DRIVER FATIGUE

My research and current developments

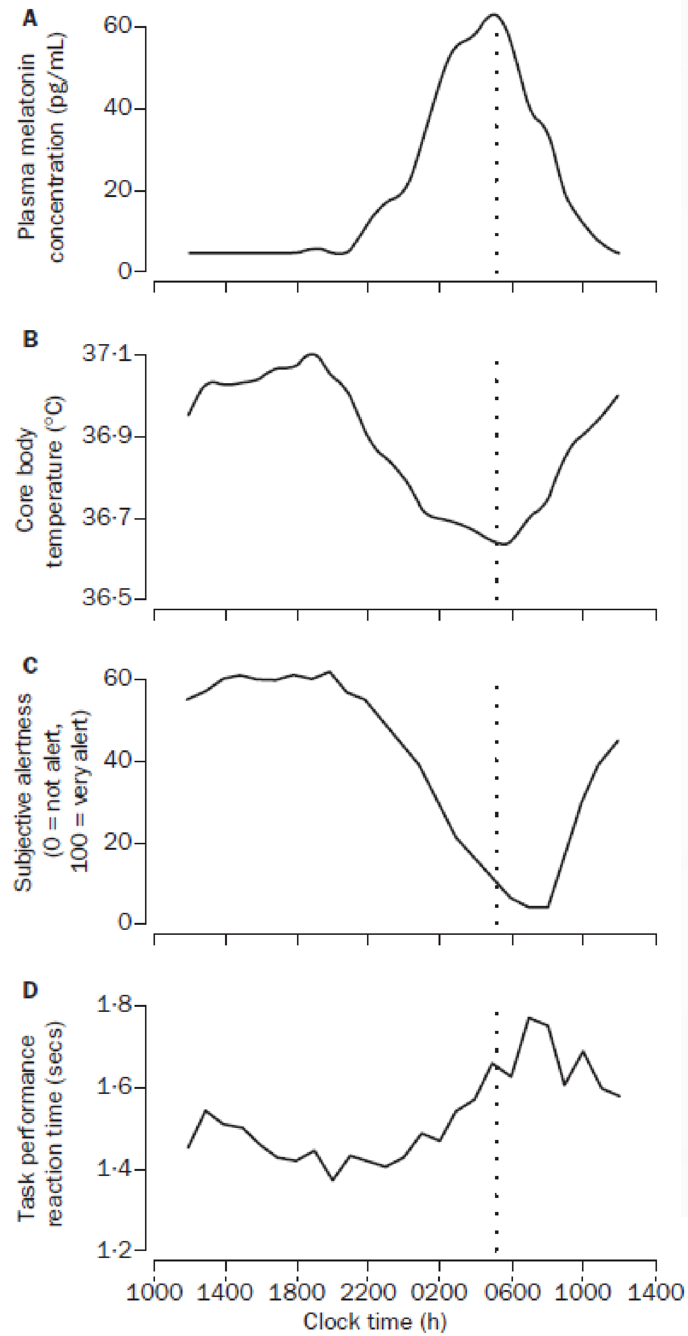
Twitter: @Liikennepsykol1

About me

- MA in psychology (Croatia, 2001)
- PhD in traffic psychology (Finland, 2009)
- Thesis about driver fatigue
- Postdoc abroad: Chalmers University of Technology, Göteborg, Sweden (2011-2013)
- Postdoc abroad: Stress Research Institute, Stockholm University, Sweden (2013-2015)
- Docent in traffic psychology 2015

We live in 24-hour society

- Increased globalization and competition-> the need for efficient and economical work times -> shift and night work, irregular and prolonged working hours
- Traditional 24-hour industries (petrochemical, power), transportation and health services, many organizations offer their services 24/7
- A natural tendency to be awake during daylight and to sleep during night -> the 24-h society challenges our biological adaptation to the 24-h cycle of light & darkness
- Increased stress, poor sleep hygiene, and partial and chronic sleep deprivation all are direct consequences of today's 24-hour society
- The concept of sleep has also dramatically changed in modern times: time asleep -> viewed as wasted time; many hours of sleeping - > associated with laziness"



Melatonin

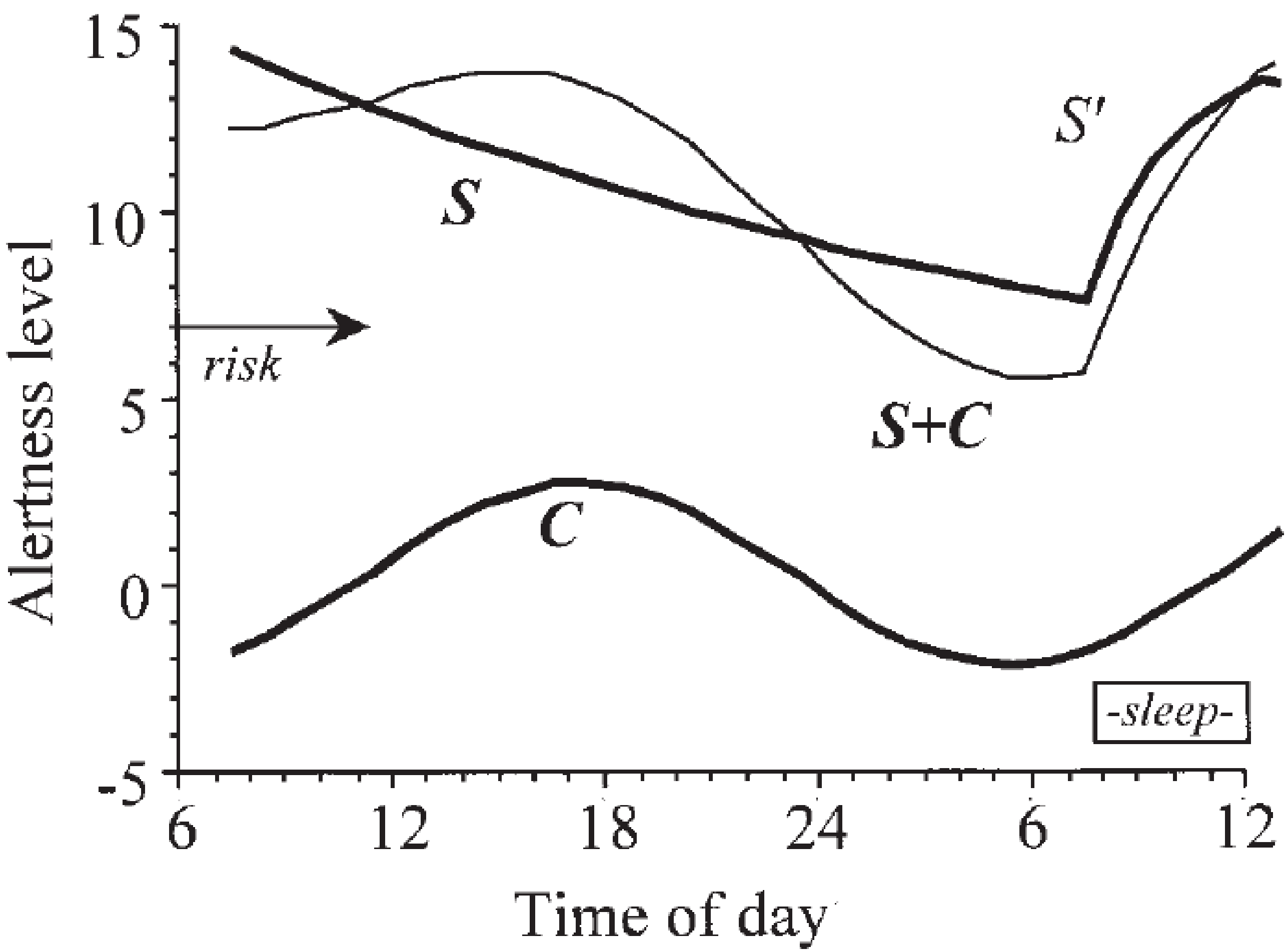
Body temperature

Subjective alertness

Task performance

Rajaratnam & Arendt
Health in a 24-h society
Lancet 2001; 358: 999–1005

Sleep



Folkard et al., 1999. Journal of Biological Rhythms

C = circadian component

S = homeostatic component during waking

S’= homeostatic component during sleep

Sleepiness vs. fatigue

- **Sleepiness** is the pressure to fall asleep or the probability of falling asleep at a particular time due to circadian and exogenous influences
- “Fatigue is one of those concepts which appear quite clear and unambiguous in everyday life but become notoriously elusive when one tries to pin them down in scientific discourse” (McDonald (1989, p. 185)
- **Fatigue** is “a diffuse sensation which is accompanied by feelings of indolence and disinclination for any kind of activity.”

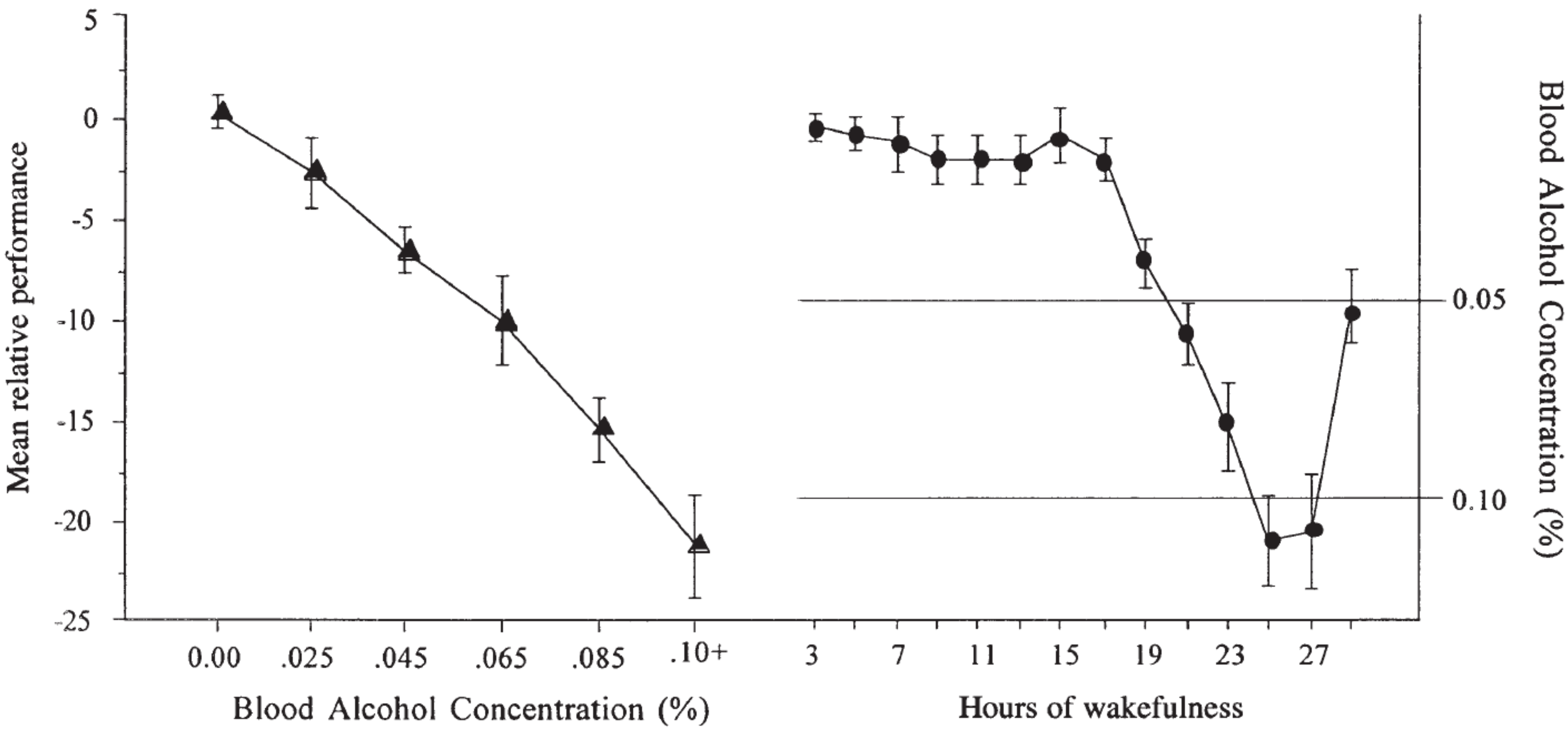
Driver fatigue: It's difficult…

- the blurred concept of fatigue
- the inexistence of a validated and reliable device for detecting the level of sleepiness (cf. the breath analyzer for alcohol levels)
- the lack of clear and objective criteria for recognizing the contribution of fatigue/sleepiness to crash causation
- given that "voluntary conduct is central to criminal responsibility," there are obvious difficulties in prosecuting drivers who cause a crash while asleep

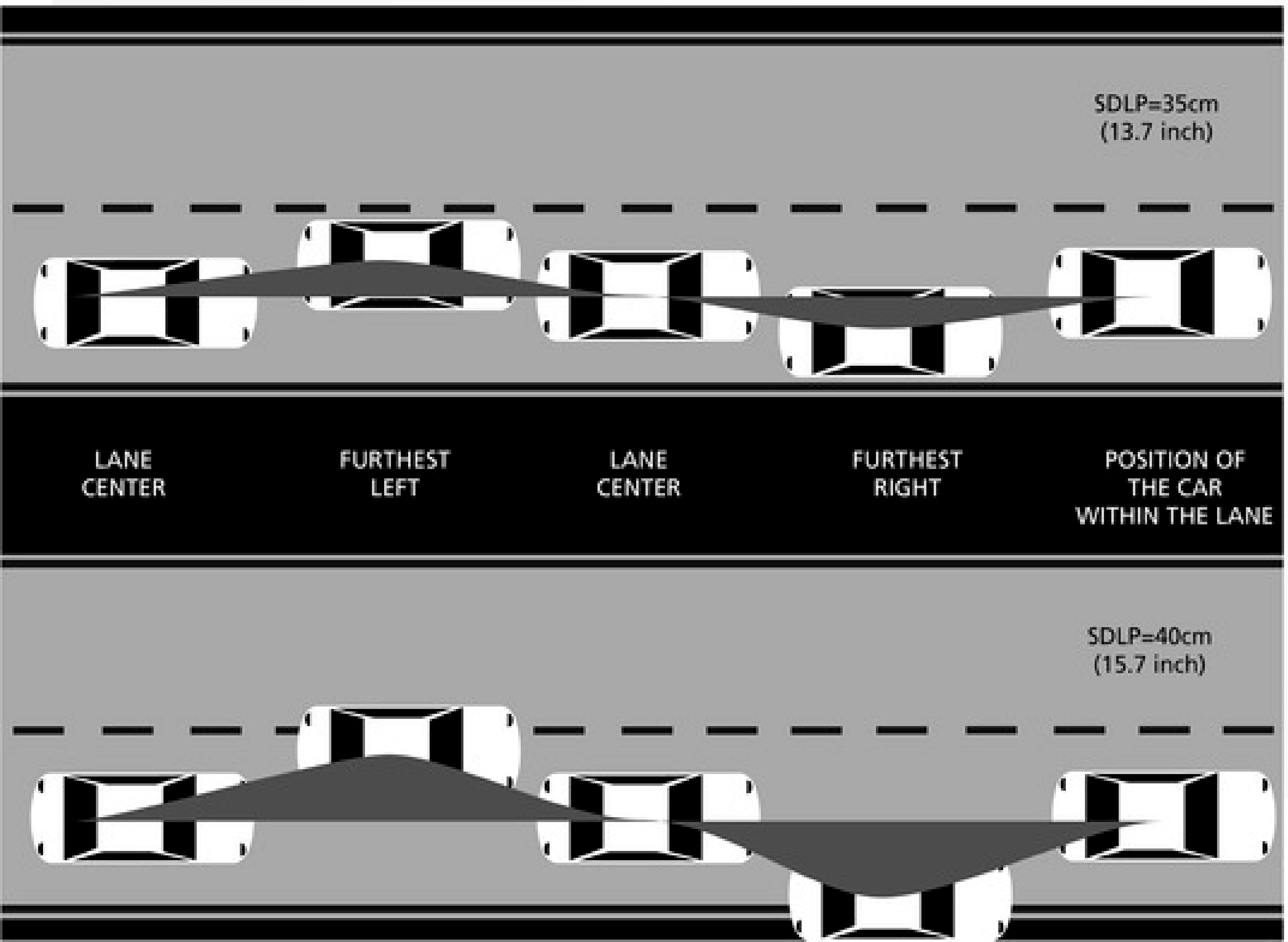
Driving context: Sleepiness vs. alcohol

Lamond & Dawson   Quantifying the performance impairment associated with fatigue J. Sleep Res. (1999) 8, 255–262

Mean relative performance levels for the response latency component of the vigilance task in the alcohol intoxication and sustained wakefulness condition



Standard deviation of lateral position (SDLP)



A.J. Monique et al.

