only shift duration was significantly associated with elevated stress. The ESS score approached significance.

Table 7. Factors associated with elevated driver stress (STRESS>5 at least once a shift).

	DF	Chi Sq	Prob. Chi Sq
Individual factors			
Age	1	0.11	0.7348
Diurnal type index	1	0.02	0.8822
Sleep need[1]	1	1.94	0.1632
ESS score[2]	1	3.31	0.0689
Trucking experience	1	0.00	0.9720
Children <7 yrs	1	0.48	0.4892
Children <18 yrs	1	1.47	0.2255
Sleep-related factors			
TST[3]	1	0.12	0.7279
Sleep efficiency[4]	1	1.61	0.2050
Fragmentation index[5]	1	2.77	0.0962
TIB[6]	1	0.03	0.8628
Napping off duty[7]	1	0.15	0.7027
Time since awakening[8]	1	2.50	0.1135
Shift-related factors			
Shift type[9]	3	6.02	0.1108
Shift duration	1	5.25	0.0219
Recovery time[10]	1	0.14	0.7071
Work-related factors			
Nature of contract (SC vs. EC)[11]	1	0.02	0.8956
Wage basis (PBH vs. PWP)[12]	2	4.11	0.1278

[1] self-assessed (subjective) daily sleep need; [2] ESS score (0–24); [3] total sleep time; [4] actigraph-based measure (TST/TIB) indicating sleep quality; [5] actigraph-based measure indicating sleep quality; [6] time in bed; [7] yes/no; [8] time elapsed from waking up till the end of a shift; [9] first night shift, successive night shift, morning shift, day/evening shift; [10] time off between two consecutive duty days; [11] SC=subcontractor, EC=employment contract; [12] PBH=payment by the hour, PWP=piecework pay

Logistic regression showed that none of the selected explanatory factors were significantly associated with the occurrence of elevated stress (STRESS>5) at the wheel. The comparison between the first and successive night shifts revealed a difference in the odds ratio, but the shift type factor as a whole failed to reach significance in the model (***Table 8***).

*Table 8. Logistic regression analysis (GEE) of the variables predicting a risk (odds ratio, OR) of the occurrence of elevated stress (*STRESS>5 at least once a shift).

Explanatory variable	**Level 1**	**OR**	**95%**	**Confidence limit**	**Prob.**
Intercept		0.87	0.00	0.41	0.0073
Age		1.00	0.97	1.04	0.8677
ESS score[1]		1.07	0.97	1.18	0.1522
Shift type	First night	1.0	1.0	1.0	
	Successive night	0.44	0.23	0.84	0.0123
	Morning	0.79	0.48	1.30	0.3571
	Day/Evening	0.44	0.16	1.19	0.1077
Shift duration		1.04	0.87	1.25	0.6444
Fragmentation index[2]		1.01	0.99	1.03	0.1989

[1] ESS score (0–24); [2] actigraph-based measure indicating sleep quality

4.4 Effects of the educational intervention

4.4.1 Self-set goals to improve driver alertness

In the end of the educational intervention, each participant was given an opportunity to make a personal alertness management plan. When focusing on their main goals (one goal per driver), 68% of the drivers choose their general health behaviours (nutrition, physical activity, weight control and sleep) to improve their alertness at the wheel, while only 20% choose behaviours to support recovery while working on specific shift schedules (sleep-wake rhythm, physical activity, relaxation). The remaining 12% of participants choose on-the-job sleepiness alertness management behaviours.

The participants assessed their self-set goals quite important to themselves (mean 5.6, SD 1.0; 1=“not at all important” vs. 7=“very important”) and they were quite committed to them (mean 5.2, SD 1.1; 1=“not at all committed” vs. 7=“very committed”).

4.4.2 Self-rated sleepiness before and after the intervention

Mean level of self-rated sleepiness before and after the intervention: *Tables 9* and *10* show the mean, minimum and maximum values (per shift) for self-rated sleepiness across the four shift types, and the two study groups and phases. Mixed model analyses revealed no systematic intervention-related difference in any of the sleepiness outcomes.

Table 9. Self-rated sleepiness (KSS) during night shifts (first and successive) before (Pre) and after (Post) the intervention. "Mean" includes all the KSS ratings of all shifts within a shift type, "Maximum" includes the maximum and "Minimum" the minimum KSS rating of all shifts within a shift type (mean±SD).

KSS score	**First night shift**		**Successive night shift**	
	Pre	Post	Pre	Post
Mean per shift				
Intervention group	3.8±1.2	3.8±1.3	3.4±1.2	3.6±1.4
Control group	4.1±1.5	4.0±1.4	3.1±1.2	3.3±1.5
Maximum per shift				
Intervention group	5.7±1.9	5.5±1.9	4.9±1.9	5.1±1.9
Control group	5.7±2.0	5.8±1.8	4.6±1.9	4.6±2.1
Minimun per shift				
Intervention group	2.5±1.0	2.6±1.2	2.4±1.0	2.7±1.2
Control group	2.6±1.3	2.8±1.4	2.1±0.9	2.4±1.3

Table 10. Self-rated sleepiness (KSS) in non-night (morning and day/evening) shifts before and after the intervention. "Mean" includes all the KSS ratings of all shifts within a shift type, "Maximum" includes the maximum and "Minimum" the minimum KSS rating of all shifts within a shift type (mean±SD).

KSS score	**Morning shift**		**Day/Evening shift**	
	Pre	Post	Pre	Post
Mean per shift				
Intervention group	2.9±1.1	3.1±1.1	3.3±1.2	2.7±0.9
Control group	3.2±1.3	3.2±1.3	3.7±1.4	3.7±1.5
Maximum per shift				
Intervention group	4.0±1.7	4.1±1.6	4.5±1.6	3.8±1.6
Control group	4.4±1.7	4.1±1.7	4.9±2.0	4.9±2.1
Minimum per shift				
Intervention group	2.1±1.0	2.4±1.1	2.5±1.1	2.1±1.0
Control group	2.3±1.2	2.4±1.1	2.5±1.3	2.7±1.2

Occurrence of elevated levels of driver sleepiness before and after the intervention: Proportion of KSS ratings indicative of elevated sleepiness in the two study groups before and after the intervention is illustrated in ***Figure 23***, and proportion of shifts including at least one KSS rating indicative of elevated sleepiness in ***Figure 24***.

Logistic regression analyses did not reveal any significant intervention-related change in the occurrence of elevated sleepiness at the wheel (KSS>5 at least once during a shift). The comparisons with each shift type revealed that the odds ratio for the occurrence of elevated sleepiness (KSS>5 at least once during a shift) tended to be lower (OR 0.2565, 95% CI: 0.0538–1.2232, p=0.0878) in the intervention than in the control group after the intervention.

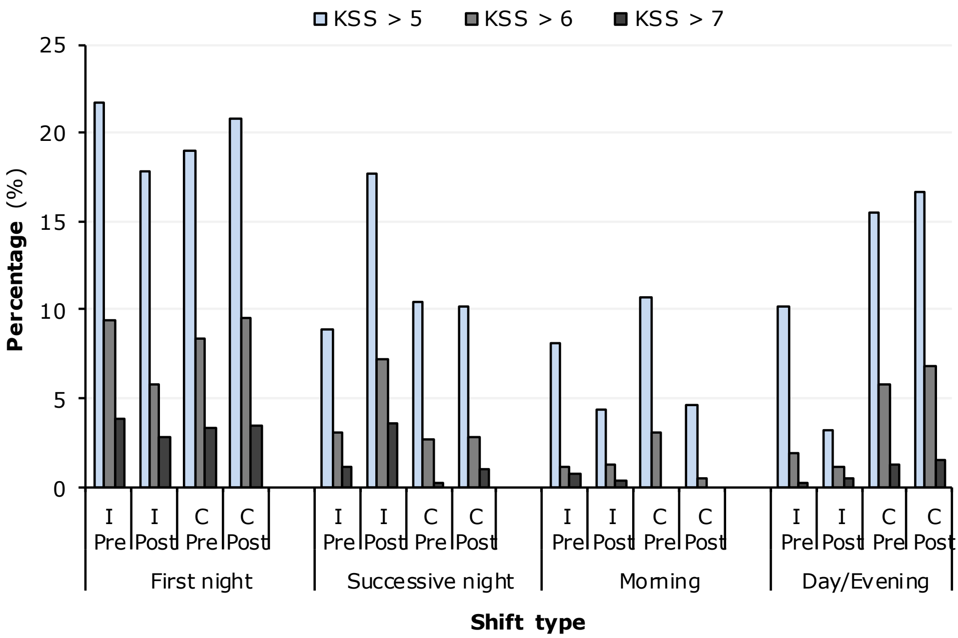

Figure 23. Proportion of KSS ratings in different shift types in the intervention (I) and control (C) groups before (Pre) and after (Post) the intervention. The total number of ratings indicative of elevated sleepiness (KSS>5, >6, or >7) in different shift types were as follows – first night shifts: 663 (I/PRE), 399 (I/Post), 394 (C/Pre), 293 (C/Post); successive night shifts: 834 (I/PRE), 804 (I/Post), 498 (C/Pre), 400 (C/Post); morning shifts: 722 (I/PRE), 568 (I/Post), 634 (C/Pre), 578 (C/Post); day/evening shifts: 470 (I/PRE), 448 (I/Post), 394 (C/Pre), 263 (C/Post).

