Sleepiness, Safety and Transport
Sergio Garbarino1,2, Giuliana Gelsomino1 and Nicola Magnavita2*
1Centre of Sleep Medicine, Department of Neuroscience, Ophthalmology, Genetics, Maternal and Child Health, University of Genoa, Genoa, Italy
2Department of Public Health, Catholic University School of Medicine, Largo A. Gemelli 8, 00168 Rome, Italy
3State Police Health Service Department, Ministry of the Interior, Rome, Italy

Abstract
The economic development of modern society requires continuous improvement of transport and their efficiency throughout the span of 24 hours. Drowsiness may be a serious risk to the safety of employees, passengers and third parties. Sleepiness at the wheel is responsible for 5% to 30% of road accidents. Several pathophysiological factors governing the driving skills were studied: lifestyles, work schedules, prolonged wakefulness, stress, and sleep disorders. Screening of sleep disorders and education of workers at proper sleep hygiene are fundamental keys to the safe transport. The individual initiatives to reduce the risk of drowsiness should be framed in a more general safety effort of the institutions.

Keywords: Sleepiness; Transport; Accident; Prevention; Sleep disorders; Safety

Introduction
Both in developed and developing countries, transport plays a prominent economic role because it conveys goods and services to customers, passengers to work or school, shops or leisure centres. Around 8.8 million Americans and 10.5 million Europeans [1] are employed in the transport sector.

Economies rely on transportation and communication systems that operate well beyond the ‘normal’ 8-hour workday to transport people and goods to meet personal and business requirements. However, the need for transport and communication systems to operate around-the-clock may exceed the capacity of human beings to work efficiently and safely. This incapacity to perform optimally around the clock is typically attributed to sleepiness that results from sleep homeostasis, circadian rhythms, and workload [2].

Road Safety is a major societal issue. In 2011, more than 30,000 people died on the roads of the European Union, i.e. the equivalent of a medium-sized town. For every death on Europe’s roads, it is estimated that there are 4 permanently disabling injuries such as brain or spinal damage, 8 serious injuries and 50 minor injuries. In 2003, the European Commission introduced an ambitious Road Safety Programme [3] which aims to cut road deaths in Europe between 2011 and 2020. The programme sets out a combination of initiatives, at European and national level that focus on improving vehicle safety the safety of infrastructures and road users’ behaviour.

Safety problems also regard railways and sea transport, air transport, pipelines, postal and courier services. Road Accidents (RA) remain the largest single cause of death among people aged 15 to 29. According to Eurostat statistics on the causes of death, the number of people in the European Union who died as a result of transport accidents (covering all transport modes) fell by 37% between 1999 and 2009 [4].

Although alcohol and recreational drugs are recognized as significant risk factors for transport accidents, the role played by sleepiness is less well known, but may be more important. This may be due to a sleep pathology, voluntary (non-pathological) sleep reduction, or activity during the circadian low. Night or morning work is a prominent factor with regard to the two latter causes. Sleep disorders with impaired or shortened sleep (as i.e. sleep apnea) are major cause of RA, more than drugs [5].

The literature abounds with studies on road safety, while less research has been carried out on industrial safety. In fact, the link between sleep restriction (or shift work) and safety is much better established in the transport industry than in other industrial areas. The reason is that driving a vehicle is a task that requires continual attention and lapses are immediately punished, whereas in most cases industrial work does not make the same demands. Nevertheless, there are important effects and consequences may be far-reaching. Many industrial disasters have occurred in off-peak hours, or when the workers lacked sleep or rest. Proper sleep management and fatigue control are priorities for workplace safety [6,7].

The pathophysiology of driving
Driving is a complex task that requires a number of skills (multitasking task). A driver continuously receives information from the road, analyses it, and reacts according to his/her knowledge of traffic systems, driving regulations, conditions of the vehicle, application of the Highway Code and previous driving experience.

Driving also involves the processing of complex visual, tactile, and auditory information in order to produce a well-coordinated motor output [8]. The capacity to drive safely declines with chronological age, and this decline is associated with an age-related decrease in several higher order cognitive abilities involving manipulation and storage of visuospatial information under speedy conditions [9]. On the other hand, younger drivers show greater vulnerability to sleep loss. After sleep restriction, younger drivers show significantly more sleepiness-related deviations and greater electro-encephalographic changes (4-11 Hz power - indicative of sleepiness) than older drivers [10].