Positive effects of Red Bull® Energy Drink on driving performance during prolonged driving

Psychopharmacology 214 (2011) 737-745

Measures of sleepiness

- Subjective sleepiness
- Physiological measures
- Sleep propensity measures
- Performance decrease measures

Subjective measures of sleepiness

- **Sleepiness as state condition (current)**
  - Karolinska sleepiness scale
  - Stanford sleepiness scale
  - Visual analog scale
- **Sleepiness as a trait**
  - Epworth sleepiness scale

Karolinska sleepiness scale (Åkerstedt and Gillberg, 1990)

How did you feel during the last five minutes?	
1	extremely alert
2	very alert
3	alert
4	rather alert
5	neither alert nor sleepy
6	some signs of sleepiness
7	sleepy, no effort to stay awake
8	sleepy, some effort to stay awake
9	very sleepy, great effort to stay awake, fighting sleep

Stanford sleepiness scale (Hoddes, Dement, & Zarcone, 1971)

Degree of Sleepiness	Scale rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not fully alert	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	x

Visual analog scales

Epworth sleepiness scale (Jones, 1991)

How likely are you to doze off or fall asleep in the following situations?
Sitting and reading
Watching TV
Sitting inactive in a public place (e.g., a theater or a meeting)
As a passenger in a car for an hour without a break
Lying down to rest in the afternoon when circumstances permit
Sitting and talking to someone
Sitting quietly after a lunch without alcohol
In a car, while stopped for a few minutes in traffic

No chance of dozing =0

Slight chance of dozing =1

Moderate chance of dozing =2

High chance of dozing =3

Total score 0-24
As usually defined, the cut-off score of 10 indicates excessive daytime sleepiness.

Objective (physiological) measures of sleepiness

- EEG (Electroencephalography) parameters
  - “the presence of alpha 8-12 Hz and theta 4-8 Hz. rhythms in the EEG of awake and active subjects can provide information on the psychophysiological state of sleepiness or lowered vigilance” (Curcio et al., 2001)

- EOG (Electrooculography) parameters
  - Blink frequency and duration

Sleep propensity measures

- **Multiple Sleep Latency Test** - MSLT (Carskadon & Dement, 1979)
    - Lights off, in bed, instruction to fall asleep, every two hours, 20min
- **Repeated Test of Sustained Wakefulness** - RTSW (Hartse et al., 1982)
    - Lights off, in bed, instruction not to fall asleep
- **Maintenance of Wakefulness Test** (Mitler et al., 1982
    - Dark room, seated in a chair, instruction not to fall asleep

Multiple Sleep Latency Test (MSLT)

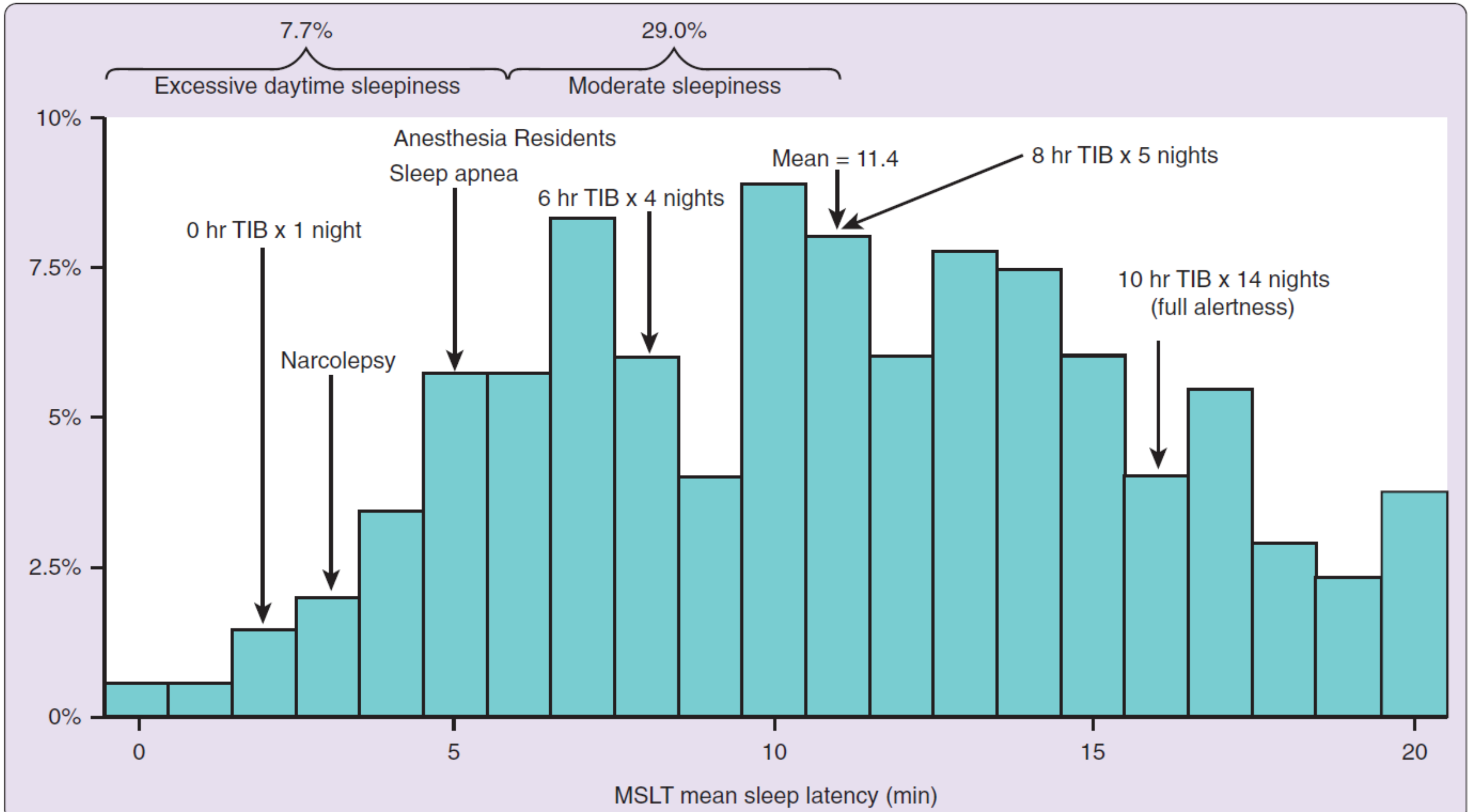


Figure 4-1 The distribution of mean daily sleep latency (min) on the multiple sleep latency test in a subsample (*n* = 259) recruited (68% response rate) from a large Southeastern Michigan random sample (*N* = 1648) representative of the U.S. population. The population mean is 11.4 minutes and this is compared to means reported for various patient groups[60,70,71] and the means found in healthy normals after various bedtime manipulations.[23,62] TIB, time in bed.

Roehrs et al., 2011
In Principles and practice of sleep medicine / [edited by] Meir H. Kryger, Thomas Roth, William C. Dement

Performance decrease measures

- Psychomotor tasks
- Cognitive tasks
- Driving task (e.g., standard deviation of lateral position)

Psychomotor vigilance task (PVT)

AMI PVT-192 Psychomotor Vigilance Task Monitor http://www.artisantg.com/ViewImage.aspx?Image=AMI_PVT192_View1.jpg&Item=69923

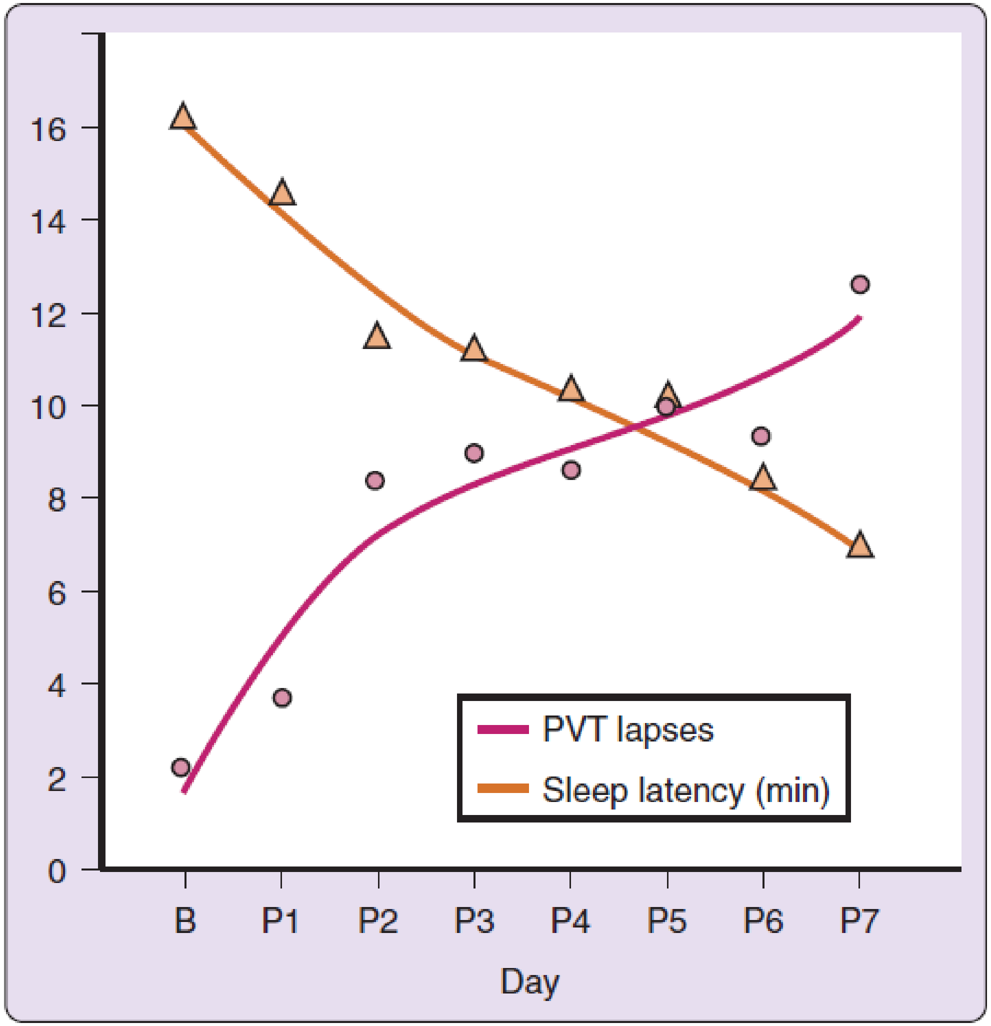


Figure 4-2 Similar functions relating mean daily sleep latency on the multiple sleep latency test (MSLT) and mean daily lapses on the visual psychomotor vigilance test (PVT) to the cumulative effects of sleep restriction (about 5 hours of bedtime nightly) across 7 consecutive nights (P1 to P7). (Redrawn from Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep 1997;20:275.)

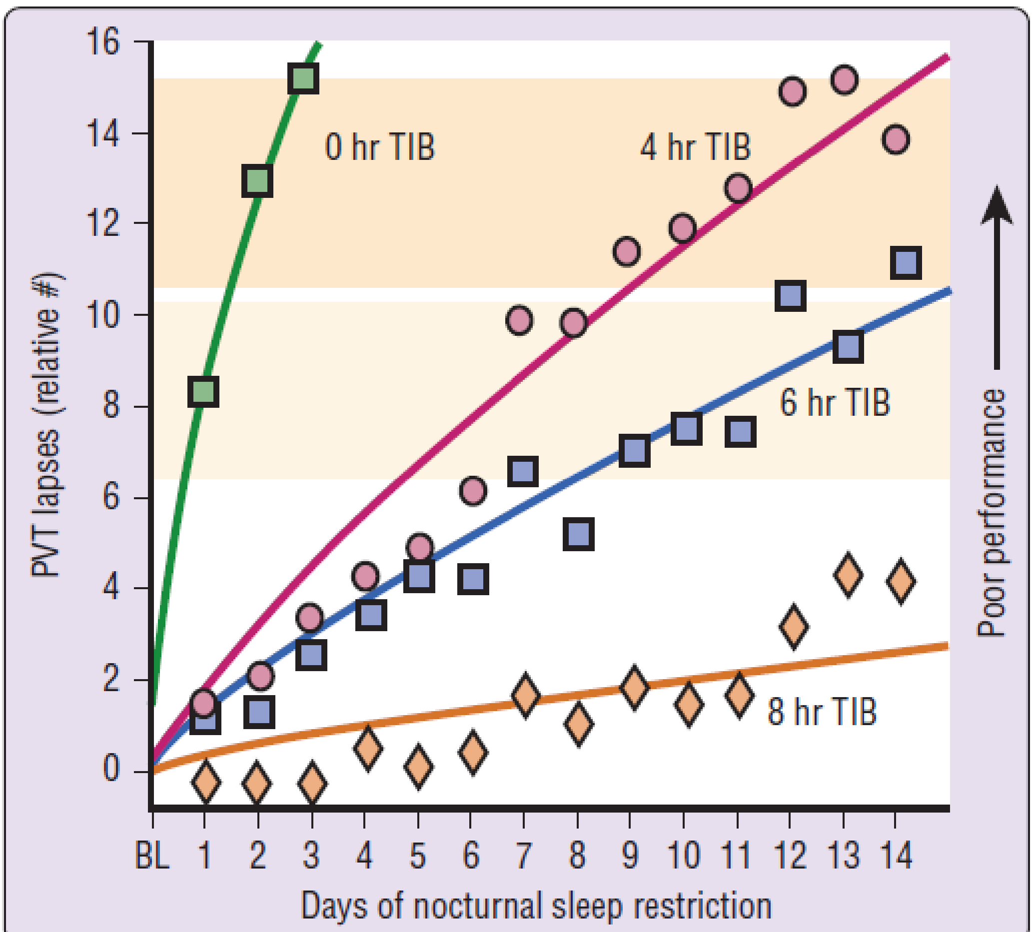
Roehrs et al., 2011

In Principles and practice of sleep medicine / [edited by] Meir H. Kryger, Thomas Roth, William C. Dement

Microsleeps

- Lasting from several to 15 seconds
- Can lead to dangerous outcomes in situations where a person’s reactions are needed practically on a second-to-second basis (e.g., while driving)

Psychomotor vigilance task (PVT)

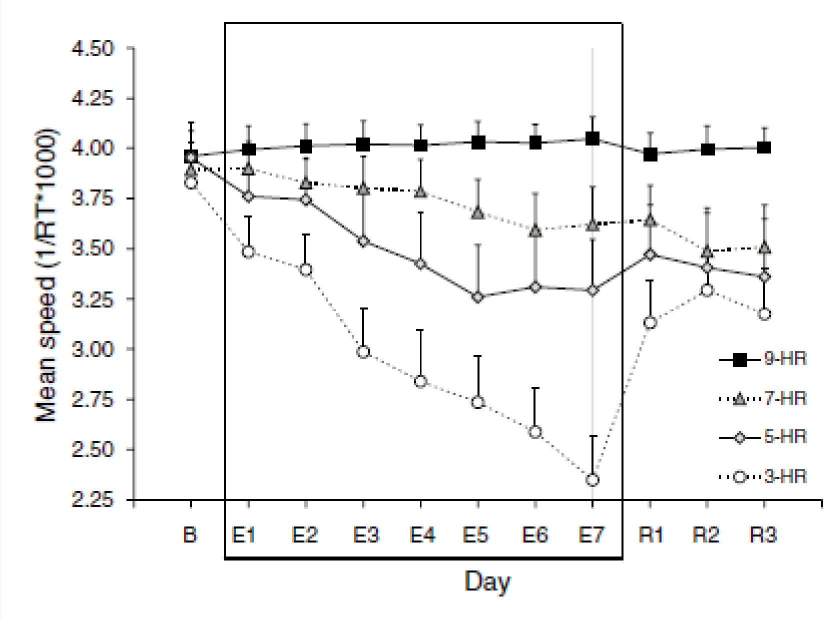


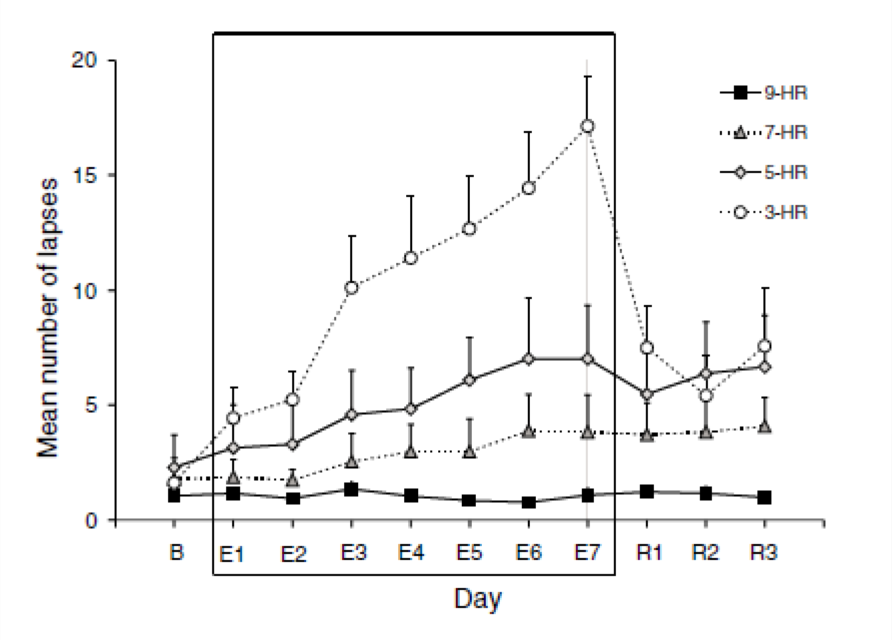
Van Dongen HP, Maislin G, Mullington JM, et al.