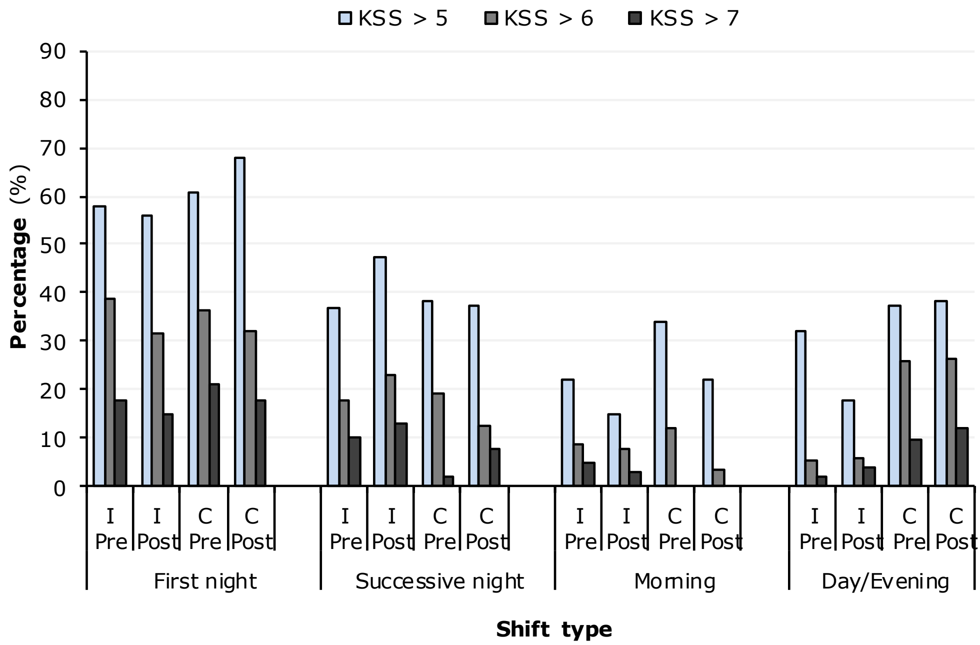

Figure 24. Proportion of shifts (in different shift types) including at least one KSS rating indicative of elevated sleepiness (KSS>5, >6, or >7) in the intervention (I) and control (C) groups before (Pre) and after (Post) the intervention.

4.4.3 Observer-rated sleepiness before and after the intervention

Figure 25 shows that in the *intervention group* the mean hourly ORD scores during the *non-night shifts* varied from 16.8 (SD 9.5) to 24.8 (SD 14.1) before the intervention and from 14.3 (SD 9.5) to 24.9 (SD 16.9) after the intervention. The corresponding ranges in the *control group* were 11.5 (SD 5.8)–21.3 (SD 11.1) and 14.2 (SD 7.2)–21.1 (SD 9.6).

During the night shifts, the mean hourly ORD values in the intervention group varied from 21.6 (SD 12.8) to 35.2 (SD 16.6) before the intervention, and from 20.3 (SD 12.3) to 33.2 (SD 13.3) after the intervention (***Figure 26***). The corresponding ranges for the control group were 14.2 (SD 6.0)–29.1 (SD 9.2) and 20.3 (SD 8.3)–32.4 (SD 12.8). All the mean hourly observed ratings fell into the ORD category of "slight sleepiness" (range 12.5–37.49).

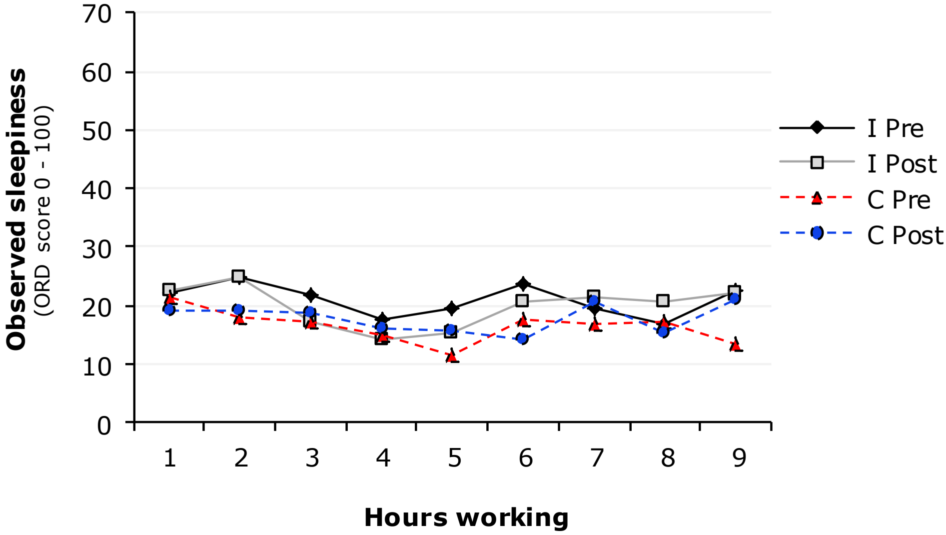

Figure 25. Mean hourly levels of observer-rated sleepiness (ORD) for the intervention (I) and control (C) group across successive hours working in non-night (morning or day/evening) shifts before (Pre) and after (Post) the intervention.

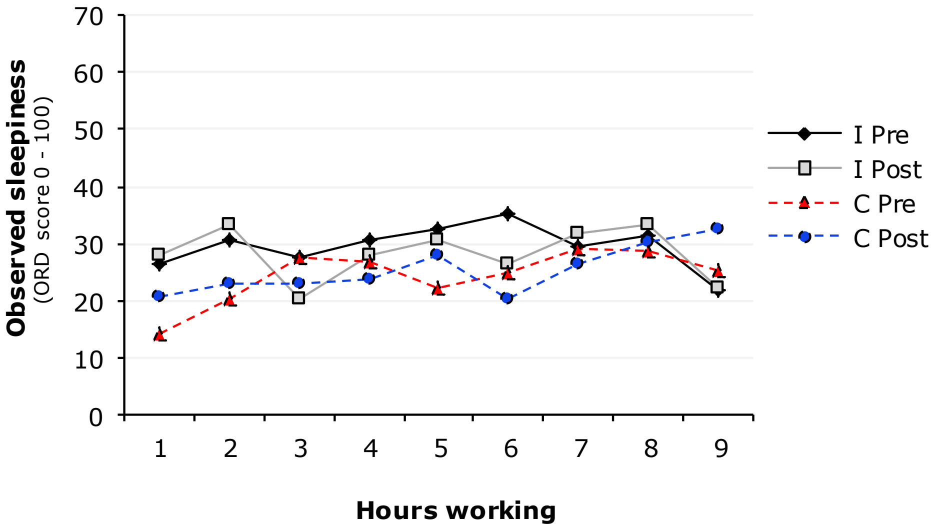

Figure 26. Mean hourly levels of observer-rated sleepiness (ORD) for the intervention (I) and control (C) group across successive hours working in night shifts before (Pre) and after (Post) the intervention.

Figure 27 shows that the mean, minimum, and maximum level of ORD scores remained at similar levels before and after the intervention in both study groups during the non-night and night shifts. The minimum values indicated high alertness (range 0.0–12.49 on the ORD), the mean values slight sleepiness (range 12.5–37.49), and the maximum values moderate sleepiness (range 37.5–62.49) before and after the intervention in the both study groups, independent of a shift type.