Night driving performance may be seriously affected by sleepiness. Simulated driving tasks have been designed to tap into the key processes

*Corresponding author: Nicola Magnavita, Department of Public Health, Catholic University School of Medicine, Largo A. Gemelli 8, 00168 Rome, Italy, Tel: +393473300367; E-mail: nicolamagnavita@gmail.com

Received January 31, 2014; Accepted March 19, 2014; Published March 26, 2014

Citation: Garbarino S, Gelsomino G, Magnavita N (2014) Sleepiness, Safety and Transport. J Ergonomics S3: 003. doi:10.4172/2165-7556.S3-003

Copyright: © 2014 Garbarino S, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
that are involved in driving. These simulations are able to investigate driving-related performance in a controlled, measurable, and safe environment. They clearly show that subjective and objective sleepiness is much higher during night conditions [11]. Sleep deprivation, sleep restriction, circadian variations and extended periods of time-on-task have been shown to cause a qualitative decline in driving performance in both on-road and simulated driving tasks [12-14].

Anecdotal claims also point out the adverse effects of larger lunches on afternoon driving ability. The 'post-lunch' dip is a bi-circadian phenomenon, largely unrelated to lunch, and worsened by a disturbed prior night’s sleep. Studies conducted with an interactive simulator showed that a heavy lunch causes significant increases in both sleepiness-related lane drifting ('incidents') and electroencephalographic (EEG) changes and a tendency to greater subjective sleepiness [15].

Individual differences in cognitive functioning during extended work hours and shift work are of considerable importance, and may be observed both in the laboratory and in the workplace. These individual differences have a biological basis in trait-like, differential vulnerability to fatigue from sleep loss and circadian misalignment. Trait-like vulnerability can be predicted partly by functional gene polymorphisms that may be located in the promoter region of the Monoamine oxidase a gene [16], and by other biological or psychological characteristics, but remains largely unexplained. A complicating factor is that individual vulnerability or resilience to sleep deprivation depends on the fatigue measurement taken into consideration—subjective versus objective assessment, or one cognitive task versus another. Such dissociation has been observed in laboratory and operational data resulting from a simulated setting. Disparity between subjective and objective measurements of fatigue may be one of the reasons why vulnerable individuals do not systematically opt out of professions involving high cognitive demands and exposure to fatigue [17].

As driving involves a number of combined cognitive processes, it is difficult to determine from a simulated driving task alone which components are causing the impairment in overall driving performance. A number of cognitive domains have been associated with crash risk in on-road driving studies, including attention and vigilance, visual processes, processing speed and reaction time, working memory and executive function [8]. Many of these functions also overlap with neurocognitive impairments observed in sleep-deprived individuals [18]. Experiments have been conducted to decompose sleep-deprived performance into underlying cognitive processes using cognitive-behavioural, neuroimaging and cognitive modelling techniques. Furthermore, computational modelling in cognitive architectures has been employed to simulate sleep-deprived cognitive performance on the basis of the constituent cognitive processes. These efforts are beginning to enable quantitative prediction of the effects of sleep deprivation to be made across different task contexts [19].

Driver inattention has been identified as one of the leading causes of motor vehicle accidents. Distractions are a common component of everyday driving. In terms of overall event durations, the most common distractions are eating and drinking (including preparations for eating or drinking), distractions inside the vehicle (reaching or looking for an object, manipulating vehicle controls, etc.), and distractions outside the vehicle. Visual attention performance significantly predicts real-world accident frequency [20]. Studies with unobtrusive video camera units showed that distractions are frequently associated with decreased driving performance, as measured by higher levels of no hands on the steering wheel, eyes directed inside rather than outside the vehicle, and lane wanderings or encroachments [21]. Low scores on attention and vigilance tasks are associated with higher crash risk rates and on-road driving performance [22]. Clearly, sleep deprivation exacerbates exponentially the distractions and attention deficit.

Aspects of motor speed, such as simple visual reaction time, are also important skills in adverse situations (e.g. being able to brake quickly if a pedestrian steps out on the road). Moderate correlations have been observed between simple reaction time tasks and on-road driving performance, with stronger correlations observed for complex reaction time [23]. Slowing of reaction times and lapses in attention are also commonly observed after periods of extended wakefulness [24,25] and are associated with lane drifting on a simulated driving task [26].

Driving is primarily automatized, although it does involve some shifts to controlled processing when routine reactions are insufficient to deal with novel or complex traffic situations. The driver needs to process multiple stimuli simultaneously, select and filter stimuli according to the road situation, and process the information in a short time frame in order to judge the traffic scene and act appropriately [27]. Therefore, information processing speed is an important component of driving. The Digit Symbol Substitution Test (DSST) is one measurement that assesses information processing and motor speed, and has been shown to be related to simulated driving performance in rested subjects [28]. Impairment in DSST performance has been observed in some [25,29] but not all [30] studies of sleep-restricted subjects. Executive, higher order function is required for integrating introspective, sensorial, and situational information, whilst suppressing distracting information by focusing attention relevant stimuli and planning a response. A number of tasks that tap into executive functions have been found to correlate with driving skills [27,28,31].