The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation.

Sleep 2003;26:117-126

Sleep deprivation and performance





G. Belenky et al.
Patterns of performance degradation and restoration during sleep restriction and subsequent recovery a sleep dose-response study
Journal of Sleep Research 12 (2003), 1–12

Reaction time and sleepiness

Table 2
Means and standard deviations (sd) of the neurocognitive tasks and the sleepiness scale in the normal sleep and sleep deprivation sessions.

Variable	*N*	Normal sleep mean (sd)	Sleep deprivation mean (sd)	*df*	*F*	*p*-Value
PVT lapses	18	1.9 (2.6)	5.06 (6.4)	1, 17	6.1	0.02
PVT median RT	18	231.2 (21.6)	256.2 (42.4)	1, 17	11.5	<0.005
Fastest 10% RT	18	189.9 (15.4)	200.3 (24.3)	1, 17	8.8	0.01
1/RT	18	2.7 (0.5)	2.3 (0.8)	1, 17	7.9	0.01
Mean simple RT	18	242.1 (22.9)	258.2 (30.1)	1, 17	11.7	0.003
Mean choice RT	18	424.9 (37.6)	459.9 (55.1)	1, 17	9.7	0.006
Digit Vigilance RT	18	410.6 (30.7)	428.7 (43.4)	1, 17	3.4	0.08
Digit Vigilance FA	18	2.0 (1.8)	1.8 (1.5)	1, 17	0.2	NS
Congruent Stroop (s)	16	32.0 (5.8)	33.4 (5.0)	1, 16	0.01	NS
Incongruent Stroop (s)	17	71.7 (15.8)	72.7 (13.9)	1, 16	0.01	NS
DSST	19	73.9 (16.7)	70.2 (15.8)	1, 17	1.9	0.19
KSS	16	3.0 (2.0)	7.5 (1.7)	1, 15	70.4	<0.001

PVT, psychomotor vigilance test; RT, reaction time; FA, false alarms; DSST, digit symbol substitution test.

Jackson et al., 2013
Cognitive components of simulated driving performance: Sleep loss effects and predictors

Sleep deprivation and decision making

- Sleep deprivation “still impairs decision making involving the unexpected, innovation, revising plans, competing distraction, and effective communication.”
- “SD presents particular difficulties for sleep-deprived decision makers who require these latter skills during emergency situations.” (Harrison & Horne, 2001)

Sleep deprivation and decision making

- the nuclear plant catastrophe at **Chernobyl** in 1986
- Incident at the **Three Mile Island** nuclear plant, US, 1979
- the chemical plant disaster in **Bhopal** in 1984, considered the worst industrial disaster to date
- the grounding of the oil tanker **Exxon Valdez** in Alaska in 1989, which was the largest oil spill in US history
- the **Space Shuttle Challenger** Accident, 1986

Useful visual field – tunnel vision

J. Rogé et al. / Vision Research 43 (2003) 1465–1472

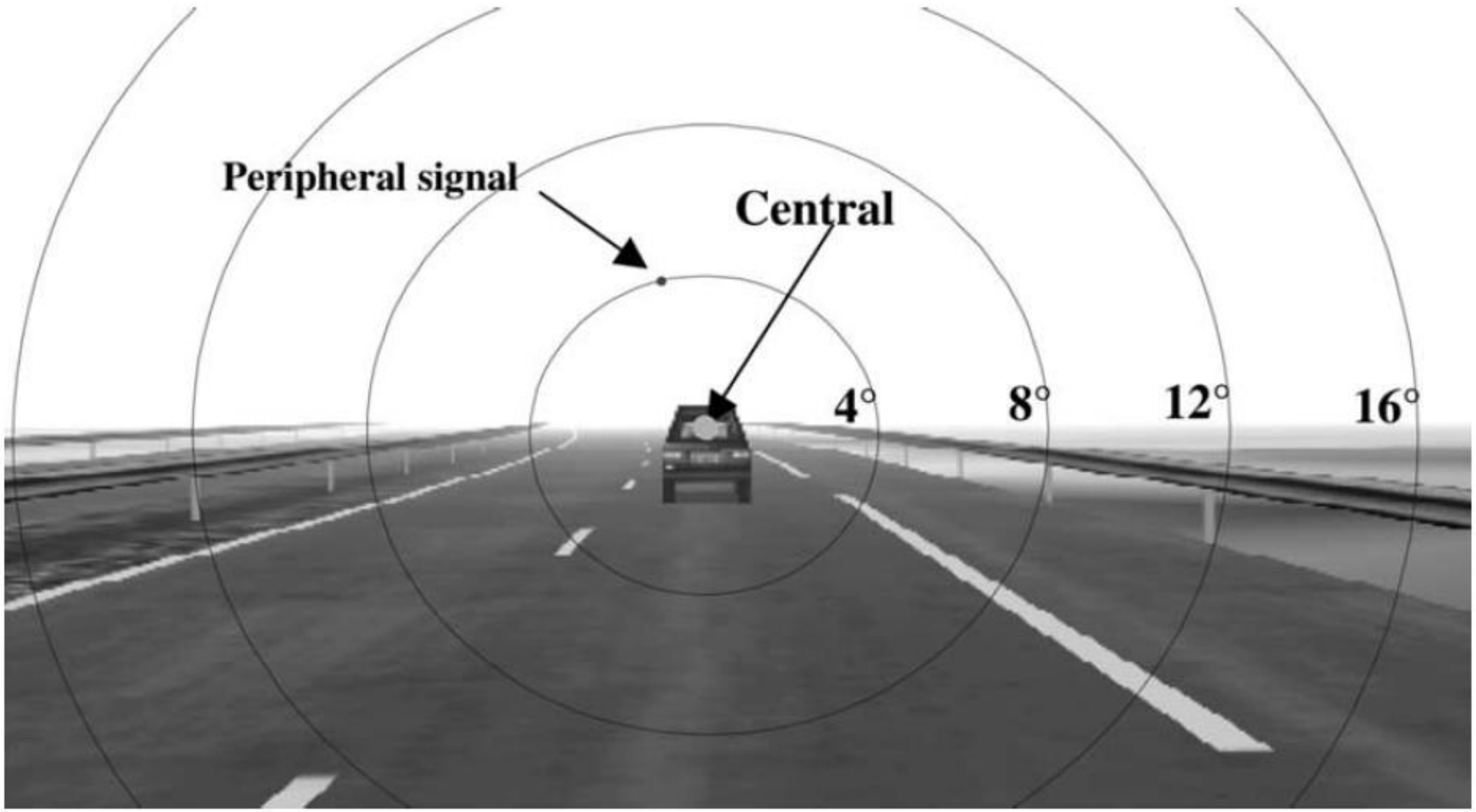


Fig. 1. The road scene presented to the subject.

Tunnel vision

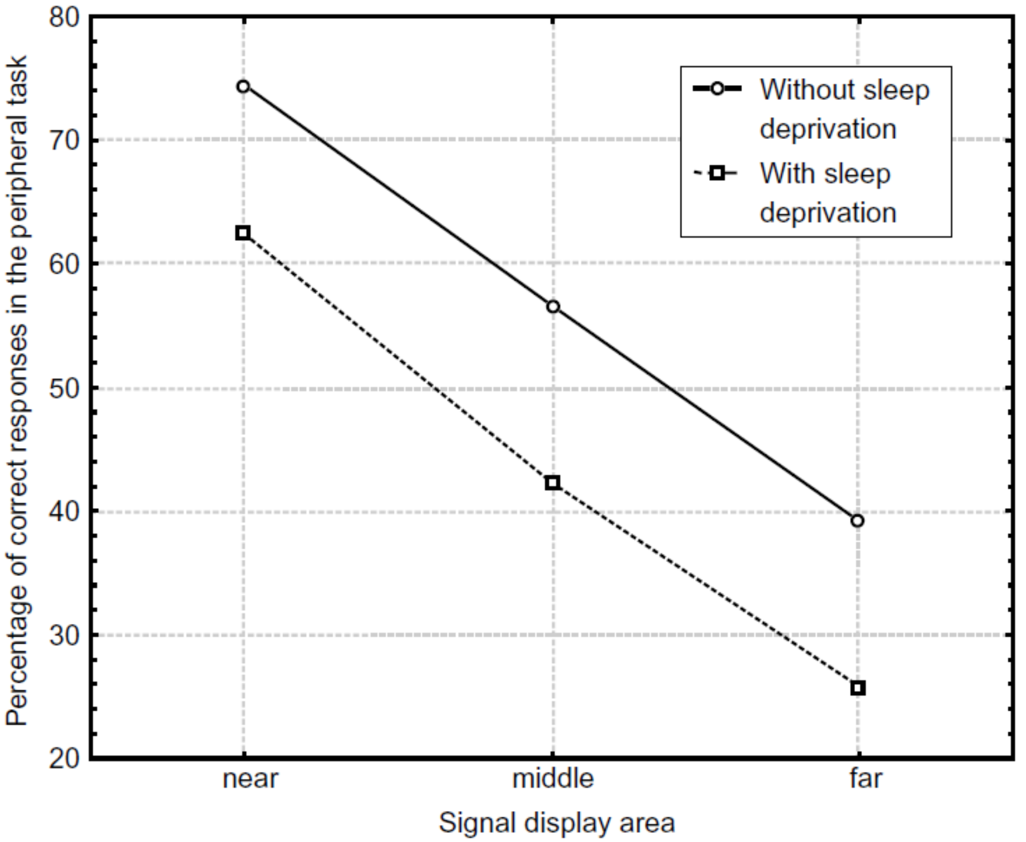
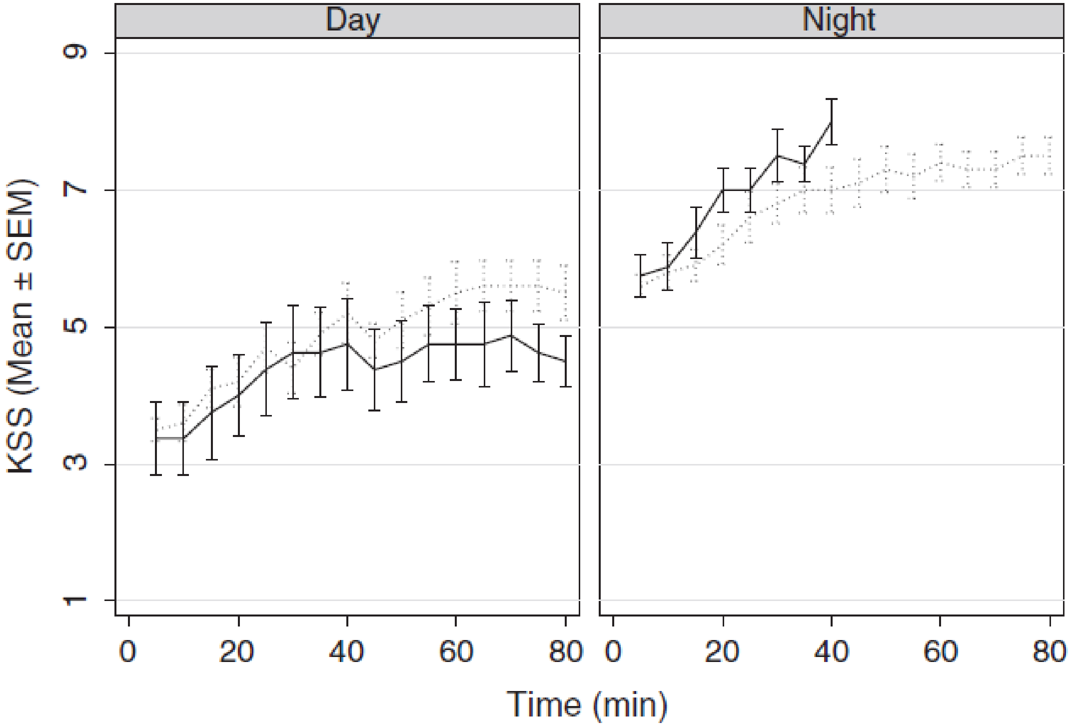


Fig. 5. Percentage of correct responses in the peripheral task as a function of sleep deprivation (without sleep deprivation versus sleep deprivation) and of signal display area (near versus middle versus far).

Roge et al.

Effect of sleep deprivation and driving duration on the useful visual field in younger and older subjects during simulator driving

Vision Research 2003 ; 43:1465–1472

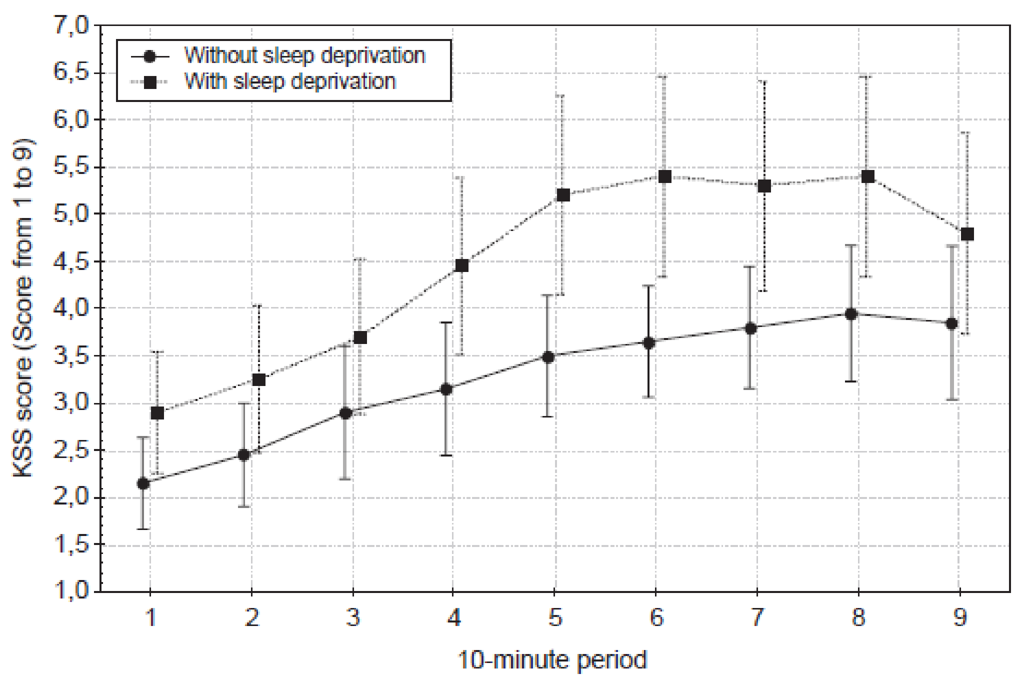


Time on task

- Time on task increases fatigue
- Interaction between sleepiness and time-on-task?

ani et al. / Physiology & Behavior 84 (2005) 715–724

Åkerstedt et al.
Having to stop driving at night because of dangerous sleepiness – awareness, physiology and behaviour J Sleep Res. (2013) 22, 380–388