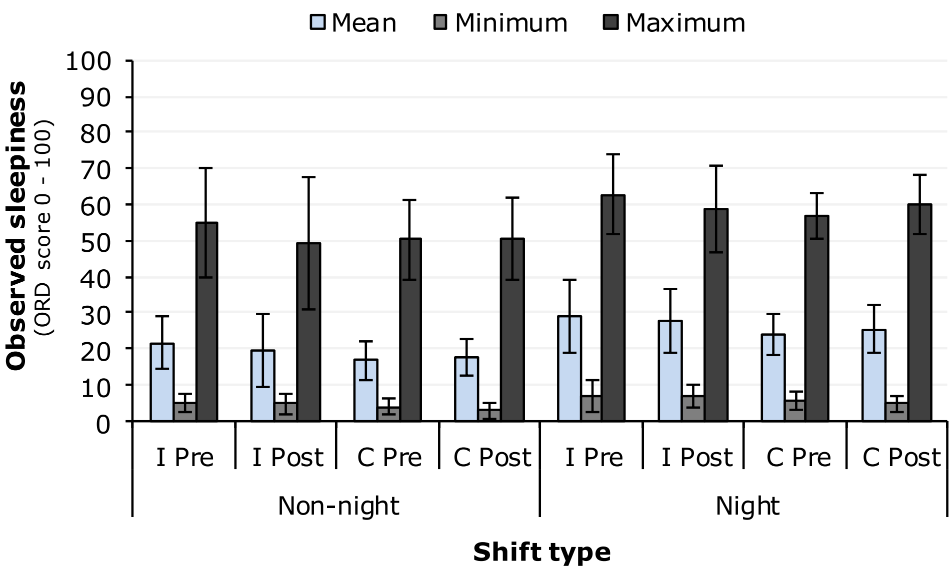

Figure 27. Mean, minimum, and maximum levels of observed sleepiness (ORD) during non-night and night shifts in the two study groups (I, C) before (Pre) and after (Post) the intervention.

During both night and non-night shifts, a small post-intervention decline in the proportion of the shifts including elevated sleepiness was found for the intervention group, but not for the control group (***Figure 28***). Unfortunately, the amount of data did not allow us to conduct a statistical test to study whether the group difference was significant after the intervention. No ORD score indicative of extreme sleepiness was found in any condition.

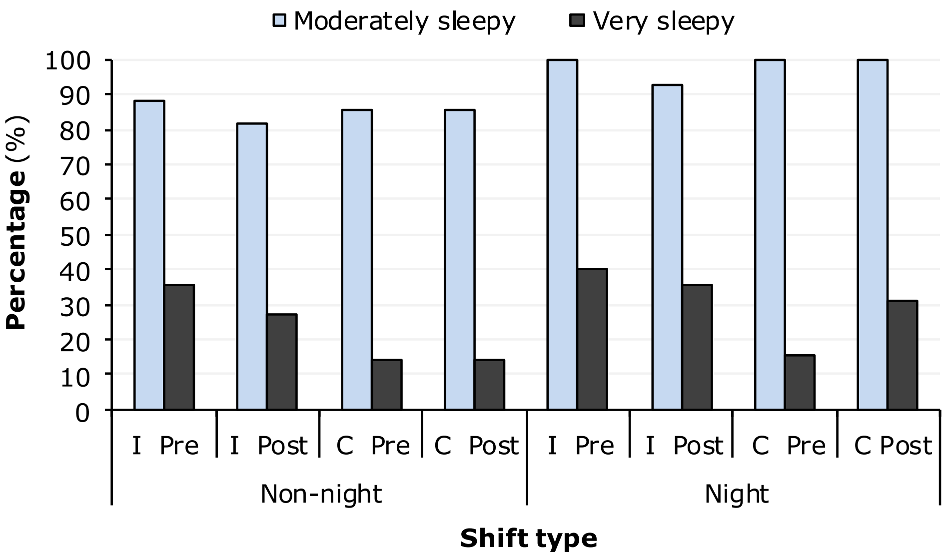

Figure 28. Proportion of night and non-night shifts before (Pre) and after (Post) the intervention during which the drivers in the two study groups (I, C) were observed (ORD) to be "moderately to very" or "very" sleepy at least once.

4.4.4 Driving style before and after the intervention

Figure 29 shows driving style (measured as indriving index) averaged over the highway segments of the trips. There was a slight improvement observable in both study groups between the pre- and post-intervention measurement phases. The improvement was independent of the shift type. No intervention-related changes were observed.

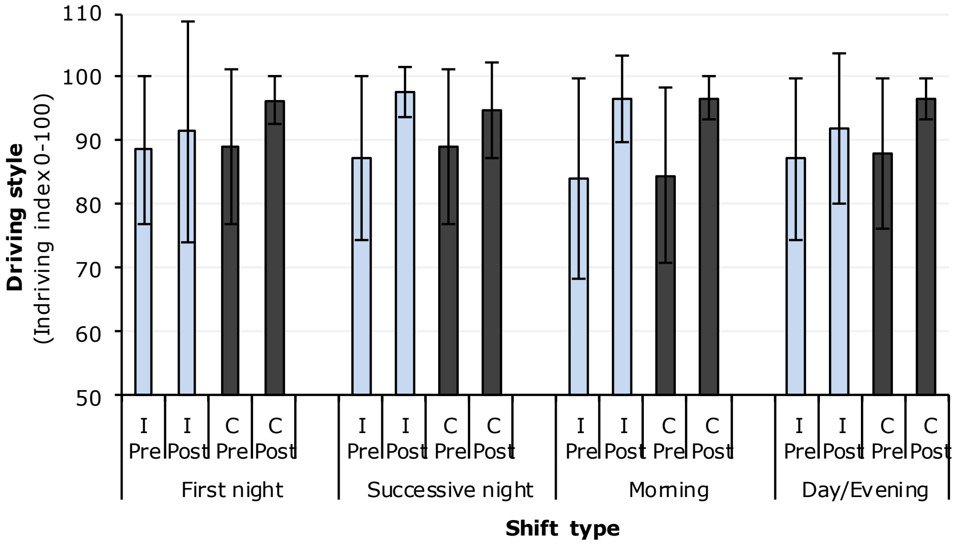

Figure 29. Driving style (indriving index) during highway segments based on vehicle tracking data in the two study groups (I, C) and measurement phases (Pre, Post).

4.4.5 Sleep before and after the intervention

Tables 11–12 show the sleep data over the two-week pre- and post-intervention measurement periods. Mixed model analyses revealed that that there was a “Group × Shift type” interaction effect on sleep length after the intervention (F(3.343)=2.68, p>0.05), but not before it (F(3.390)=2.21, *p*=0.09). The planned contrast revealed that the group difference approached significance in the first night shift of the post-intervention phase (t(343)=-1.78, *p*=0.07), but not in the other shift types. Time in bed (main sleep period) prior to the first night shift was on average 49 minutes longer in the intervention group than in the control group. No other differences in sleeping between the groups were found after the intervention.

Table 11. Diary- and actigraph-based results for sleep in relation to different shift types for both study groups and measurement phases (Pre, Post).

	First night shift		**Successive night shift**		**Morning shift**		**Day/Evening shift**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Measurement days (n)								
Intervention group	58	46	80	79	83	71	60	56
Control group	35	30	49	42	60	64	49	38
Bedtime (h:min)								
Intervention group	0:04±3:01	0:09±1:43	7:12±2:45	7:36±2:54	22:26±1:18	22:05±1:08	23:33±1:43	0:07±1:59
Control group	23:46±2:42	0:25±2:12	7:39±3:41	6:15±2:37	22:20±1:12	22:05±1:05	0:26±2:58	0:04±1:48
Get up time (h:min)								
Intervention group	8:22±3:47	9:02±2:35	14:18±2:37	14:15±2:49	4:56±0:59	4:35±1:06	7:09±1:45	7:45±1:55
Control group	8:20±3:59	8:36±3:24	14:14±3:23	13:30±2:21	4:46±0:57	4:41±0:55	8:33±2:18	8:05±1:35
Actigraph-based measures								
TIB[1] (h:min)								
Intervention group	8:19±2:37	9:00±2:07	7:06±1:23	6:38±1:27	6:32±1:14	6:32±1:02	7:39±1:30	7:36±1:24
Control group	8:32±2:02	8:11±2:23	6:34±1:32	7:10±1:34	6:28±0:57	6:37±0:53	8:07±1:33	8:00±1:09
TST[2] (h:min)								
Intervention group	7:13±2:16	7:47±1:40	6:12±1:14	5:49±1:20	5:46±1:09	5:39±1:00	6:39±1:27	6:40±1:23
Control group	7:33±1:51	7:05±2:13	5:48±1:20	6:21±1:17	5:38±1:05	5:48±0:50	7:09±1:23	7:00±1:01
Sleep efficiency[3] (%)								
Intervention group	86.8±5.7	86.9±6.6	87.3±5.3	87.7±6.1	88.4±4.3	86.5±7.0	86.5±6.1	87.5±6.0
Control group	88.6±4.8	86.1±5.8	88.5±5.9	88.9±4.7	86.7±9.9	87.7±5.4	88.1±5.1	87.7±5.6
Fragmentation index[4]								
Intervention group	29.5±12.2	27.8±12.2	28.9±11.7	28.7±13.0	24.6±10.4	26.0±14.4	28.7±12.9	30.0±15.9
Control group	25.8±12.8	30.5±12.3	27.1±15.4	26.8±11.6	25.7±14.2	26.7±12.2	29.8±12.5	31.4±12.0

[1] time in bed; [2] total sleep time; [3] actigraph-based measure (TST/TIB) indicating sleep quality; [4] actigraph-based measure indicating sleep quality

Table 12. Diary- and actigraph-based results for sleep in relation to recovery days and days off for both study groups and measurement phases (Pre, Post).