The frontal cortex is largely thought to control attention and executive function and is vulnerable to events. Many conditions that impair frontal lobe functioning, such as aging, can potentially lead to a driver taking inappropriate risks, having poor insight into performance deficits, concentrating on inappropriate thoughts and actions, and having problems making behavioural modifications based on new information from the road scene.

A significant problem of our society, in which there are more and more elderly drivers due to the aging population, is the interaction between the senile degeneration of the higher functions and driving ability. There are few ways of discerning driving risks in patients with early dementia and mild cognitive impairment. Some recent findings suggest that there may be a link between hippocampal atrophy and difficulties with lane control in persons with mild cognitive impairment [32]. These observations, if confirmed, could provide useful information for the evaluation of driving skills.

Neuroimaging studies demonstrate that even a single night of sleep deprivation may negatively impact on driving performance [33]. Driving performance and neurocognitive vigilance rates and reaction times are significantly impaired after sleep deprivation [34]. Combined sleep deprivation and circadian effects (frequently present during night time driving) might have more significant effects on executive function. Short-sleep duration/sleep deprivation is common in shift and night workers. Consequently they are more likely to be at higher risk of experiencing increased fatigue than daytime workers and the unemployed [35].

To date, little is known about the link between insomnia and the risk of motor vehicle accidents. An international cross-sectional survey conducted across 10 countries showed that 20.9% of subjects suffering from insomnia reported having had at least one home accident within
the past 12 months, 10.1% at least one work accident, 9% reported having fallen asleep while driving at least once and 4.1% reported having had at least one car accident related to their sleepiness. Reduced total sleep time may be one of the factors accounting for the high risk of accidents in individuals who complain of insomnia [36].

Sleep and fitness to drive

Sleepiness plays an important role in major commercial vehicle crashes [37-42]. The prevalence of excessive sleepiness in the general population around the world ranges from 6.2 to 32.4%, with an inheritability of 38-40% [16].

In the U.S.A., a series of studies by the National Transportation Safety Board (NTSB) have highlighted the significance of sleepiness as a factor behind accidents involving heavy vehicles [43]. In the very thorough 1995 study, the NTSB came to the conclusion that 52% of 107 one-vehicle accidents involving heavy trucks were fatigue related; in 17.6% of the cases, the driver admitted to falling asleep. As early as 1990 the NTSB indicated fatigue as the most important cause (31%) of fatal accidents involving heavy trucks in which the driver had been killed. The extent of fatal, fatigue-related accidents is considered to be around 30% (1990s). This compares with approximately the same level of incidence in the air-traffic sector, while equivalent accidents at sea are estimated at slightly below 20% [44].

The National Sleep Foundation has been conducting the Sleep in America survey since 1991. The survey is representative of the U.S. population aged between 23 and 60. The 2013 NSF Sleep in America Poll confirmed that those who classify themselves as exercisers report better sleep. It then follows that non-exercisers report worse sleep and health. The study also indicated that, during the 12-month span prior to the survey, 32% of the respondents stated they had driven drowsy ≥ once/month, and 36% admitted to briefly nodding-off while driving, with 2% having experienced a drowsy-driving accident or near accident [45].

Since excessive daytime fatigue and sleepiness increase the risk of driving crashes, and sleepiness originates both from voluntary and pathological conditions, addressing impairment in commercial drivers requires addressing both insufficient sleep and a less common sleep apnea [46].

Epidemiological studies indicate that sleep-related crashes represent up to 20% of all traffic accidents in industrial societies [40,47-49], and driving while drowsy has been identified as the major cause of fatal road crashes [37-39]. Very recent studies confirm that there is an almost six-fold increase in the odds of crashes involving injury for vehicles driven by people who are not fully alert or sleepy, or by people reporting less than 6h of sleep during the previous 24 hour [50].

A cross-sectional telephone study using a representative sample of 62.8 million inhabitants from 3 American states, showed that 19.5% of the sample had moderate excessive sleepiness and 11.0% had severe excessive sleepiness. Factors associated with moderate excessive sleepiness were sleeping 6h or less per main sleep episode; obstructive sleep apnoea syndrome (OSAS); insomnia disorder; restless legs syndrome; major depressive disorder; anxiety disorder; use of tricyclic antidepressant; presence of heart disease; cancer, and chronic pain [51].

Drowsy driving is a major public health problem. A study in the USA showed that working > 40 hr per week and shift work are associated with increased risk of drowsy driving. Odds ratios for falling asleep behind the wheel are higher in shift workers with symptoms of insomnia or excessive sleepiness compared to day workers and shift workers without sleep complaints [52].