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

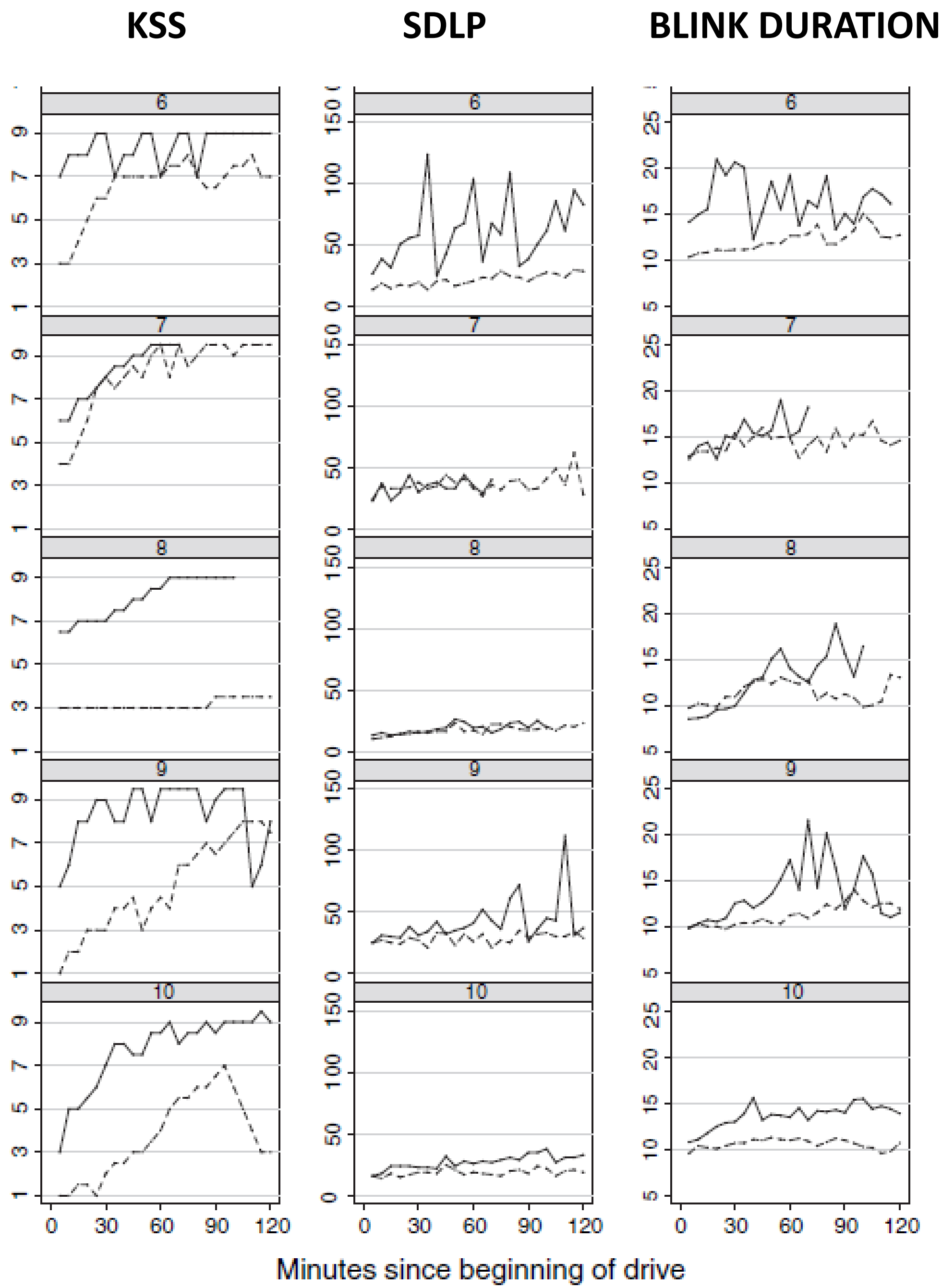
Table 3.1 The range of effects of sleep deprivation

COGNITIVE PROCESSES:	BEHAVIORS:
Difficulty concentrating	Less spontaneous
Invasive daydreaming while engaged in cognitive work	Over responsiveness
errors of omission > errors of commission	Microsleeps
Disorientation	Decrease in vigilance
Perceptual distortions and hallucinations	Decreased sense of humor
Greater indecisiveness	Less able to deal effectively with unfamiliar situations
Slowing of mental processes such as reaction time	Involuntary sleep attacks
Decrease in short-term memory	Less desire to socialize
Decrease in creativity and mental flexibility	Decreased psychomotor performance
Decline in logical reasoning ability for complex problems	Clumsiness
Decreased attention	Slurring of speech
Decreased information processing	Harder to "find the right word"
Interference with executive functions[a]	Increased motor vehicle accidents
Decrease in integrative ability	
Lapses of consciousness	PHYSIOLOGICAL:
Confusion	Heart palpitations
Negative impact on mood	Fall in body temperature (about 0.8 °F)
Difficulty multitasking	Slow eyelid closures
	Droopy eyelids
SUBJECTIVE:	Itchy eye
Lethargy	Tremor
Sense of partial loss of control	Weight gain
Disorientation	Greater gag and deep tendon reflexes
Irritability and negative moods	Increased SNS activity
Even paranoia in some individuals	Hormonal changes
	Increased caloric intake
	Weight gain
	Decreased resistance to infection
	Increased ghrelin
	Decreased leptin
	Increased insulin resistance (decreased glucose tolerance)
	Increased hunger

[a] A complex behavior involving decision making, working memory, ability to appropriately stick to task, reasonable risk taking, and so forth

EFFECTS OF SLEEP DEPRIVATION

W. H. Moorcroft, Understanding Sleep and Dreaming, 2013



Intra and inter individual differences

2-h drive (08:00–10:00 hours) after a normal night sleep and after working a night shift.

Ingre et al.

Subjective sleepiness, simulated driving performance and blink duration: examining individual differences

J. Sleep Res. (2006) 15, 47–53

SLEEPINESS

SLEEP

Physiological sleepiness
- EEG Electroencephalography
- EOG Electrooculography

Subjective sleepiness
- Current (KSS, SSS)
- Trait (ESS)

FATIGUE

- Blur concept
- Difficult to measure
- Motivation component

Sleep propensity measures
- Multiple Sleep Latency Test
- Repeated Test of Sustained Wakefulness
- Maintenance of Wakefulness Test

INTRA & INTER INDIVIDUAL DIFF.

PERFORMANCE

- Psychomotor tasks
- Cognitive tasks
- Driving task (SDLP)

- Lapses
- Reaction times
- Attention
- Time-on-task
- Time of day

24-H SOCIETY

- poor sleep hygiene
- partial and chronic sleep deprivation
- sleep disorders

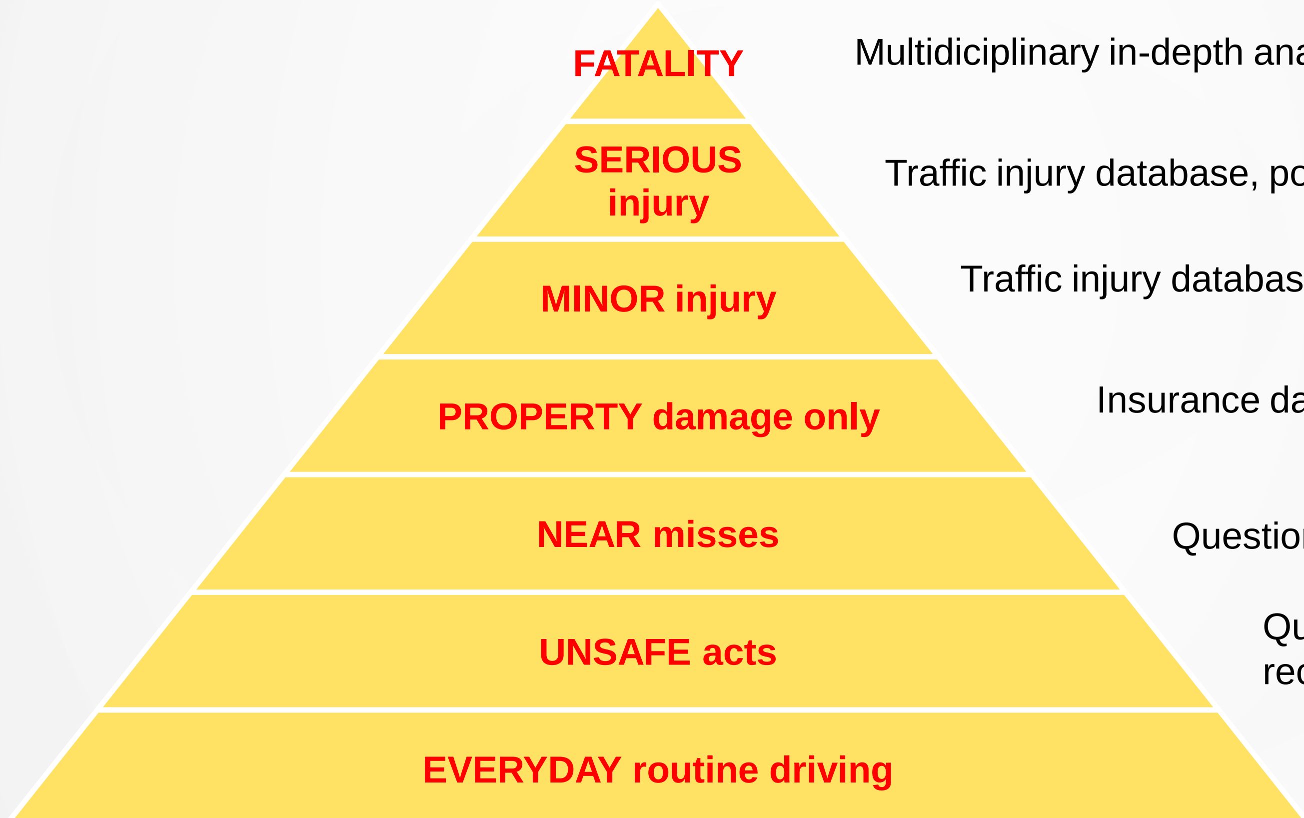
RESEARCH

- Laboratory experiments
- Population studies
- On-road experiments
- Naturalistic driving
- Crash data

DRIVING

DRIVER FATIGUE

CRASH STATISTICS



Multidiciplinary in-depth analysis

Traffic injury database, police reports

Traffic injury database, police reports

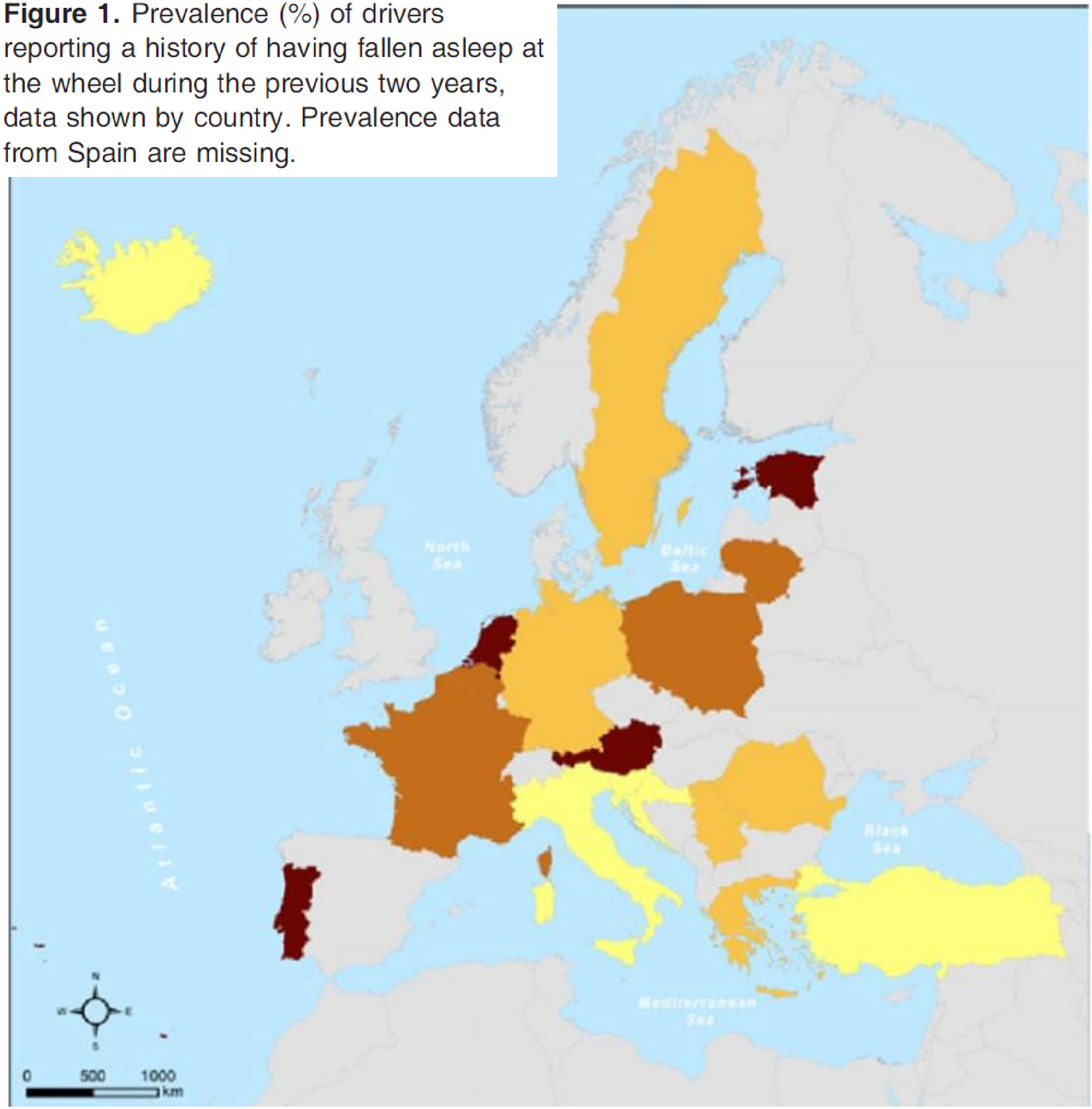
Insurance databases

Questionnaires, naturalistic studies

Questionnaires, driver records, naturalistic studies

Questionnaires

Figure 1. Prevalence (%) of drivers reporting a history of having fallen asleep at the wheel during the previous two years, data shown by country. Prevalence data from Spain are missing.



Legend:

Prevalence (%) of falling asleep at the wheel (previous 2 years)

- 6.1 – 12.4
- 12.5 – 17.4
- 17.5 – 21.9
- 22.0 – 34.7

Goncalves et al.

Sleepiness at the wheel across Europe: a survey of 19 countries

J Sleep Res. (2015)

Table 2 Number and proportion (%) of respondents who fell asleep at the wheel in the previous 2 years, and who had an accident due to falling asleep in that period, by country

	Falling asleep at the wheel					*Accident due to sleepy driving*				
	No		*Yes*			*No*		*Yes*		
Country	n	%	n	%	P	n	%	n	%	P
Austria	225	65.8	117	34.2 (29.2, 39.5)	<0.001	333	97.4	9	2.6 (1.2, 4.9)	<0.001
Belgium	745	78.1	209	21.9 (19.3, 24.7)		944	99.0	10	1.0 (0.5, 1.9)	
Croatia	217	93.9	14	6.1 (3.4, 10.0)		230	99.6	1	0.4 (0.0, 2.4)	
Estonia	188	73.7	67	26.3 (21.0, 32.1)		248	97.3	7	2.7 (1.1, 5.6)	
France	1866	80.7	447	19.3 (17.7, 21.0)		2292	99.1	21	0.9 (0.6, 1.4)	
Germany	629	82.9	130	17.1 (14.5, 20.0)		750	98.8	9	1.2 (0.5, 2.2)	
Greece	204	82.6	43	17.4 (12.9, 22.7)		244	98.8	3	1.2 (0.3, 3.5)	
Iceland	514	87.6	73	12.4 (9.9, 15.4)		586	98.8	1	0.2 (0.0, 0.9)	
Italy	1006	88.2	135	11.8 (10.0, 13.8)		1126	98.7	15	1.3 (0.7, 2.2)	
Lithuania	192	81.7	43	18.3 (13.6, 23.8)		231	99.1	2	0.9 (0.1, 3.1)	
Netherlands	32	65.3	17	34.7 (21.7, 49.6)		49	100.0	0	0.0 (0.0, 7.3)	
Poland	1589	79.3	415	20.7 (19.0, 22.5)		1964	98.0	40	2.0 (1.4, 2.7)	
Portugal	849	77.7	244	22.3 (19.9, 24.9)		1074	98.3	19	1.7 (1.0, 2.7)	
Romania	559	82.8	116	17.2 (14.4, 20.2)		666	98.7	9	1.3 (0.6, 2.5)	
Serbia	139	83.2	28	16.8 (11.4, 23.3)		165	98.8	2	1.2 (0.1, 4.3)	
Slovenia	282	89.8	32	10.2 (7.1, 14.1)		311	99.0	3	1.0 (0.2, 2.8)	
Spain	–	–	–	–		503	97.5	13	2.5 (1.3, 4.3)	
Sweden	407	87.3	59	12.7 (9.8, 16.0)		463	99.4	3	0.6 (0.1, 1.9)	
Turkey	76	88.4	10	11.6 (5.7, 20.3)		86	100.0	0	0.0 (0.0, 4.2)	

–, No data available for this item.

Goncalves et al.