	Recovery day		**First day off**		**Successive day off**	
	Pre	Post	Pre	Post	Pre	Post
Measurement days (n)						
Intervention group	39	33	76	74	68	48
Control group	18	22	48	51	51	36
Bedtime (h:min)						
Intervention group	7:00±3:15	7:55±3:54	0:07±1:45	0:02±2:10	0:24±1:47	0:28±1:45
Control group	6:44±2:12	6:40±3:05	0:09±1:37	0:24±2:13	0:55±2:05	0:30±1:36
Get up time (h:min)						
Intervention group	12:46±2:42	13:21±3:12	9:09±1:52	9:09±1:51	9:16±1:45	9:19±1:39
Control group	12:51±2:26	12:18±2:48	8:43±1:59	8:48±1:57	9:16±2:13	9:04±1:54
Actigraph-based measures						
TIB[1] (h:min)						
Intervention group	5:47±2:07	5:29±2:01	9:07±1:33	9:06±2:04	8:47±1:25	8:55±1:38
Control group	6:06±1:02	5:32±1:12	8:31±1:48	8:24±1:46	8:24±1:26	8:28±1:11
TST[2] (h:min)						
Intervention group	5:02±1:51	4:37±1:44	7:58±1:21	8:00±1:47	7:43±1:12	7:41±1:27
Control group	5:22±1:03	4:45±1:04	7:30±1:38	7:26±1:31	7:26±1:15	7:29±1:07
Sleep efficiency[3] (%)						
Intervention group	87.1±5.4	84.8±9.9	87.5±5.6	88.2±6.7	88.0±5.0	86.2±6.7
Control group	87.8±3.8	86.1±6.5	88.2±5.3	88.8±6.0	88.7±7.4	88.4±5.9
Fragmentation index[4]						
Intervention group	27.8±11.0	30.4±18.0	27.9±12.6	28.7±14.2	27.4±12.0	31.3±15.3
Control group	28.4±15.2	27.9±17.8	29.9±16.0	26.9±13.3	27.6±15.1	26.5±13.3

[1] time in bed; [2] total sleep time; [3] actigraph-based measure (TST/TIB) indicating sleep quality; [4] actigraph-based measure indicating sleep quality

4.4.6 Use of sleepiness countermeasures before and after the intervention

Sleepiness countermeasures used in the two study groups before and after the intervention are presented in ***Tables 13*** and ***14***. Logistic regression analyses revealed no difference between the study groups in the frequency in which the different countermeasures were used after the intervention. The "Group × Shift type" interaction effect did not reach significance either, i.e. no intervention-related changes in the use of sleepiness countermeasures in the different shift types were found.

Table 13. Use of sleepiness countermeasures during prescribed rest breaks in different shift types in the two study groups (I, C) before and after the intervention.

		First night shift		**Successive night shift**		**Morning shift**		**Day/ Evening shift**	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Measurement days (n)	I	58	46	80	79	83	71	60	56
	C	35	30	49	42	60	64	49	38
Sleepiness countermeasure		**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Caffeine	I	58.6	75.0	75.0	74.0	64.2	56.3	66.1	66.7
	C	77.1	66.7	81.6	83.3	80.0	65.6	61.2	64.9
Nap	I	24.1	27.3	8.8	18.2	7.4	9.9	1.7	3.7
	C	14.3	20.0	12.2	11.9	3.3	0.0	2.0	2.7
Light meal	I	55.2	47.7	55.0	55.8	71.6	66.2	67.8	50.0
	C	45.7	60.0	46.9	59.5	58.3	54.7	36.7	56.8
Heavy meal	I	3.4	9.1	10.0	7.8	9.9	7.0	6.8	13.0
	C	5.7	6.7	10.2	14.3	10.0	9.4	12.2	5.4
Nicotine	I	13.8	20.5	27.5	23.4	16.0	9.9	28.8	29.6
	C	31.4	36.7	42.9	38.1	43.3	39.1	26.5	24.3
Walk outdoors	I	19.0	4.5	16.3	9.1	11.1	7.0	5.1	5.6
	C	17.1	16.7	14.3	11.9	8.3	9.4	8.2	10.8
Socializing	I	24.1	22.7	33.8	28.6	25.9	29.6	13.6	27.8
	C	25.7	20.0	38.8	28.6	23.3	21.9	18.4	13.5
Duties	I	5.2	13.6	6.3	6.5	3.7	8.5	0.0	11.1
	C	5.7	10.0	8.2	2.4	3.3	14.1	10.2	18.9
Other	I	1.7	4.5	2.5	0.0	7.4	2.8	6.8	1.9
	C	2.9	0.0	2.0	0.0	8.3	0.0	4.1	0.0

Table 14. Use of sleepiness countermeasures outside prescribed breaks in different shift types in the two study groups (I, C) before (Pre) and after (Post) the intervention.

		First night shift		**Successive night shift**		**Morning shift**		**Day/Evening shift**	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Measurement days (n)	I	58	46	80	79	83	71	60	56
	C	35	30	49	42	60	64	49	38
Sleepiness countermeasure		**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Coffee	I	31.0	45.5	32.5	39.0	12.0	23.9	25.0	7.4
	C	37.1	30.0	36.7	23.8	18.3	20.3	6.1	27.0
Nicotine	I	5.2	9.1	13.8	9.1	6.0	8.5	11.7	0.0
	C	20.0	16.7	24.5	16.7	16.7	15.6	8.2	10.8
Sweets	I	6.9	9.1	7.5	2.6	0.0	2.8	3.3	5.6
	C	5.7	6.7	12.2	11.9	10.0	1.6	0.0	2.7
Soft drink	I	13.8	6.8	23.8	13.0	0.0	2.8	0.0	1.9
	C	0.0	6.7	8.2	0.0	1.7	1.6	0.0	0.0
Energy drink	I	3.4	6.8	2.5	2.6	2.4	0.0	3.3	1.9
	C	8.6	3.3	0.0	4.8	1.7	3.1	0.0	0.0
Body movements while driving	I	19.0	25.0	8.8	19.5	6.0	11.3	8.3	1.9
	C	14.3	16.7	10.2	14.3	6.7	4.7	10.2	8.1
Break in truck (no nap)	I	0.0	0.0	1.3	1.3	1.2	1.4	0.0	0.0
	C	0.0	3.3	0.0	0.0	0.0	1.6	0.0	0.0
Break (nap)	I	10.3	11.4	1.3	5.2	1.2	0.0	0.0	0.0
	C	0.0	3.3	0.0	2.4	3.3	0.0	2.0	0.0
Break to walk outdoors	I	10.3	2.3	5.0	3.9	3.6	0.0	1.7	0.0
	C	11.4	10.0	2.0	4.8	3.3	0.0	2.0	16.2
Break (exercise outdoors)	I	0.0	0.0	0.0	0.0	1.2	0.0	1.7	1.9
	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opening window	I	6.9	4.5	3.8	1.3	0.0	2.8	1.7	0.0
	C	14.3	13.3	10.2	9.5	11.7	7.8	6.1	0.0
Adjusting temperature	I	8.6	2.3	7.5	3.9	0.0	1.4	1.7	3.7
	C	2.9	3.3	2.0	4.8	5.0	0.0	0.0	0.0
Turning on radio/stereo	I	0.0	4.5	0.0	5.2	0.0	0.0	0.0	1.9
	C	0.0	3.3	2.0	0.0	0.0	0.0	2.0	2.7
Turning up radio/stereo	I	8.6	9.1	8.8	6.5	2.4	2.8	3.3	1.9
	C	5.7	0.0	14.3	7.1	0.0	0.0	2.0	8.1
Singing/Whistling/Talking	I	6.9	2.3	7.5	7.8	2.4	2.8	3.3	1.9
	C	8.6	0.0	16.3	0.0	1.7	0.0	10.2	0.0
Accelerating speed	I	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decelerating speed	I	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Active driving	I	1.7	0.0	0.0	1.3	4.8	0.0	5.0	0.0
	C	2.9	0.0	2.0	2.4	1.7	0.0	0.0	0.0
Socializing	I	19.0	25.0	25.0	31.2	12.0	7.0	11.7	13.0
	C	14.3	13.3	20.4	16.7	8.3	3.1	4.1	13.5
Other	I	5.2	4.5	1.3	0.0	1.2	0.0	1.7	0.0
	C	2.9	0.0	10.2	0.0	3.3	1.6	4.1	0.0

5 DISCUSSION

The main findings of the present study can be divided into three parts. First, the results showed that 1) driver sleepiness occasionally reaches levels that are likely to compromise safe driving and that 2) the main factors contributing to driver sleepiness are the *night time driving*, *insufficient sleep* prior to a shift, *long shift duration* and high perceived *sleep needs*. Second, the current study showed that 3) driver stress quite seldom reaches clearly elevated levels and that 4) the main self-reported sources of driver stress are the *poor weather conditions*, *problems with loading/unloading a truck*, and *personal issues*. Third, the study found that 5) an educational intervention on alertness management is not likely to result in significant improvements in drive alertness or in the use of alertness management strategies.

5.1 Levels and sources of driver sleepiness

In all, the findings showed that the mean levels of driver sleepiness assessed by drivers' self-reports (KSS) and their observed behaviours (ORD) did not indicate *elevated levels of driver sleepiness* in the selected four shift types. On the other hand, there was a significant proportion of shifts (18.5%) during which the drivers rated themselves *severely to extremely sleepy* (KSS>6) at least once. Furthermore, behavioural signs of *severe sleepiness* (e.g., an eyelid closures of 2–3 seconds, cross-eyed look, lack of apparent activity) were found in more than 25% of the video-recorded shifts. Almost all video-recorded non-night and night shifts included at least one 1-minute epoch indicative of at least *moderate sleepiness* (KSS>5). On the basis of self-ratings, the first night shifts proved to be particularly sleepiness-inducing. Approximately every tenth self-rating during the first night shifts was indicative of *severe to extreme sleepiness* (KSS>6). Approximately one third of the first night shifts included at least one self-rating indicative of severe to extreme sleepiness. The preliminary ORD results did not show such a difference between night and day time driving.

These estimates of sleepy driving can be considered fairly conservative, as the KSS ratings were given only once an hour, and the ORD analysis was conducted for only about 10% of the total driving hours (six 1-minute epochs per hour). If the sampling rate of these sleepiness measures had been higher, the proportion of shifts including signs of sleepiness probably would have been higher. Compared to a previous study on train drivers, the prevalence of nigh shifts with severe sleepiness was somewhat lower in the current study. Among the train drivers, severe self-reported sleepiness occurred in 50% of the night shifts (Härmä et al. 2002). However, it should be noted that the train drivers were ask to report their sleepiness level every time they felt severely sleepy during a trip, while in the current study the level of sleepiness was inquired once an hour independent of its level. This difference in the way of collecting the data probably explains at least some of the discrepancy in the results.

Both subjective and observed estimates of severe sleepiness are known to be associated with increased frequency of prolonged eye blinks, problems in lateral position control of the vehicle, and with a risk for involvement in at-fault critical incidents in real driving conditions (Hanowski et al. 2003; Sandberg et al. 2011). In the current study, an attempt was also made to study the relationship between elevated sleepiness at the wheel and objectively measured driving style and fuel consumption. The preliminary descriptive findings were slightly suggestive of an impaired driving style as a function of an increase in self-rated sleepiness, but unfortunately the number of observations was too low to conduct any statistical test. In future, more fine-grained analyses are needed to further investigate this relationship. One way to do this is to divide each trip into one-hour segments on the basis of sleepiness self-ratings, and examine whether the driving style metrics differ between the hours including ratings of elevated sleepiness and between those hours that do not include such ratings.

The amount of data on fuel consumption remained too low to draw any conclusion. However, the above-mentioned fine-grained analysis of self-rated sleepiness and driving style is likely to provide elements to say more about fuel consumption as well, since the level of fuel consumption is associated with driving style metrics.

The factors contributing to elevated sleepiness at the wheel were examined two ways. First, logistic regression analyses was used to examine which of the potential individual-, sleep- and work-related factors were significantly associated with elevated self-rated sleepiness. The main finding was that especially sleep- and shift-related factors proved to be significant. One of the most interesting findings was that the first night shifts were more strongly associated with elevated sleepiness than the successive night shifts. Secondly, the participants were asked to report the sources of sleepiness, if they had felt sleepy at the wheel. Also these self-assessments of factors contributing to sleepiness indicated that night-time driving and inadequate prior sleep underlay driver sleepiness.

There are at least two aspects to the finding suggesting a stronger sleepiness-inducing effect of the first night shifts compared to the successive night shifts. First, the number of successive night shifts was quite low. There were on average three successive night shifts, if single night shifts were excluded from the calculations. Thus, the proportion of conditions in which sleep restriction and sleepiness would have accumulated over several days was quite small. Secondly, the amount of data did not allow studying separately those successive night shifts that were immediately preceded by, for example, three to four night shifts. It could be that the level of sleepiness clearly increased over several successive night shifts, especially during the last two or three shifts. Altogether, these findings suggest that the first night shift is the most disadvantageous shift type in terms of driver sleepiness and that the difference in sleepiness between successive night shifts and the other shift types is quite small. However, this rule of thumb probably only applies to the shift schedules that do not include long spells of sleep-disturbing shifts such as night, early morning and late evening shifts. The sleepiness-provoking characteristic of the first night shift is mainly explained by two main factors: time of the day and a long period of sustained wakefulness (Åkerstedt 1998). In the current study, time since awakening was also strongly associated with the occurrence of elevated sleepiness at the wheel.

In addition to the shift type, the amount and quality of sleep prior to a shift were associated with elevated driver sleepiness. On average, a one-hour decrease in main sleep duration was associated with a 33% increase in the risk for elevated self-reported sleepiness. Similarly, a percent decrease in sleep efficiency was associated with a 4% increase in the same risk. These finding are in accordance with the previous on-road study on truck drivers (Hanowski et al. 2003) which suggest that driver sleepiness could be reduced by training on sleep hygiene.

The diary- and actigraph-based data showed that, compared to successive days off (sleep duration 7.5 hours), the amount of sleep was clearly reduced prior to morning (sleep duration 6.5 hours) and successive night shifts (sleep duration approximately 6 hours), but not prior to day/evening (sleep duration 7.5 hours) or first night shifts (sleep duration 8 hours). In all, the sleep durations prior to different shift types were somewhat longer than previously reported. For example, Mitler et al. (1997) found that long-haul truck drivers slept (time in bed) approximately 5 hours per day when working on a five-day schedule. Dingus, Neale, Garness et al. (2002) reported that truck drivers obtained approximately 6 hours of sleep per day based on self-reports. However, these kinds of comparisons between the studies are not straightforward, as the participating drivers' shift schedules may differ significantly in many respects (e.g., rotation, duration, timing).

A crucial question is: what is the amount of sleep that is insufficient considering safe driving. Interestingly, Hanowski et al. (2003) reported that elevated levels of sleepiness were associated with an increased risk of at-fault incident involvement among truck drivers, and that short or poor quality sleep in turn elevated the risk of being sleepy at the wheel. In fact, drivers who were involved in at-fault incidents and assessed being sleepy at the time of the incident, reported 5.3 hours of prior sleep, while their colleagues who were involved in incidents where another driver was at fault, reported 6.1 hours of prior sleep. In the current study, short sleep duration (main sleep period <6 hours) prior to a shift was most common prior to morning and successive night shifts. Total sleep time preceding a shift was less than 6 hours in approximately half of the morning and successive night shifts, whereas the same held true for only one-fifth of the first night and one-fourth of the day or evening shifts. On the other hand, the proportion of shifts during which the drivers were sleepy (elevated levels of sleepiness) was clearly highest for the first night shifts. This finding emphasizes the importance of factors, such as time since awakening, time of day, as well as sleep quality and quantity, in driver alertness.

An intriguing finding was the significance of perceived (self-assessed) sleep need for driver sleepiness: each additional hour of sleep need was associated with more than a two-fold increase in the risk of elevated sleepiness. This finding may be interpreted to show that professional drivers with a higher *biological* sleep need are more inclined to show sleepiness at wheel than their colleagues with lower sleep need. On the other hand, the finding may also be explained by the professional drivers frequently reporting being sleepy at the wheel also assessing their sleep need higher than average, even though their elevated sleepiness would, in reality, result from other factors than high biological sleep need (e.g., circadian factor). However, this finding of the role of perceived sleep need is of importance in practice, since it seems to provide an important piece of information on the risk of elevated sleepiness at the wheel.