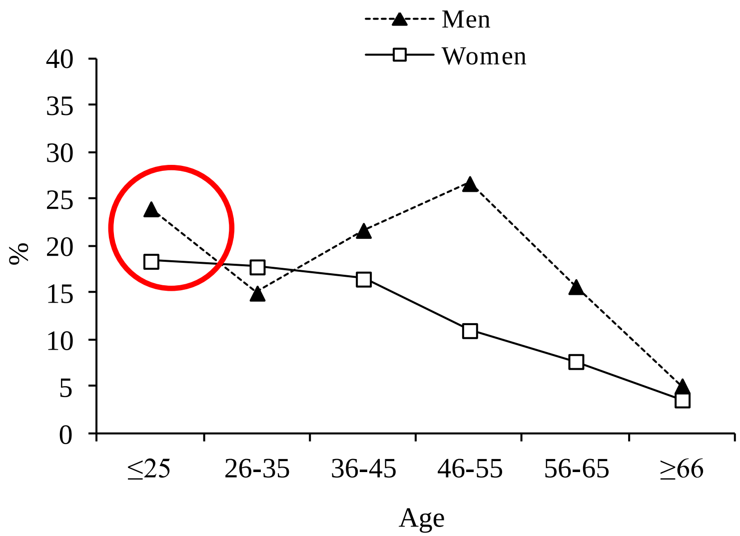
Sleepiness at the wheel across Europe: a survey of 19 countries

J Sleep Res. (2015)

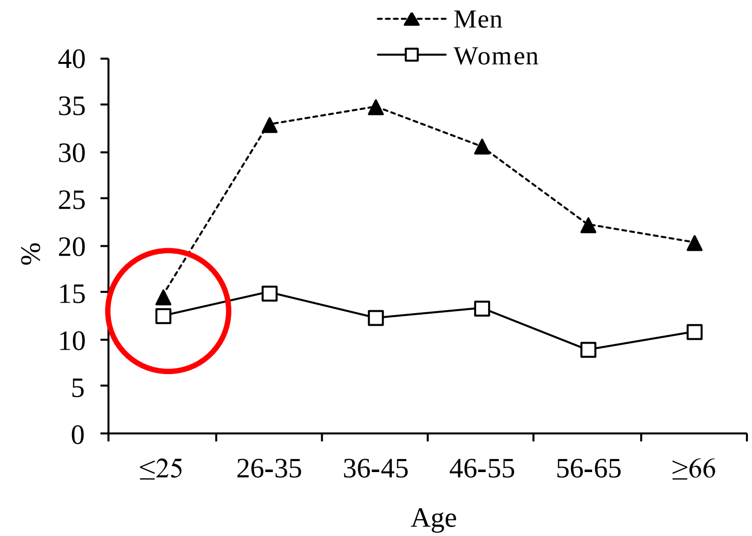
Driver fatigue: self-reports

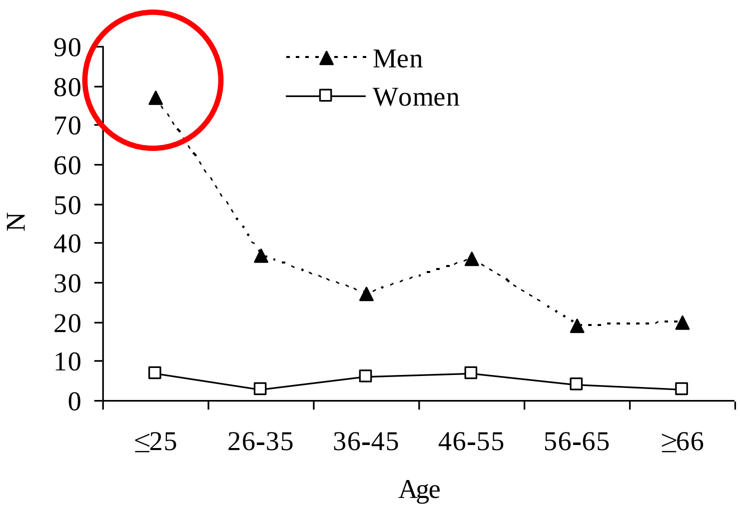
- 29% of British men reported being close to falling asleep while driving in the past 12 months (Maycock, 1997).
- One-fifth of Finnish drivers (19.5%) reported falling asleep behind the wheel during their driving career, with 15.9% reported having being close to falling asleep or having difficulties staying awake when driving during the previous twelve months.

Close to fall asleep during the last 12 months
(representative sample N=1121)

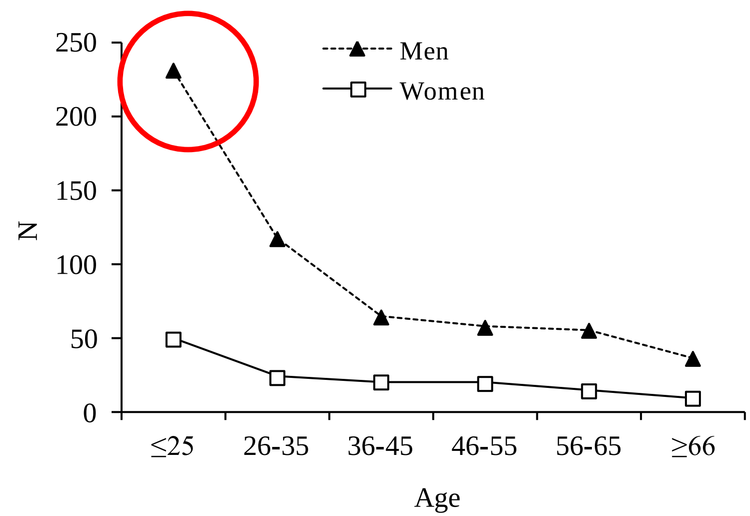


Fell asleep while driving during lifetime
(representative sample N=1121)





Falling-asleep fatal accidents
(N=247; 1991-2001)



Drivers punished because of fatigued driving
(N=694; 2004-2005)

Radun I:
Doctoral thesis

Crash statistics: time of day

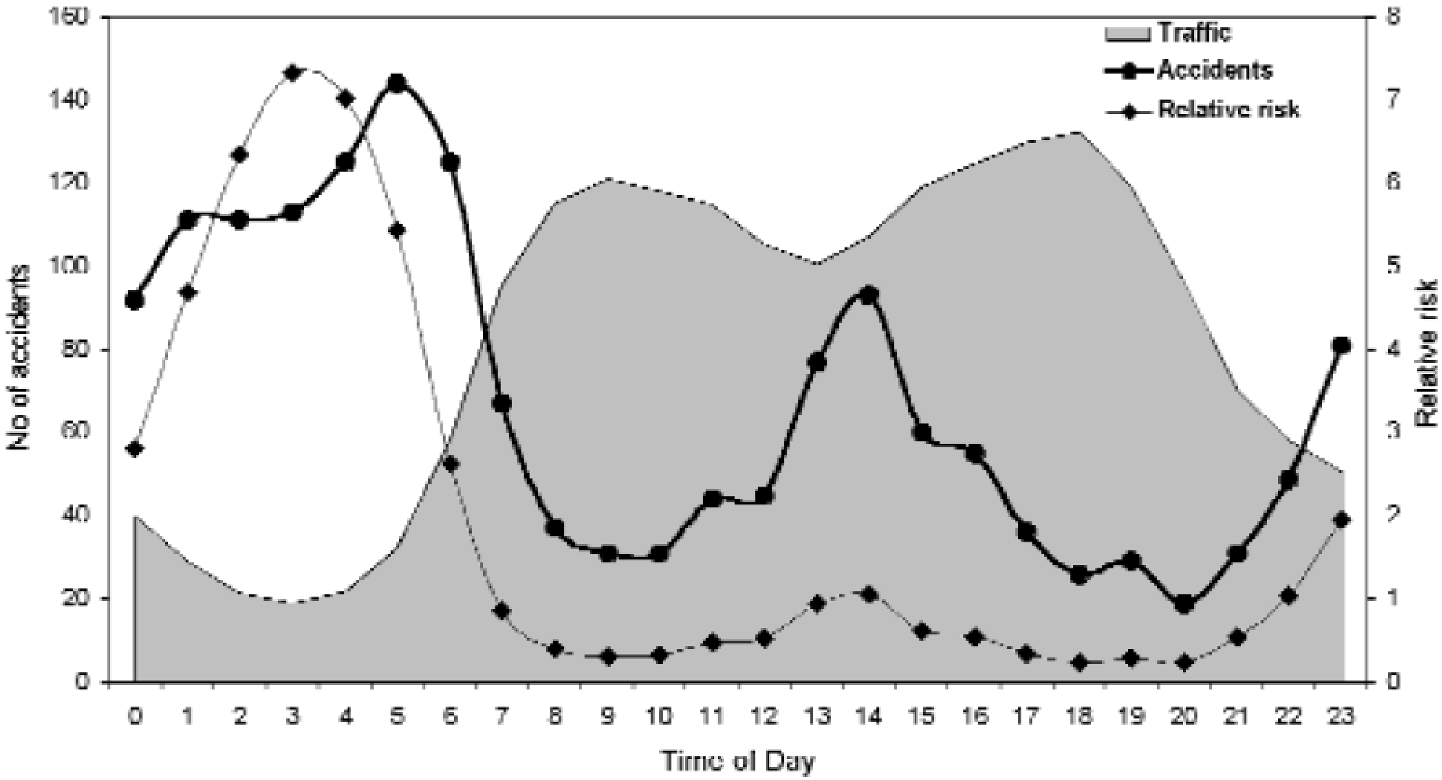


Figure 1. ***Time distribution of sleep-related accidents and traffic during the day. Heavy line: total counts of hourly sleep-related accidents during the five years considered in the study. Gray area: percent traffic distribution of the traffic density during the day. Thin line: relative risk of sleep-related accidents (see the text for the definition)***

Garbarino et al.

Sleep related vehicle accidents on Italian highways

G Ital Med Lav Erg 23 (2001) 430-434

Naturalistic driving studies

Table 3
Results of the matched-paired t-tests comparing mean sleep quantity before the critical incident to overall sleep quantity (all critical incident data)

Condition	Sample size	Sleep quantity before incident (h)		Overall sleep quantity (h)		t-Stat	$P(T \leq t)$ (two-tailed)
		Mean	S.D.	Mean	S.D.		
Previous-24-h vs. overall sleep quantity	38	5.28	2.03	6.63	1.47	−4.5177	0.0001

Table 4
Results of the matched-paired t-tests comparing mean sleep quantity before the critical incident to overall sleep quantity (truck driver at-fault data)

Condition	Sample size	Sleep quantity before incident (h)		Overall sleep quantity (h)		t-Stat	$P(T \leq t)$ (two-tailed)
		Mean	S.D.	Mean	S.D.		
Previous-24-h vs. overall sleep quantity	29	5.25	2.15	6.70	1.65	−3.9175	0.0005

Hanowski et al
The sleep of commercial vehicle drivers under the 2003 hours-of-service regulations
Accident Analysis and Prevention 39 (2007) 1140–1145

Multidisciplinary expert consensus statement on drowsy driving (Czeisler et al., 2016)

- “Drivers who have slept for two hours or less in the preceding 24 hours are not fit to operate a motor vehicle.”

- “Panelists further agreed that most healthy drivers would likely be impaired with only 3 to 5 hours of sleep during the prior 24 hours.”

100 Car Naturalistic Driving Study

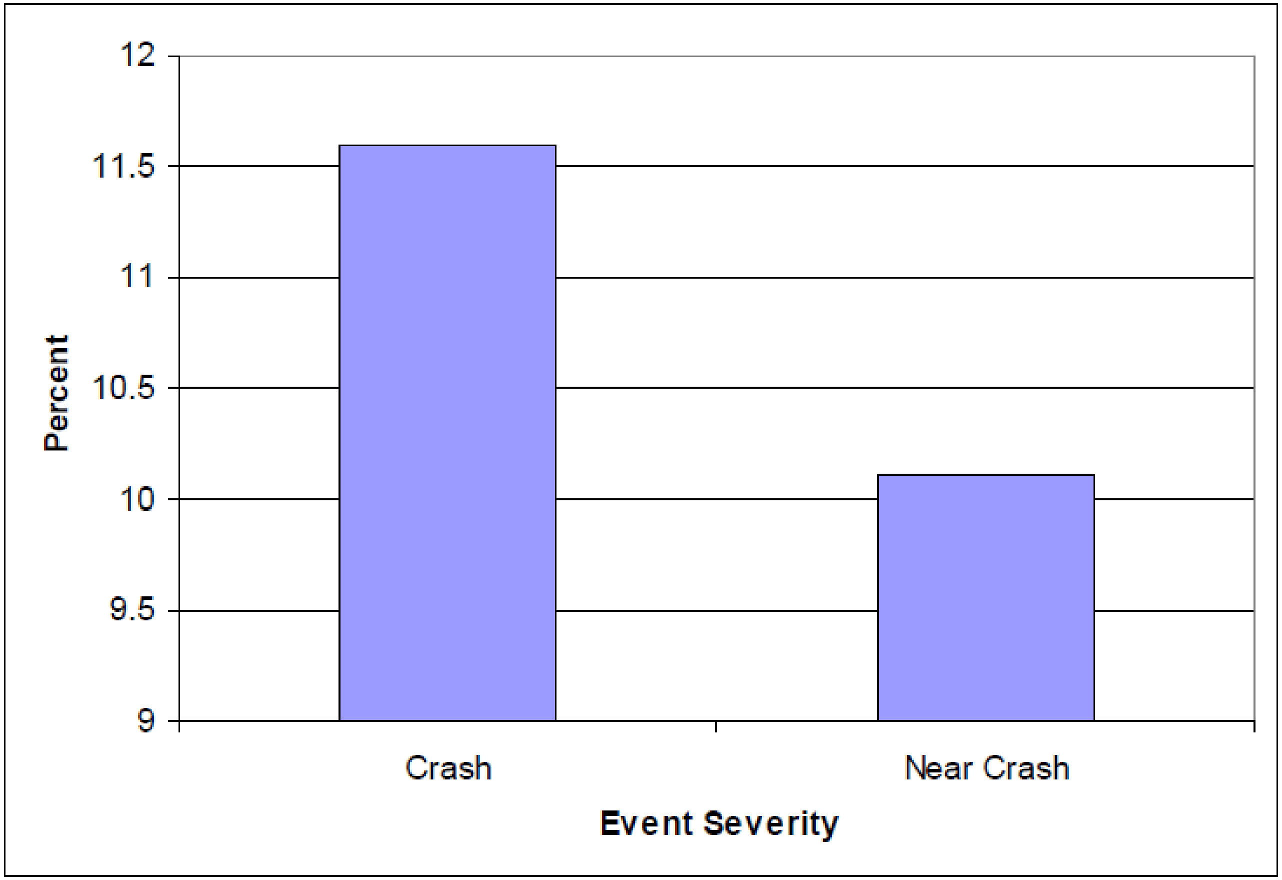


Figure 3. Percent of all crashes and near-crashes where fatigue was considered to be a contributing factor.

Klauer et al.

The Prevalence of Driver Fatigue in an Urban Driving Environment: Results from the 100-Car Naturalistic Driving Study

Virginia Tech Transportation Institute Blacksburg, Virginia

Factors that predispose a driver to fatigue (WHO, 2009)

Factors that predispose a driver to fatigue

Drivers at risk of fatigue	Temporal factors causing fatigue	Environmental factors in fatigue	Sleep-related factors
Young drivers (up to 25 years)	Driving between 02.00 and 05.00	Driving in remote areas with featureless terrain	Driving with sleep debt
Drivers over 50 years	More than 16 hours of wakefulness before trip	Monotonous roads	Driving with a sleep-related condition
Males	Long work period before trip	Main arterial roads	Driving when normally asleep
Shift workers	Long time since start of trip	Long-haul driving	Drivers disposed to nodding off
Those for whom driving is part of job	Irregular shift work before trip	Unexpected demands, breakdowns, etc.	Driving after poor-quality sleep
Those with medical conditions (such as narcolepsy)	Driving after successive nights of shift work	Extreme climatic conditions	
After consuming alcohol	Driving under time pressure	Driving an unfamiliar route	
Driving after inadequate rest and sleep	Some drivers are drowsy in the afternoon		

Source: reproduced from reference *120*, with minor editorial amendments, with the permission of the author.