The drivers were also asked to report the sources of sleepiness at the wheel during each trip. These reports, which were made in 43% of the shifts and most often during the first night shifts (58%), revealed very similar factors underlying elevated sleepiness as did the results of the logistic regression analyses. Problems with sleep quantity and/or quality (regardless of the shift type) and time of the day (night shifts) were reported most frequently as the sources of sleepiness. In all, the findings based on both statistical analyses and self-assessments suggest the current EU rules on driving, rest, and working hours in general do not prevent driver sleepiness, especially during night shifts, due to a shortage of sleep, long periods of sustained wakefulness, and the circadian rhythm of human alertness. Consequently, in addition to educational interventions targeted at professional drivers, additional sleepiness countermeasures are needed. This will be discussed in depth later in this report.

Interestingly, the findings suggest that the drivers quite often felt themselves so sleepy at the wheel that they had to resort to using sleepiness countermeasures outside prescribed rest breaks as well. Sleepiness countermeasures were reported used while driving in 6 out of 10 night shifts and 4 out of 10 morning or day/evening shifts. Also the number of sleepiness countermeasures used during a single shift was higher for night shifts than for morning and day/evening shifts. The most frequently used sleepiness countermeasures while driving (when feeling sleepy at the wheel) were caffeine in various forms, nicotine, socializing and moving the body while driving. All these sleepiness countermeasures were used, on average, in more than every tenth trip and their use was pronounced while driving at night. Compared to these sleepiness countermeasures, taking a break from driving to nap was infrequently used. This finding may be explained by the fact that the drivers took a nap quite often during their prescribed rest breaks. This was reported in every fifth first night shift and every tenth successive night shift.

Two recent questionnaire studies investigated the kinds of sleepiness countermeasures non-professional and professional drivers use on the road and the factors associated with their use (Anund et al. 2008; Asaoka 2012). According to the study by Anund et al. (2008), the most common sleepiness countermeasures were taking a break to have a short walk, turning on the radio, opening a window and drinking coffee. These countermeasures were reported by approximately half of the respondents. Taking a break to nap was only reported by less than every fifth respondent, but being a professional driver clearly increased the use of this countermeasure. Also caffeine ingestion was more common among the professional than the non-professional drivers. Of the most used sleepiness countermeasures listed by Anund et al. (2008), only drinking coffee was frequently used in the present study. In addition, napping breaks were quite commonly used in both studies. Due to clear differences in the target groups, methodology and data analysis, direct comparison between the studies may, however, be difficult.

Taking a rest break as a sleepiness countermeasure on the road was reported by 40% of professional drivers, while the corresponding proportions were clearly lower for taking a nap (20%) and caffeine ingestion (28%). A new and important finding was that not having been involved in sleep-related traffic accident significantly decreased the use of nap breaks and caffeine.

Overall, napping breaks and caffeine have been found to be the most effective sleepiness countermeasures on the road, whereas opening a window or turning on the radio have been suggested to have only a minor or even zero effect on driver alertness (Philip , Taillard, Moore et al. 2006; Sagaspe, Taillard, Åkerstedt et al. 2008; Schwarz, Ingre, Fors et al. 2012). In the present study, the long-haul truck drivers preferred caffeine as well, and it was used frequently during prescribed rest breaks independent of the shift type and outside them while driving during night time. Napping was clearly a less common countermeasure and its use was mainly limited to the prescribed rest breaks during night shifts. The drivers reported taking naps in 10% (successive night shifts) to 20% (first night shifts) of their night shifts. These findings left plenty of room for improvements in the use of napping breaks on the road.

5.2 Levels and sources of driver stress

Altogether, driver stress was not found to reach as high levels as driver sleepiness. At least *moderate stress* (*i.e. moderate to extreme stress,* STRESS>5) were observed approximately in every fifth shift and *severe to extreme stress* (STRESS>6) in every thirteenth shift. As a comparison, the corresponding frequencies for elevated sleepiness were 1.8–2.7 times higher. Further, the results on HRV measurements indicated that no significant stress levels were reached during day or night time driving. For example, the RMSSD values, which serve as a proxy for the level of parasympathetic activity, fell within a range of normal values (Bonnemeier, Richardt, Potratz et al. 2003).

Compared to self-rated sleepiness, the self-ratings of stress were not affected by the shift type or by the number of successive hours working. This finding is somewhat unexpected, since – as the alertness and traffic density are lower at night time – the stress levels during night shifts would be expected to be lower too. However, the time-of-day effect was to some extent observable in the heart rate variability results. Both the mean heart rate level and the variability in beat-to-beat intervals indicated increased parasympathetic activity during the night shift compared to the non-night shifts, and a similar trend was observed for the RMSSD results. However, these differences were relative small, which makes it logical why similar differences were not found for the self-ratings of stress.

It is of importance to take into account the diurnal variation in heart rate and in many HR-based parameters when interpreting our results. Due to this variation the mean heart rate level is usually lower during night shifts than day time shifts (Ito, Nozaki, Maruyama et al. 2001). As the SDNN and RMSSD parameters are closely related to the heart rate level, it is understandable that they also exhibit diurnal variation to some extent. This probably partly explains our observations of increased SDNN and RMSSD levels during the night shifts. However, the LF/HF ratio, which indicates a balance between sympathetic and parasympathetic nervous systems, did not indicate reduced alertness during the night trips. This finding is consistent with the study of Ito et al. (2001) in which the LF/HF ratio did not differ between day and night shifts in female nurses. However, there are also conflicting findings regarding the LF/HF ratio during day and night time work (Furlan, Barbic, Piazza et al. 2002).

Since the self-ratings of stress did not markedly vary between the shift types or within shifts, the weak association between driver stress and various individual-, sleep-, or work-related factors is explicable. The self-reported sources of stress indicated that approximately 4 out of 10 shifts included at least one stress-provoking factor. Only one of the self-reported stressors was clearly work-related (loading or unloading a truck), while the others were related to either prevailing weather conditions or personal issues. Somewhat surprisingly, tight schedules or long trips did not stand out. In all, these findings propose that long-haul truck drivers do not often exhibit signs of clearly elevated stress levels while driving.

As the frequency of self-ratings indicative of elevated stress was low there was not enough data to reliably study the relationship of elevated stress levels to driving style. Our descriptive findings, however, suggest that a more detailed analysis could reveal that an elevated stress level is associated with impaired driving style. This question remain to be seen in further analyses in which this relationship will be studied at a precision of one work hour instead of a precision of one work shift. The results of these analyses will probably shed some light on the question of whether elevated driver stress is associated with increased fuel consumption.

5.3 Driver training as a mean to reduce driver sleepiness

Overall, the observed benefits from the educational intervention were minor. One sign of an improvement in sleepiness post-intervention was observed for the day or evening shifts. In this shift type, the risk of elevated sleepiness (KSS>5) at the wheel was lower (OR 0.26) post-intervention in the intervention group compared to the control group. Another sign of an intervention-related improvement was an increase in time in bed (main sleep period) prior to the first night of a night shift spell. No other signs of improvements could be found.

Compared to previous studies our main finding of the ineffectiveness of an educational intervention in combating sleepiness at the wheel among professional drivers is somewhat surprising. For example, Gander et al. (2005) reported on an intervention consisting of a 2-hour live-presentation and a comprehensive material of the training materials that was tailored for light and heavy vehicle drivers. The presentation itself involved the following sections: the physiological basis of sleepiness, the impact of sleepiness on driving skills and crash risk, recommendations for personal countermeasure strategies, company policies with regard to workplace napping, referral to specialist treatment for suspected sleep disorders, and a discussion session. The training materials were tailored for the participating drivers and they included examples of regulatory environments and working conditions with a particular emphasis on local examples. The main findings of the study were that the knowledge of the subject matter improved among the participants and about half of them reported changes in the alertness management strategies they used at home and at work. These changes included improvements, for example, in sleep habits, diet, exercise, caffeine consumption, rescheduling shifts, taking nap breaks during a shift, and in the use of in-cabin countermeasures.

Another study that has found alertness management training effective was conducted on day time industrial workers with signs of excessive day time sleepiness (Melamed & Oksenberg 2002). The intervention comprised of an assessment of sleep disorders by means of two questionnaires and a 90-minute presentation and discussion on sleep disorders, sleepiness, sleep hygiene, effects of sleepiness on performance and quality of life, and possible treatments for excessive daytime sleepiness. The educational part of the intervention was conducted in small groups. The participants were also provided with a feedback on their assessment results and a confidential letter to a physician. The authors concluded that the intervention significantly reduced work-related injury risk among workers with symptoms of excessive day time sleepiness upon a one-year follow-up.

The conflict between the results of these two studies and the current study can be explained with several differences in the design, methodology, and the intervention itself. Of the three studies, the present study was the only one that was carried out as a randomized controlled trial. Moreover, the current study was the only one that actually measured sleepiness at work before and after an intervention and employed a diary to collect data on behaviours underlying alertness at work (e.g. sleep-wake behaviour, caffeine consumption). On the other hand, it is also important to discuss the interventions and try to assess whether some of the differences pertaining to them might explain the inconsistencies in the results.

In all, the content of the interventions implemented in the above studies seem to be quite similar. All of them consisted of a relative short presentation on the basics of sleep and sleepiness and coping strategies to alleviate sleepiness. Like Gander et al. (2005), the present study made an attempt to personalise the training by, for example, taking into account the working hours of the trainees when providing them with the personal estimations of their alertness during their typical shifts, and giving them recommendations of effective measures and strategies to counteract sleepiness at the wheel.

On the other hand, unlike the studies of Gander et al. (2005) and Melamed and Oksenberg (2002), our intervention did not include any feedback of the assessment of sleep and sleepiness or a referral to a medical doctor. The reason for this procedure was our aim to develop an educational intervention that could be carried out by trainers who are not sleep specialists, but for example psychologists or nurses with a specialisation in occupational health. The lack of these two components in our intervention may partially explain the observed differences in the results regarding the effectiveness of a short educational intervention in combating driver sleepiness. On the other hand, our data did not provide any evidence that, for example, the drivers with higher scores on the ESS would have been more at risk of elevated sleepiness at the wheel than the other drivers. This finding suggests that having provided the drivers with signs of elevated day time sleepiness with referrals to a medical doctor would probably not have made the intervention more effective. However, this question warrants further research.

The drivers' self-set goals to improve their alertness at the wheel are also worth discussing. Most drivers decided to try improvements in their general health behaviours relating to nutrition, physical exercise, weight control or sleep. These kinds of goals may be too general to actually change behaviours pertinent to alertness at wheel. On the other hand, the drivers considered their personal goals important to themselves and were quite strongly committed to achieving their goals. These two observations suggest that even self-set goals taken seriously by the person him/herself in the end of an educational intervention on alertness management do not necessarily lead to significant improvements in alertness at the wheel in the next couple of months. It is, however, possible that improvements in general health behaviour occur slowly and that, for example improved physical fitness or losing weight develops into improved alertness only in the long run.

An important question is also whether restricting the intervention to truck drivers played a role in the results. Gander et al. (2005) emphasised the importance of training not just drivers but also other key personnel of trucking companies to be able to develop and implement appropriate policies and procedures within the organisations. These policies and procedures may include issues such as shift scheduling and recommendations for things to do when feeling sleepy behind the wheel.

There are also other additional components to our alertness management intervention that could enhance its effectiveness. On the basis of a recent systematic review on dietary and physical activity interventions (Greaves, Sheppard, Abraham et al. 2011), these kinds of components could be mobilisation of social support, encouragement for self-monitoring, providing feedback on progress, and actively providing contact time following the initial training session. A recent RCT study conducted on white-collar workers at an information-technology service company suggests that the last-mentioned component is indeed important (Nishinoue, Takano, Kaku et al. 2012). The authors reported that the workers who received both a 40-minute sleep hygiene lecture (including a 10-minute discussion) and a 30-minute individual training on one of three behavioural techniques (relaxation, stimulus control, sleep restriction) showed clearly better improvements in sleep quality assessed by a standardised questionnaire than their colleagues who received the lecture only. This finding suggests that adding individual training to a group-based intervention could enhance its effectiveness.

Altogether, the findings of the present study suggest that driver alertness is difficult to be improved by a brief, yet well-designed training programme, and that the idea of recommending this type of intervention to be used in the drivers' in-service training should be taken with reserve. What seems to be quite evident is that a single informative presentation on the basics of sleep, sleepiness, and alertness management does not, as such, improve driver alertness. Adding components such as improving working conditions and/or safety culture within an organization are also needed to advance the situation on the ground. A question of interest is also whether this type of intervention would work better with young drivers who are just beginning their work career and have not yet developed rigid alertness management routines.

5.4 Study limitations

There are a few limitations that need to be acknowledged regarding the current study. One of them pertains to representativeness of the sample. When considering the generalizability of the findings, the degree to which the sample represented Finnish truck drivers is important. As the study was not designed to examine the *prevalence* of sleepiness or stress in this group of employees, the sampling method did not meet the standards set for that kind of study. However, compared to the samples of two other studies examining the prevalence of sleep and sleepiness among the Finnish truck drivers, the sample of the current study seems quite similar in terms of mean age (current study: 38.2 years vs. Häkkänen & Summala (2000): 42.3 years vs. Partinen & Hirvonen (2006): 40.3 years), experience in professional driving (current study: 15.3 years vs. Partinen & Hirvonen

(2006): 17.8 years), Body Mass Index (current study: 27.7 vs. Häkkänen & Summala (2000): 27.1 vs. Partinen & Hirvonen (2006): 27.7), and mean ESS score (current study: 6.9 vs. Partinen & Hirvonen (2006): 7.5). Therefore, the current findings are not likely to overestimate the prevalence of sleepiness and stress among the studied group of workers.

Another limitation of the study relates to the fact that the study was designed to contain only one intervention. The findings regarding the effectiveness of the educational intervention cannot be generalised and compared to interventions involving, for instance, individual coaching, educating managers along with drivers or amendments in working conditions (e.g., re-scheduling shifts, official recommendations for alertness management).

Third study limitation concerns the time elapsed between the intervention and post-intervention measurements. The time period was four to five months which may not be enough to see improvements resulting from changes in general health behaviours – the most common personal objectives the drivers set for themselves to improve their alertness at the wheel.

Most of the current findings on driver sleepiness and stress were based on self-ratings. However, there are many individual- and condition-related factors that may bias the results. For example, individuals may differ in their ability and motivation to assess their sleepiness at the wheel, and prolonged driving on a monotonous highway is known to make it more difficult to self-assess sleepiness (Schmidt, Schrauf, Simon et al. 2009).

Finally, the current findings regarding the use of alertness management strategies can also be criticised as they were solely based on drivers' self-reports, and the drives were not, for example, instructed to report their caffeine consumption at home. Therefore, it is possible that there were some changes in the use of alertness strategies but the methods and measurements used in the present study were not able to detect them.

5.5 Conclusions

All in all, the results of the current study showed that driver sleepiness is a rather common phenomenon among Finnish long-haul truck drivers and that driver sleepiness is particularly common in the beginning of night shift spells (the first night shift). A brief one-time group-based educational intervention on alertness management does not by itself seem to significantly improve driver alertness. The latter finding calls for other – or additional – measures to be implemented to mitigate the problem of sleepiness among professional drivers. These measures include particularly amendments to the work itself.

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APPENDIX A

Sleep/work diary for one measurement day (continues on the following page).

UNI- JA TYÖPÄIVÄKIRJA **PÄIVÄ 1 ___.___.20___**

Osio 1: HERÄÄMISEN JÄLKEEN

1. Mihin aikaan nousit ylös sängystä?	:
2. Mihin aikaan menit nukkumaan?	:
3. Kuinka kauan nukahtamisesi kesti?	
4. Kuinka monta kertaa heräsit kesken unien?	
5. Kuinka kauan olit kokonaisuudessaan hereillä unijakson aikana?	
6. Kuinka kauan kokonaisuudessaan nukuit?	
7. Jos otit alkoholia ennen nukkumaanmenoa, kuinka monta annosta joit? (ks. Alkoholinkulutus -taulukko)	
8. Jos käytit unilääkitystä ennen nukkumaanmenoa, kuinka paljon (mg) lääkettä otit? Unilääkkeen nimi: ____________________	

9. Millainen vireystasosi on nyt heräämisen jälkeen? (ympyröi numero)

0	1	2	3	4
Huono		Kohtalainen		Hyvä

10. Kuinka hyvin mielestäsi nukuit? (ympyröi numero)

0	1	2	3	4
Huonosti		Kohtalaisesti		Hyvin

Osio 2: TYÖVUORON JÄLKEEN (ks. Vastausvaihtoehdot *)

11. Mitä teit virallisten lepotaukojen aikana? (kohta 2.)	
12. Jos koit ajon aikana väsymystä, mitä teit? (kohta 3.)	
13. Jos koit ajon aikana väsymystä, mistä arvelet sen johtuneen? (kohta 4.)	
14. Jos koit ajon aikana stressiä, mistä arvelet sen johtuneen? (kohta 5.)	
15. Esiintyikö ajon aikana vaara- tai muita poikkeustilanteita? (ympyröi vastauksesi) Jos esiintyi, kuvaa tapahtunutta kohtaan 1.	Kyllä / Ei

* Vastausvaihtoehdot (Osio 2.):