SHIFT WORK AND WORK TRIPS

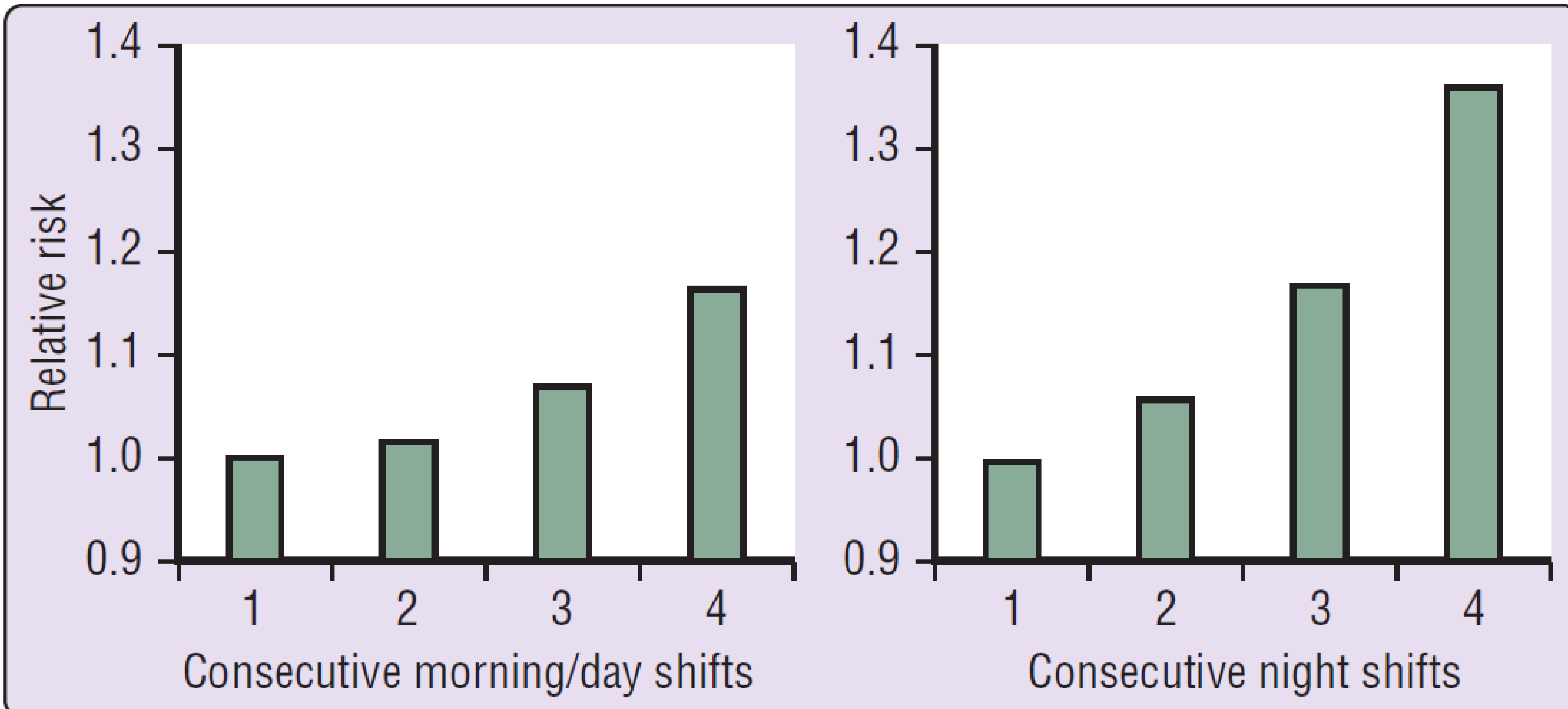
Occupational accidents

- 50% of all work-related accidents in 1988 in the U.S. were potentially related to sleepiness, leading to economic losses of 43 to 56 billion dollars (Leger, 1994).
- Up to 40% of all fatal and serious occupational injuries occur in transport-related incidents (workplaces or during commute journeys)

Risk of accidents and injuries at work

(Van Dongen and Hursth. Fatigue, Performance, Errors, and Accidents

In Principles and practice of sleep medicine / [edited by] Meir H. Kryger, Thomas Roth, William C. Dement.—5th ed.)



Shift workers: extended shifts and road crashes

Table 2. Odds Ratios for Falling Asleep while Driving or while Stopped in Traffic, According to the Monthly Number of Extended Work Shifts.*

Question	0 Extended Work Shifts				1–4 Extended Work Shifts				≥5 Extended Work Shifts			
	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio (95% CI)	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio (95% CI)
Did you nod off or fall asleep while driving?	3035	199	0.066	1.00	3068	286	0.093	1.82 (1.73–1.93)	6933	872	0.126	2.39 (2.31–2.46)
Did you nod off or fall asleep while stopped in traffic?	3039	311	0.102	1.00	3078	508	0.165	1.74 (1.68–1.81)	6944	1608	0.232	3.69 (3.60–3.77)

* Data are from interns' monthly reports on extended shifts. The number of person-months varies because nonresponses were eliminated from the analysis. Rates represent the proportion of months in which participants reported one or more incidents of nodding off or falling asleep, regardless of how many incidents were reported. CI denotes confidence interval.

LK. Barger et al.

Extended Work Shifts and the Risk of Motor Vehicle Crashes among Interns

The New England journal of medicine 2005 352;2 (2005), 125-134

Coming home after the night shift

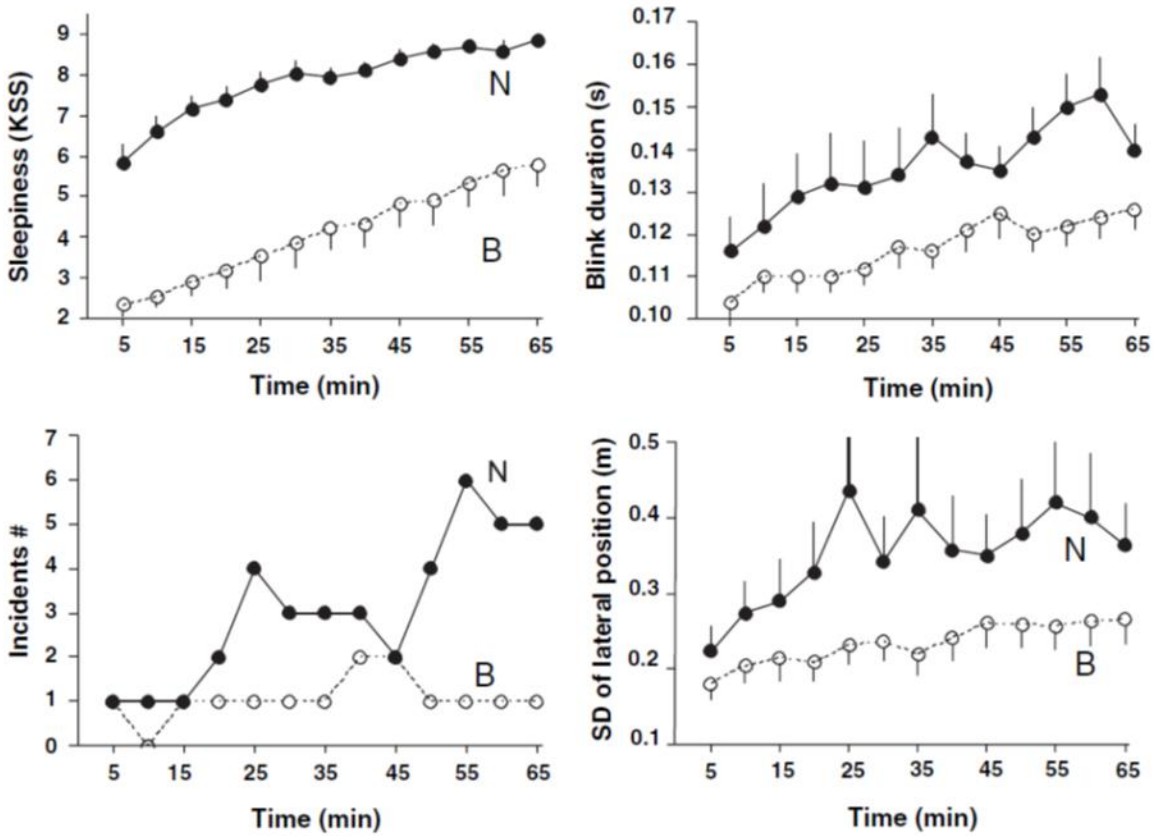


Figure 1. Mean ± SE of driving performance, subjective sleepiness (KSS), and eye closure duration in 5-min intervals for each 5 min of the drive. N, no sleep/night work condition; B, baseline condition (normal night sleep); incidents = two wheels crossing the lane marker; accident = four wheels crossing the lane marker; Sdlat = standard deviation of the lateral position of the vehicle.

T. Åkerstedt et al.

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

Journal of Sleep Research 14 (2005), 17–20

SLEEP DISORDERS

Sleep disorders

- **Insomnia:** “the presence of an individual's report of difficulty with sleep;” initiating and maintaining
- **Obstructive sleep apnea (OSA)**: breathing repeatedly stops and starts during sleep
- **Narcolepsy**: “excessive daytime sleepiness that typically is associated with cataplexy and other rapid eye movement (REM) sleep phenomena such as sleep paralysis and hypnagogic hallucinations”.

Sleep disorders and performance

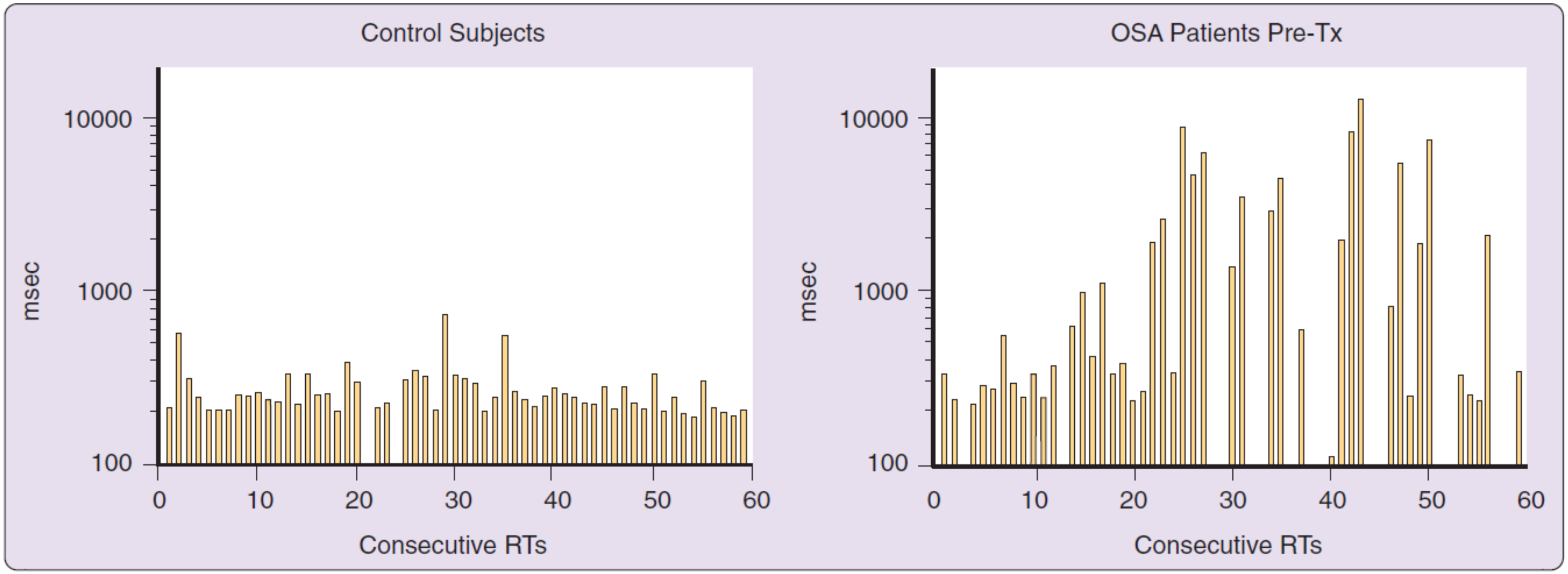
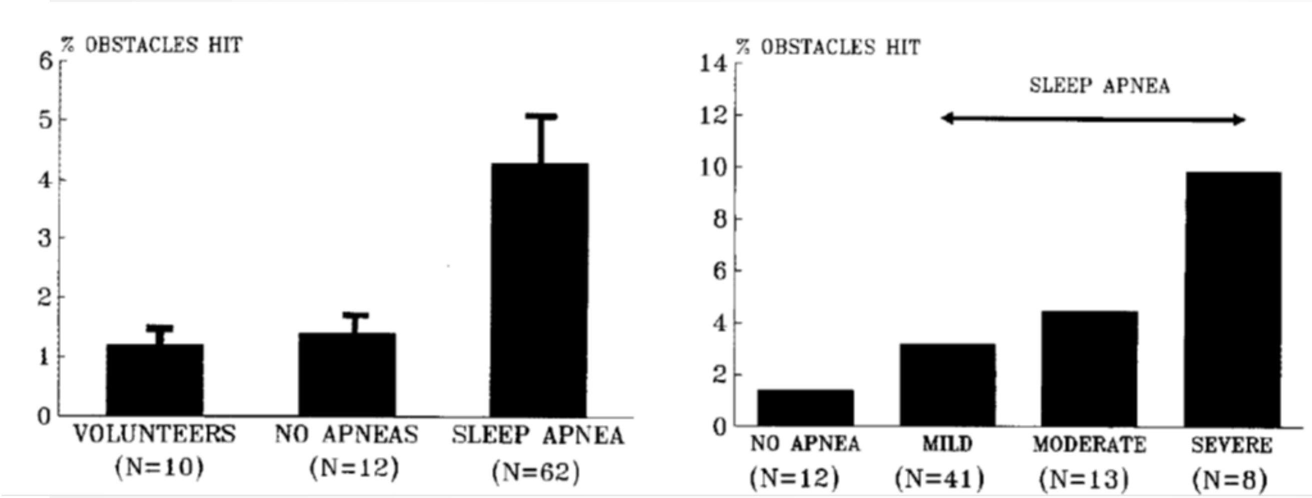


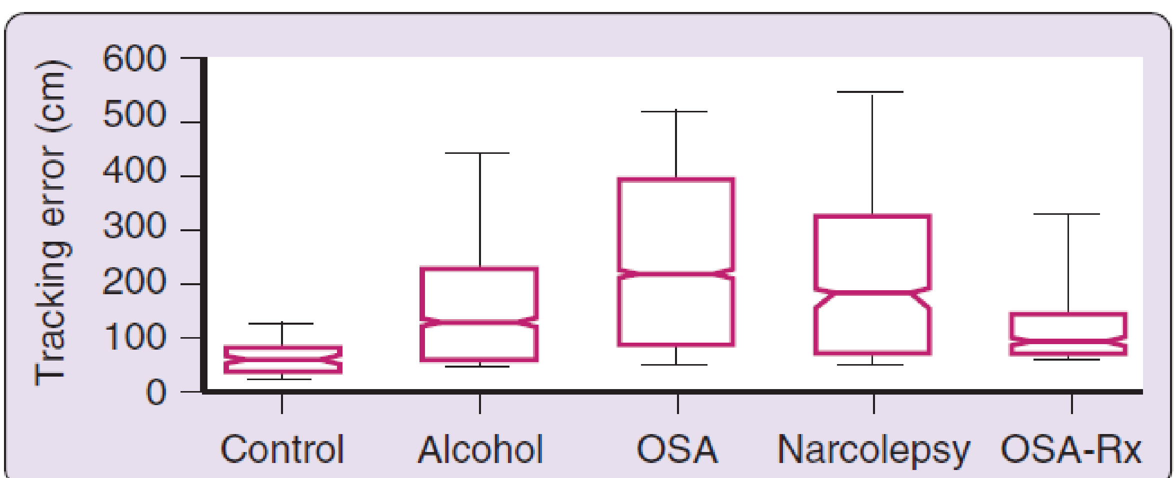
Figure 104-2 Comparison of performance of normal controls and sleep apnea patients on the Psychomotor Vigilance Task. Sleep apnea patients demonstrate increased reaction time, indicated by the *bars*, and lapses in response, indicated by the *blank spaces*. (From Chugh D, Dinges D. Mechanisms of sleepiness. In: Pack A, editor. Pathogenesis, diagnosis, and treatment of sleep apnea. New York: Marcel Dekker; 2002. p. 273.)

Divided Attention Driving Task. OSA, obstructive sleep apnea. (From George CF. Vigilance impairment: assessment by driving simulators. Sleep 2000;23(Suppl. 4):S115-S118, p. S116.)

SLEEP DISORDERS



Findley et al
Vigilance and automobile accidents in patients with sleep apnea or narcolepsy
Chest 103 (1995) 619-624



Divided Attention Driving Task. OSA, obstructive sleep apnea. (From George CF. Vigilance impairment: assessment by driving simulators. Sleep 2000;23(Suppl. 4):S115-S118, p. S116.)

SLEEPINESS AND SUBSTANCES

Sleepiness and alcohol (low BAC)

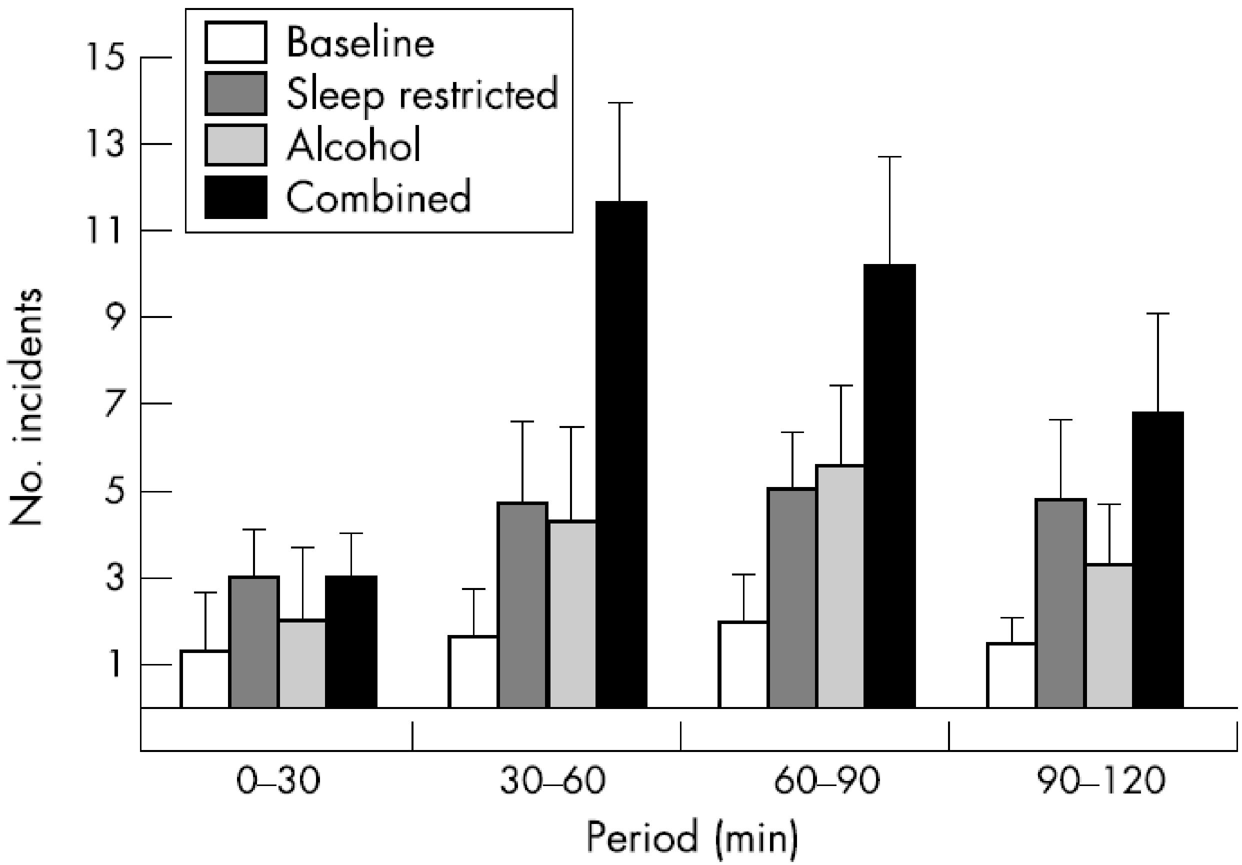


Figure 1 Mean (SE) of sleep related driving incidents (lane drifting) over the four consecutive 30 minute periods, for the four conditions.

Horne et al.

Driving impairment due to sleepiness is exacerbated by low alcohol intake

Occup Environ Med 2003;60:689–692

Effects of drugs: benzodiazepines

- Reducing anxiety, sedative effects, sleep inducing, muscle relaxation
- Often used in combination with alcohol
- Attention and psychomotor impairment

Residuals effects of benzodiazepines

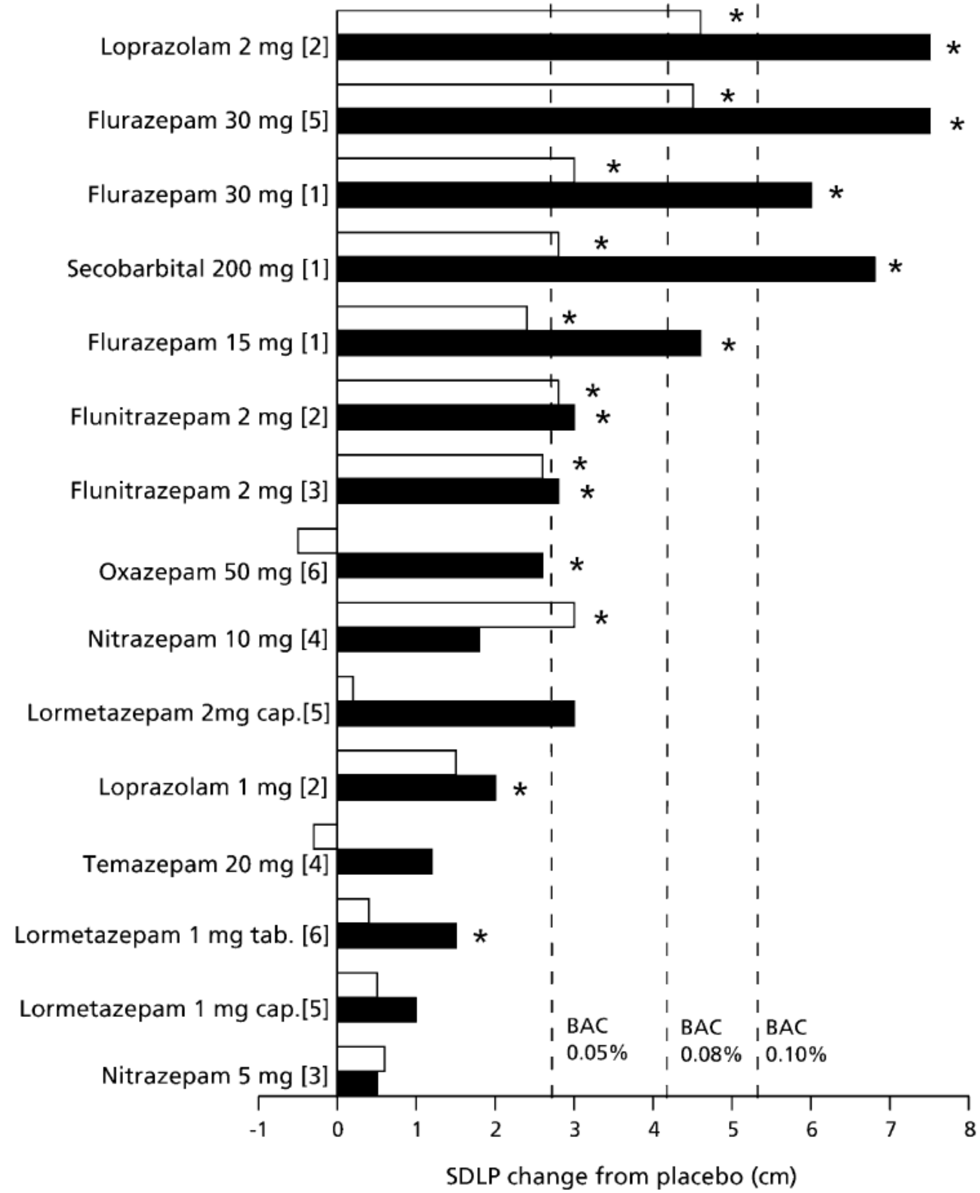


Figure 4 Effects of benzodiazepine hypnotics on actual driving determined after two successive treatment nights. SDLP changes from placebo (cm) are shown for the morning test sessions (10–11 h after bedtime administration; black bars) and the afternoon test sessions (16–17 h after bedtime administration; open bars). Significant differences from placebo are indicated by (*). BAC, blood alcohol concentration, cap., capsules, tab., tablets, Study numbers[1–6] are shown between brackets.

Verster et al.

Residual effects of sleep medication on driving ability

Sleep Medicine Reviews (2004) 8, 309–325

Effects of drugs: Amphetamines

- Amphetamine acts as central nervous system stimulant
- Resistance to fatigue, increase of motivation and concentration, loss of appetite
- During WWII amphetamine was extensively used to combat fatigue and increase alertness in soldiers

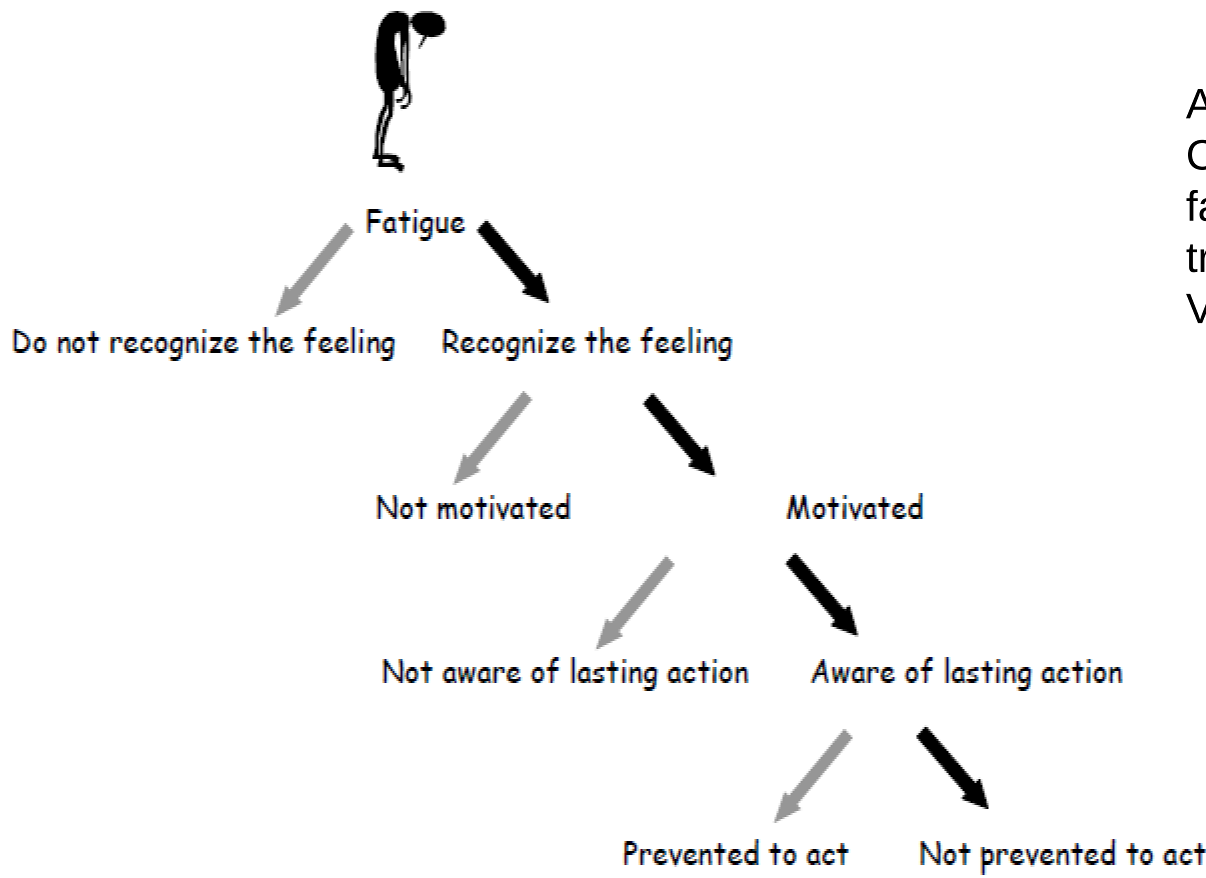
- Amphetamines are stimulants, but it is typical that after a long acute use and prolonged wakefulness (e.g., several days), an exhausted user will fall asleep and remain asleep for 12-18h -> falling asleep while driving

COUNTERMEASURES

Countermeasures

- Drivers' countermeasures
- Society and industry
  - Safety campaigns
  - Environmental interventions
  - Technology-based interventions
  - Regulations, traffic law, and criminal law

Drivers’ decisions

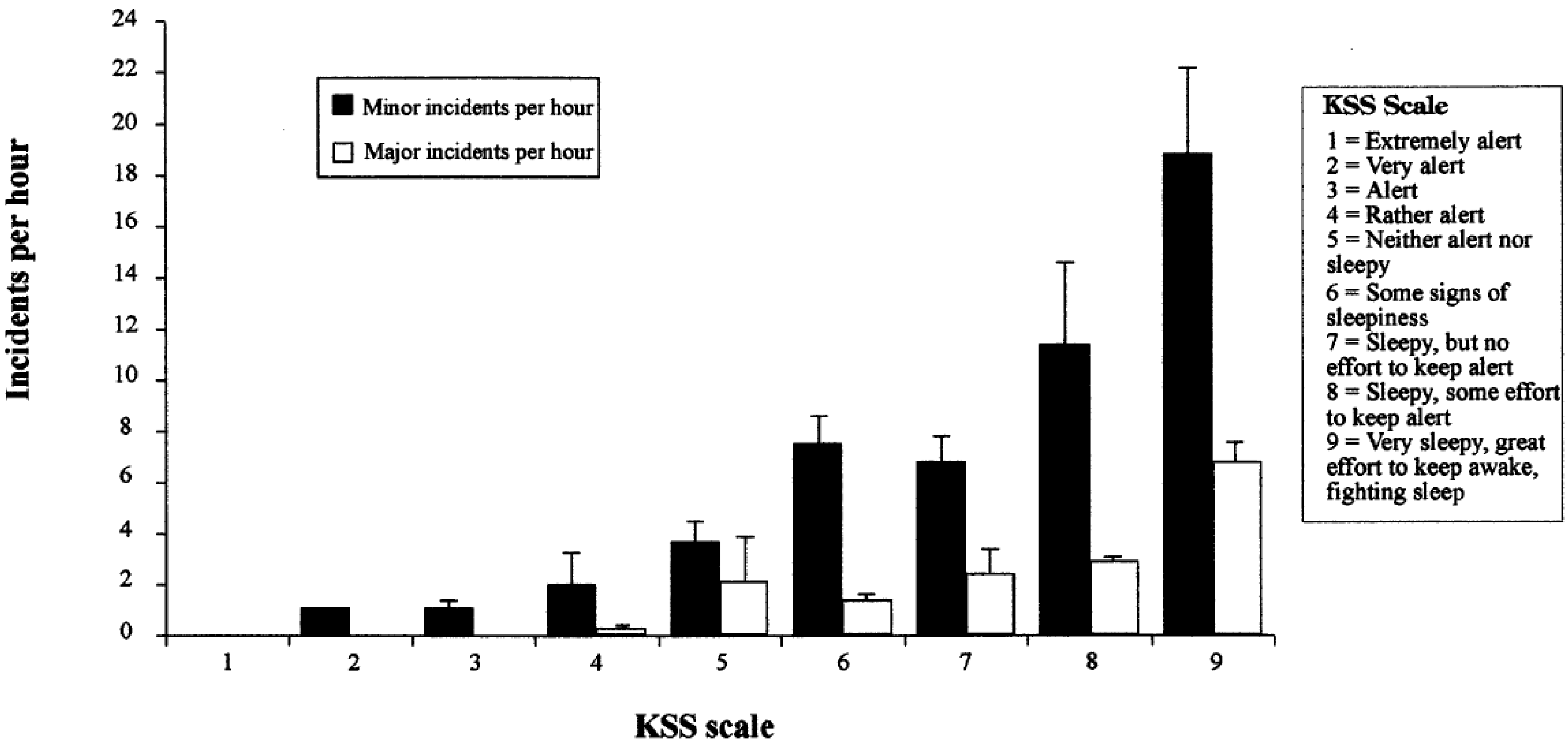


Anund et al. 2015
Countermeasures for fatigue in transportation.
VTI report

Figure 1. The chain of decisions in order to avoid increased risk of crash when the driver is fatigued.

Awareness of sleepiness and driving performance

Reyner & Horne Falling asleep whilst driving: are drivers aware of prior sleepiness?
Int J Legal Med (1998) 111 : 120–123



Awareness of sleepiness and driving performance

- Driving simulator studies show that drivers are aware of sleepiness before any driving incidence
- However, in real life these symptoms of sleepiness are not taken seriously enough
- People do not associate sleepiness with the risk
- Apply ineffective countermeasures

Self-reported countermeasures

Table 2 Drivers' countermeasures against sleepiness while driving – percent of drivers who indicated the used countermeasure when sleepy

Countermeasure	*Total (%)*
Stop and go for a short walk	54
Turn on the radio/stereo	52
Open the window	47
Drink coffee	45
Ask the passenger to engage in conversation	35
Eat candy	32
Sing/whistle/talk	31
Stop and exercise outside the vehicle	28
Stop and rest for a short time – while seated	26
Body movements while driving	27
Turn up the radio/stereo	26
Drink lemonade	26
Eat fruit	26
Stop and sleep for a short while – remain seated	18
Turn on the fan or the AC	16
Use nicotine	14
Drive slower	13
Drive more actively	13
Other	7
Drink an energy drink, e.g. Red Bull	6
Drive faster	5
Take caffeine pills	1
Increase the heat	0

Anund et al.
Driver sleepiness and individual differences in preferences for Countermeasures
J. Sleep Res. (2008) 17, 16–22

Nordbakke and Sagberg
Sleepy at the wheel: Knowledge, symptoms and behaviour among car drivers
Transportation Research Part F 10 (2007) 1–10

What did you do to avoid falling asleep when you started feeling tired?	Total ($n = 1280$)
Opened the window	52
Stopped and got out of the car	50
Put on music	36
Talked to myself or sang	24
Ate sweets/drank sodas	17
Drank coffee	15
Asked passenger(s) to talk to me	13
Drank water	11
Stopped and had a nap	10
Stopped to eat	8
Drove faster or overtook	2
Talked in mobile phone	2

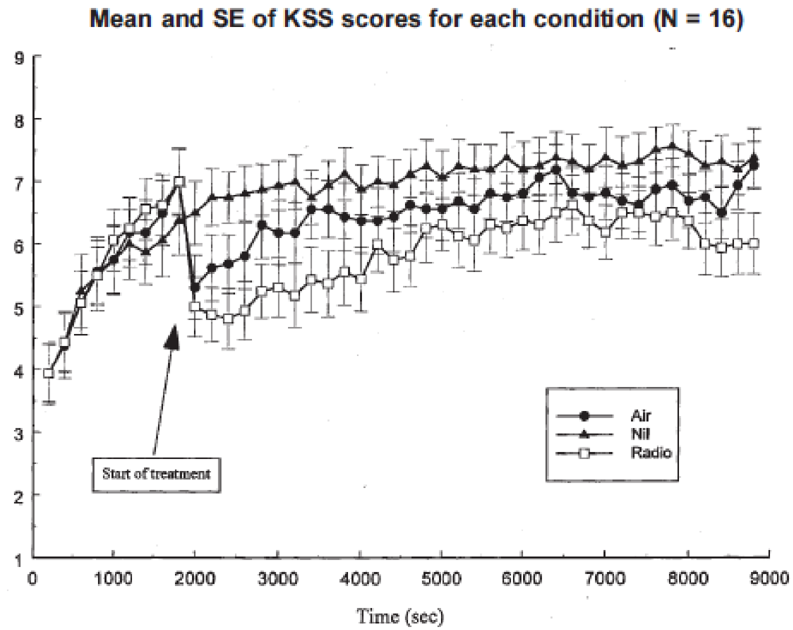


Figure 2.—Mean (with s.e. bars) subjective sleepiness trends (KSS scores - 200-second intervals) under all conditions. RADIO significantly reduced subjective sleepiness for the first, third and fourth 30 min post-treatment periods.