2. Mitä teit virallisten lepotaukojen aikana? (Kysymys 11.)

1. Join kahvia / kola- tai energiajuomaa.
2. Otin nokoset.
3. Söin kevyen ateria / välipalan.
4. Söin runsaasti rasvaa / sokeria sisältäneen aterian / välipalan.
5. Tupakoin.
6. Kävin ulkona kävelemässä virkistyäkseni.
7. Keskustelin ihmisten kanssa.
8. Huolsin autoa.
9. Jotain muuta, mitä? ______________________________

3. Jos koit itsesi väsyneeksi ajon aikana, mitä teit? (Kysymys 12.)

0. En kokenut itseäni väsyneeksi ajon aikana.
1. Join kahvia.
2. Käytin nikotiinia (savukkeita, nuuskaa).
3. Söin makeisia.
4. Join virvokkeita.
5. Join energiajuomaa.
6. Otin kofeiinitabletteja.
7. Liikuttelin kehoani ajaessani.
8. Pysähdyin ja lepäsin (nukkumatta) hetken aikaa ajoneuvossa.
9. Pysähdyin ja nukuin hetken aikaa ajoneuvossa tai huoltoaseman tiloissa.
10. Pysähdyin ja kävin ulkona kävelyllä.
11. Pysähdyin, kapusin ulos ja tein vähän taukoliikuntaa.
12. Avasin ikkunan.
13. Käynnistin tuulettimen tai ilmastointilaitteen.
14. Muutin ohjaamon lämpötilaa.
15. Avasin radion / stereot.
16. Lisäsin radion / stereoiden äänen voimakkuutta.
17. Lauloin / viheltelin / juttelin.
18. Ajoin lujempaa.
19. Ajoin hiljempaa.
20. Ajoin aktiivisemmin.
21. Juttelin jonkun kanssa.
22. Jotain muuta, mitä? ______________________________

Osio 3: ENNEN NUKKUMAANMENOA

16. Jos sinulla oli tänään työpäivä, mihin aikaan työvuorosi alkoi?	:
17. Jos sinulla oli tänään työpäivä, mihin aikaan työvuorosi päättyi?	:

18. Millainen vireystasosi oli tänään? (ympyröi numero)
0 Huono — 1 — 2 Kohtalainen — 3 — 4 Hyvä

19. Kuinka paljon koit tänään stressiä / huolta? (ympyröi numero)
0 En lainkaan — 1 Vähän — 2 Kohtalaisesti — 3 — 4 Paljon

20. Kuinka kokonaisuudessaan voit tänään? (ympyröi numero)
0 Huonosti — 1 — 2 Kohtalaisesti — 3 — 4 Hyvin

1. **Jos sinulle sattui työajon aikana vaaratilanne / -tilanteita** ("läheltä piti" -tilanne tai onnettomuus) **tai muuta poikkeavaa** (esim. rengasrikko), **kuvaa tapahtunut vastaamalla seuraaviin kysymyksiin:**

   1. Mitä tapahtui?
   2. Mistä poikkeus- / vaaratilanne johtui?
   3. Mitä tilanteesta seurasi?
   4. Vaara- / poikkeustilanteen päivämäärä ja kellonaika?
   5. Muuta huomioitavaa?

   Tilanne 1 (lisää tarvittaessa *Tilanne 2* jne.)

   ____

4. **Jos koit itsesi väsyneeksi ajon aikana, mistä arvelet sen johtuneen?** (Kysymys 13.)

   0. En kokenut itseäni väsyneeksi ajon aikana.
   1. Epäsäännöllisestä / vähäisestä / huonolaatuisesta unesta.
   2. Pitkästä ajosta ilman taukoa.
   3. Tien luonteesta (esim. suora ja leveä tie).
   4. Liikenneolosuhteista (esim. vähän liikennettä).
   5. Ohjaamossa vallitsevista olosuhteista (esim. lämpötila).
   6. Näkyvyydestä (esim. pimeys).
   7. Tien kunnosta (esim. kuiva tie).
   8. Vuorokaudenajasta (esim. yö).

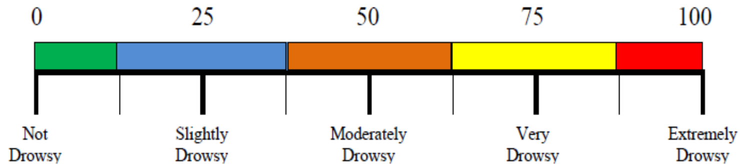
5. **Jos koit stressiä ajon aikana, mistä arvelet sen johtuneen?** (Kysymys 14.)

   0. En kokenut stressiä ajon aikana.
   1. Pitkästä ajoajasta.
   2. Tiukasta aikataulusta.
   3. Ongelmista lastaamisessa tai lastin purkamisessa.
   4. Ajoneuvon huonosta kunnosta.
   5. Ajoneuvoon tulleesta viasta.
   6. Huonosta ajokelistä.
   7. Liikenneruuhkista.
   8. Muiden kuljettajien käyttäytymisestä.
   9. Tien huonosta kunnosta.
   10. Liikenteen poikkeusjärjestelyistä.
   11. Heikentyneestä toimintakyvystä (esim. väsymyksestä, sairaudesta).
   12. Henkilökohtaiseen elämään liittyvistä tekijöistä.
   13. Jostain muusta, mistä? ______________________

Alkoholinkulutus	**Annosta**
1 pullo (0,33 l) keskiolutta tai siideriä	1
1 lasi (12 cl) viiniä	1
1 pullo (0,33 l) IV-olutta	1,3
1 annos viinaa (4 cl)	1
1 tuoppi (0,5 l) IV-olutta	2
1 pullo (0,75 l) mietoa viiniä	6
1 pullo (0,75 l) väkevää viiniä	10–11
1 pullo (0,5 l) viinaa	13

APPENDIX B

The ORD rating scale and its descriptions adapted from Wierwille and Ellsworth (1994) (Wiegand et al. 2009, 24).



Five Levels of Drowsiness

- **Not Drowsy (0 - 12.49):** A driver who is not drowsy while driving will exhibit behaviors such that the appearance of alertness will be present. For example, normal facial tone, normal fast eye blinks, and short ordinary glances may be observed. Occasional body movements and gestures may occur.

- **Slightly Drowsy (12.5 – 37.49):** A driver who is slightly drowsy while driving may not look as sharp or alert as a driver who is not drowsy. Glances may be a little longer and eye blinks may not be as fast. Nevertheless, the driver is still sufficiently alert to be able to drive.

- **Moderately Drowsy (37.5 – 62.49):** As a driver becomes moderately drowsy, various behaviors may be exhibited. These behaviors, called mannerisms, may include rubbing the face or eyes, scratching, facial contortions, and moving restlessly in the seat, among others. These actions can be thought of as countermeasures to drowsiness. They occur during the intermediate stages of drowsiness. Not all individuals exhibit mannerisms during intermediate stages. Some individuals appear more subdued, they may have slower closures, their facial tone may decrease, they may have a glassy-eyed appearance, and they may stare at a fixed position.

- **Very Drowsy (62.5 – 87.49):** As a driver becomes very drowsy, eyelid closures of 2 to 3 seconds or longer usually occur. This is often accompanied by a rolling upward or sideways movement of the eyes themselves. The individual may also appear not to be focusing the eyes properly, or may exhibit a cross-eyed (lack of proper vergence) look. Facial tone will probably have decreased. Very drowsy drivers may also exhibit a lack of apparent activity, and there may be large isolated (or punctuating) movements, such as providing a large correction to steering or reorienting the head from a leaning or tilted position.

- **Extremely Drowsy (87.5 – 100):** Drivers who are extremely drowsy are falling asleep and usually exhibit prolonged eyelid closures (4 seconds or more) and similar prolonged periods of lack of activity. There may be large punctuated movements as they transition in and out of intervals of dozing.

Sleepiness and stress at the wheel are known to be common among professional drivers. Given the safety-sensitive nature of the job, it would be essential for neither of these conditions to reach levels compromising safe driving. The current field study examined the levels of sleepiness and stress at the wheel in a group of Finnish long-haul truck drivers, and the potential factors contributing to the sub-optimal levels of arousal. Over and above, the study examined whether driver alertness could be amended by short one-time alertness management training. The results revealed that driver sleepiness reaches potentially risky levels, especially during the first night shift in the beginning of a shift spell. No clear evidence was found to support the idea that educating professional drivers on alertness management would be sufficient for mitigating their sleepiness on the road.

FINNISH INSTITUTE OF OCCUPATIONAL HEALTH

Topeliuksenkatu 41 a A, 00250 Helsinki
www.ttl.fi

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UNIVERSITY OF HELSINKI

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