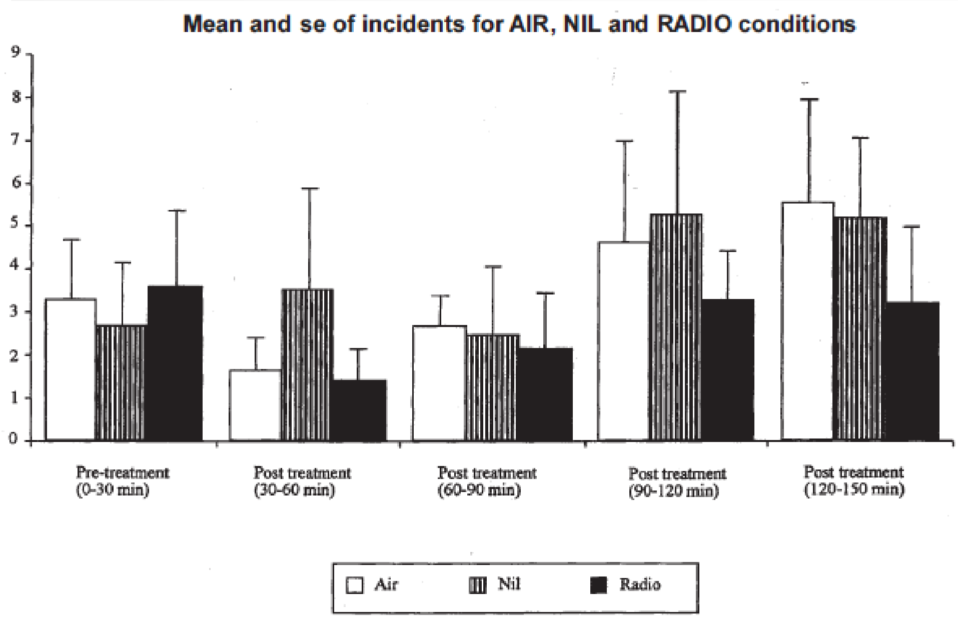


Figure 1.—Mean number of incidents per 30 minutes for all (N=16) subjects and the three treatment conditions. There was a significant effect of time, with the first post-treatment hour being less than the second hour (see text for further details). There was no significant difference between treatments, although there was a trend for RADIO to reduce incidents during the post-treatment period, particularly for the first half hour, when AIR also had some (non-significant) effect.

While sleepy drivers may believe that these countermeasures are effective in improving their alertness, this is not reflected to the extent of their belief in their otherwise deteriorating driving performance.

Reyner and Horne

Evaluation of In-Car' Countermeasures to Sleepiness: Cold Air and Radio

SLEEP, Vol. 21, No. 1, 1998

Caffeine and nap

Reyner and Horne Suppression of sleepiness in drivers: Combination of caffeine with a short nap Psychophysiology (1997), 721-725

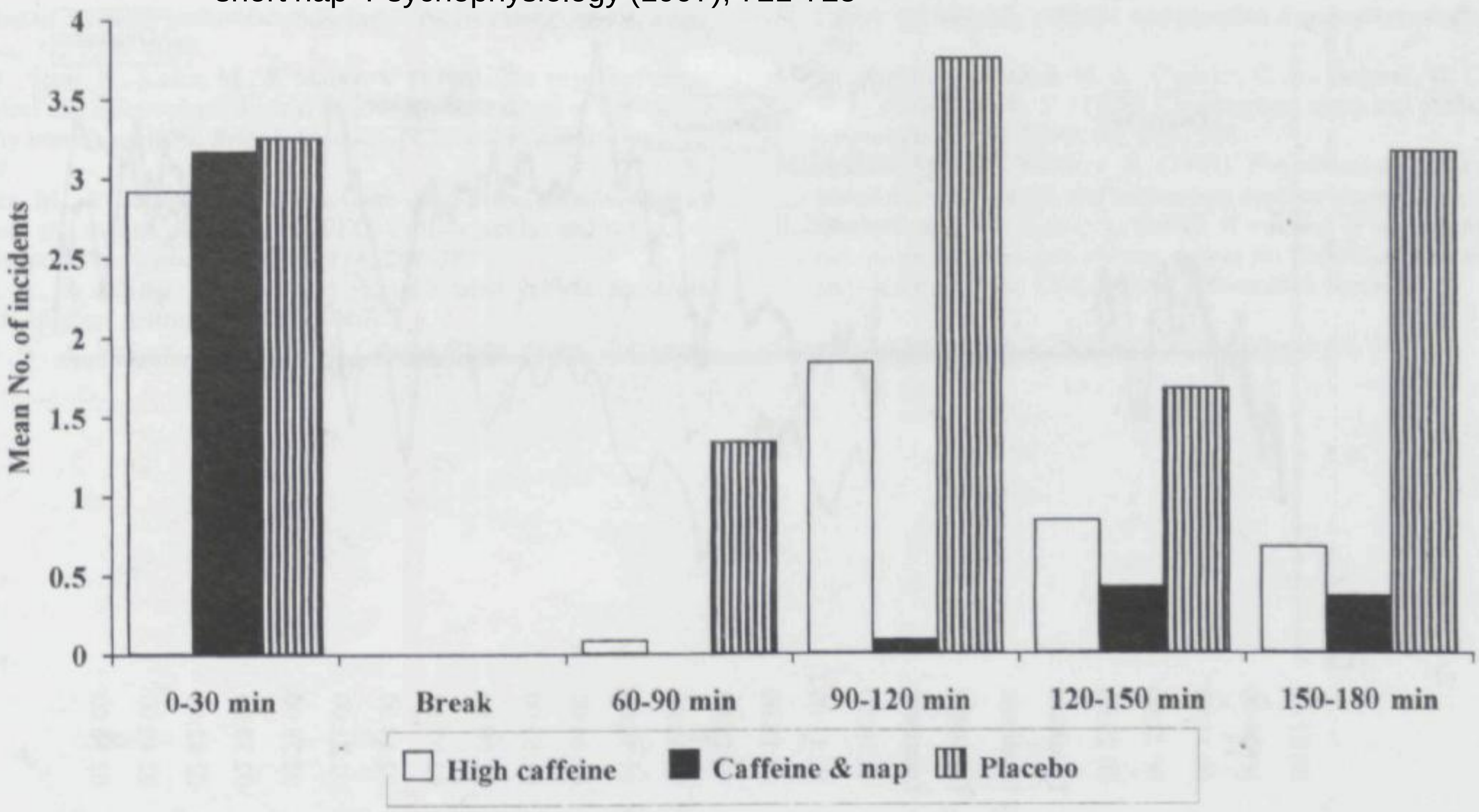
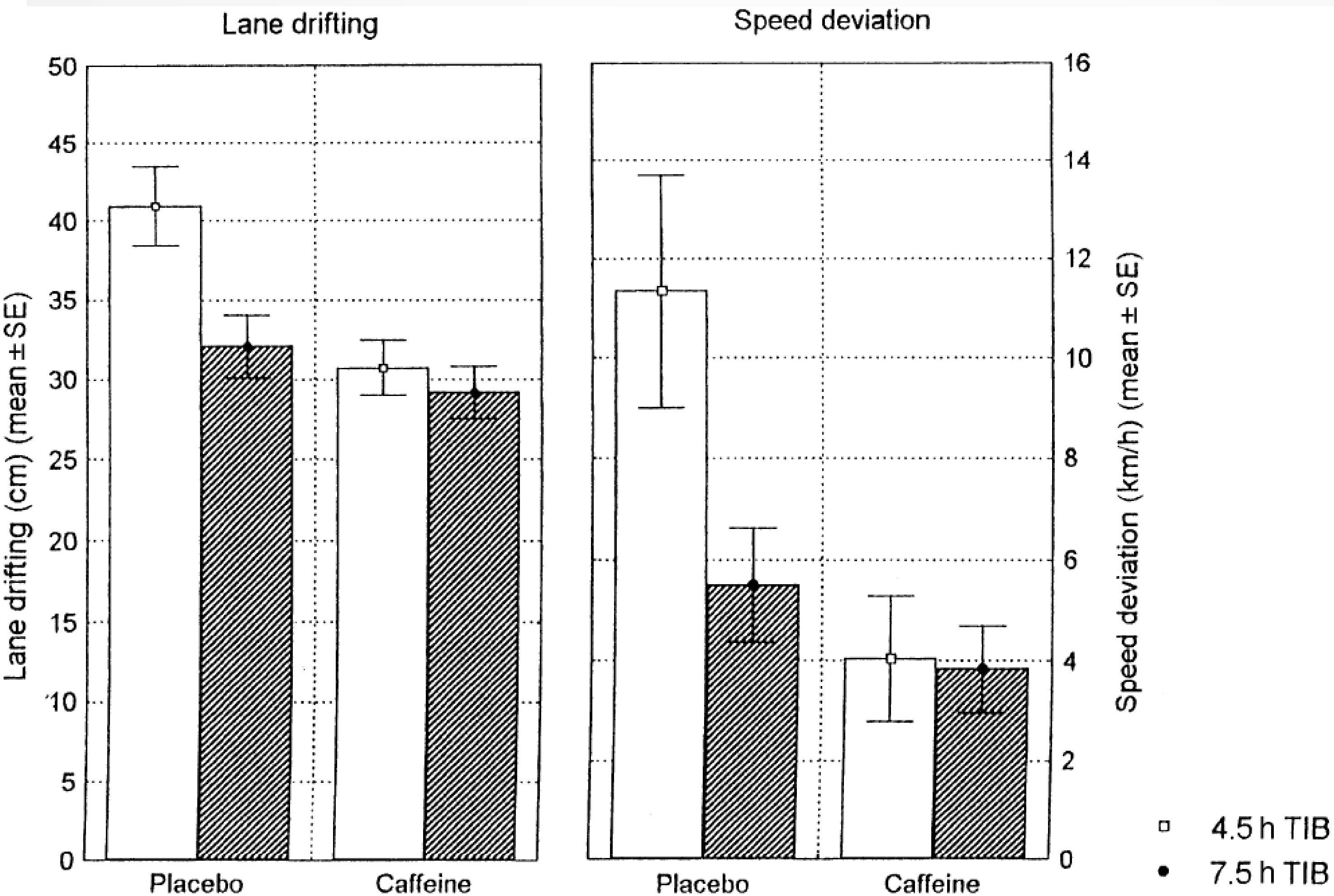


Figure 1. Mean number of sleep-related incidents for caffeine (200 mg), caffeine-and-nap, and placebo, shown in 30-min blocks.

Caffeine



E. De Valck and R. Cluydts

Slow-release caffeine as a countermeasure to driver sleepiness induced by partial sleep deprivation

J. Sleep Res. (2001) 10, 203±209

Safety campaigns (Flatley & Reyner, 2000)

- Education of the general public about the dangers, and to gain general disapproval of driving whilst sleepy
- Education of ‘high risk’ population groups using appropriate material
- Education of other opinion formers using appropriate material

Other campaigns might have negative impact

- Traffic campaigns advising drivers to avoid peak hours during holiday weekends or seasons can place many fatigued drivers on the roads.
- As many as 47% of acutely sleep-deprived drivers on a long vacation trip on a major European highway had restricted their sleep prior to departure following such campaigns promoting a “safe trip.”
- Starting a drive in the late evening or early morning may help to avoid traffic jams but adds to the risk of falling asleep behind the wheel, especially for drivers not used to driving at that time of the day or the long distances typical for vacation trips.

Technology-based interventions (Dinges & Mallis, 1998)

- Readiness-to-perform and fitness-for-duty technologies (e.g., the PVT Psychomotor Vigilance Test)
- Mathematical models of alertness dynamics joined with ambulatory technologies (e.g., Fatigue Audit InterDyne system)
- Vehicle-based performance technologies (e.g., steering and braking movements)
- In-vehicle, on-line, operator status monitoring technologies (e.g., eyelid closures, physiological measures).

EYE/EYELID MOVEMENTS

PubliSystems

Optalert

Rumble stripes

Driver fatigue and law

Finnish traffic law (RTA; Article 63): ‘‘A person that does not meet the requirements for driving because of illness or tiredness or another similar reason or whose health condition no longer fulfills the requirements needed for granting a driver’s license must not drive a vehicle’’ (unofficial translation)

Swedish traffic law: ‘‘Vehicles may not be driven by a person who, due to illness, fatigue, intoxication by either alcohol, other stimulants, or sedatives, or for any other reason, cannot operate the vehicle in a safe manner’’ (unofficial translation).

Maggie’s Law (New Jersey, US): Under this law a driver who causes a fatal accident after being awake for more than 24 consecutive hours can be convicted of second degree vehicular homicide, sentenced to up to 10 years in prison, and fined a maximum of $100,000.

DRIVER FATIGUE AND THE LAW

- Driving while fatigued is (extremely) dangerous!

- How negligent is a person who is driving while extremely fatigued?

- Do such drivers deserve to be punished harsher?
  - Law change?
  - Change in law application?

- How are we going to deal with these drivers (from the law perspective)?
  - Police officer education?
  - Clear guideliness?
  - Expert witneses?

SUMMARY OF MY STUDIES

My doctoral thesis

- Fatigued driving: prevalence, risk factors and groups, and the law (2009)
- 6 peer-reviewed articles

- Mentors: professor Heikki Summala and research professor Mikael Sallinen
- Opponent: professor Göran Kecklund (Stockholm University)

Study I. Multidisciplinary investigation teams vs. courts

- 2,980 fatal accidents studied in depth (1991-2001)
- In 247 cases (8.3%) the driver had fallen asleep; 57 (23.1%) had survived.
- Included: head-on crashes; fatality in the other vehicle ➡ N=10 (9 nine court decisions)

- **Teams:** Despite the obvious difficulties with the data collection, the investigation teams provided sufficient information and explanation as to why falling asleep was the most probable cause of these nine accidents.

- **Courts:** There was wide variation in the court discussions and decisions. The court extensively deliberated on the role of fatigue in the four cases and only one driver was charged under the article of the Road Traffic Act covering driver fatigue.

<u>Large differences in the discussions held and conclusions reached between VALT teams and Finnish district courts.</u> (information given to the multidisciplinary VALT teams by an accident's participants is confidential and cannot be used in court)

Study II. Drivers punished because of fatigued driving (n=694)

- Drivers (N= 768) punished under Article 63 (2004–2005; Vehicle Administration driver record database). Fatigue: 694 (90.4%)

- Accidents, predominantly single vehicle, were the most common (92.5%) consequence of fatigued driving.
- Almost every twentieth driver was punished because his vehicle was drifting on the road.
- The presence of alcohol or drugs was noted in 13% of the cases.
- Although fatigue-related accidents are thought to be serious, our data shows that most of the accidents (81.6%) did not involve personal injuries.

- <u>Only 3.1% of drivers punished because of fatigued driving officially denied falling asleep of being tired.</u>

Study III. Prosecutors' and police officers' experience, education, knowledge, and attitudes about fatigued driving

- Online survey: prosecutors (N=96), local (N=100) and traffic police officers (N=129)

- Two-thirds (65.9%) of traffic and four out of five (79%) local police officers investigated an accident in which the driver was suspected of falling asleep.
- Similarly, 69% of prosecutors had a case of driver suspected of falling asleep and causing an accident.

- Only 23% of traffic and 8% of local police officers have received training about fatigue in traffic.
- A great majority (95%) of police officers receiving such training found it useful, while 80% of those without such training believe that such training would be beneficial for them.

Conclusions

- Definitions and operationalizations: fatigue vs. sleepiness
- Measuring sleepiness: subjective, physiological and performance
- Frequent mismatch between these measures: intra and inter individual differences
- Sleepiness and crashes: self-reports and official records
- Acute or chronic sleepiness, people with increased daytime sleepiness – sleep disorders, shift work
- Countermeasures: sleep is the best countermeasure! Napping and caffeine, working hours regulations

- Sleepiness increases the risk of mistakes and accidents!