Commercial truck drivers are especially prone to drowsy driving. A congressionally mandated study of 80 long-haul truck drivers in the United States and Canada found that drivers averaged less than 5 hours of sleep per day [53]. It is no surprise then that the US National Transportation Safety Board (NTSB) reported that drowsy driving was probably the cause of more than half of crashes leading to a truck driver’s death [54]. According to the US National Highway Traffic Safety Administration (NHTSA) for each truck driver fatality, another three to four people are killed [55].

More recent studies confirm that a significant proportion (2.9%) of commercial drivers report near-miss sleepy accidents during their journeys [56]. A study in Tanzania showed that truck drivers usually drive an average of 10.6 h without a break, with several drivers reporting that they had to drive 24 h without rest. Almost 40 percent of the drivers reported being involved in at least one crash. Sleepiness was one of the most common causes of accidents [57]. A comparison between three Norwegian surveys on road safety, conducted in 1997, 2003, and 2008 showed that tiredness or sleepiness behind the wheel still contributes to between 1.9 and 3.9 per cent of all types of accident. Accident-involved drivers who were not responsible for the accident, reported a reduction in the incidence of sleep behind the wheel for the preceding year, decreasing from 8.3 per cent in 1997 to 2.9 per cent in 2008 [58].

Individual sleepiness symptoms are related to impairment during acute sleep deprivation and might be able to assist drivers in recognizing their own sleepiness and ability to drive safely. Research has revealed a few indicators of drowsiness and drowsy driving [59-61]. These include: frequent blinking, longer duration blinks and head nodding, having trouble keeping one’s eyes open and focused, memory lapses or daydreaming, drifting from one’s driving lane or off the road. As drivers are not always aware that they are becoming impaired as a result of sleepiness, using specific symptoms of sleepiness might assist with recognition of drowsiness-related impairment and help drivers judge whether they are safe to drive a vehicle. A recent study showed that symptoms related to visual disturbance and impaired driving performance are most accurate at detecting severely impaired driving performance [62].

Although people who fall asleep for more than a few minutes are often aware of those lapses in wakefulness, drivers may not be aware of shorter lapses and micro-sleeps, which can also have serious consequences when a quick reaction is needed to avoid high-speed crashes [63]. Most people also are not aware of how drowsiness affects their driving performance, even without falling asleep. Studies suggest that people cannot reliably detect how sleepy they are, and when they are likely to fall asleep, presumably because they are either unaware of, or do not pay attention to signs that sleep onset is likely [64]. People frequently deny how sleepy they are, and whether sleepiness interferes with their driving. Factors that strongly suggest a sleep-related accident include a vehicle leaving the road and a lack of braking, skid marks, or other evidence that the driver made no attempt to avoid crashing. Police investigators often take that evidence into consideration when classifying an accident as sleep-related.

Sleepiness caused by sleep disorders

Sleep disorders are the most common sources of excessive daytime sleepiness (EDS) and fatigue. Several studies performed in the last 20
years show a clear relationship between sleep disorders and RA. Those with OSAS frequently complain of EDS because of non-restorative and continuously disrupted sleep [65,66]. This is also the situation with other sleep disorders, such as restless leg syndrome, periodic limb movement disorder, narcolepsy, and insomnia [67].

Studies on the relationship between sleep disorders and RA are impressive. In an Australian study it has been observed that approximately 50% of injured motor drivers surviving vehicle collision had at least one sleep-related risk factor [68]. In a large cohort of regular highway drivers, 16.9% complained of at least one sleep disorder, 5.2% reported obstructive sleep apnea syndrome, 9.3% insomnia, and 0.1% narcolepsy and hypersomnia; 8.9% of drivers reported experiencing at least once a month an episode of sleepiness at the wheel so severe they had to stop driving. One-third of the drivers (31.1%) reported near-miss accidents (50% being sleep-related), 7.2% reported a driving accident in the past year, and 5.8% of these driving accidents were sleep-related [69].

OSAS, one of the main medical causes of excessive daytime sleepiness, has been shown to be a risk factor for motor vehicle crashes [70].

There are several reasons for this high prevalence. Firstly, the prevalence of OSAS is rather high in the general population, as it ranges between 2% and 4% [71]. In selected populations the prevalence of OSAS has been reported to range from 12% [72] to 26% [73] or even 50% [74].

Knowledge about risk is established for over 30 years. Findley et al. [75] found a higher risk of RA among patients suffering from sleep-related breathing disorders compared to controls. Haraldsson et al. [76] observed that the single-car accident rate was almost 12 times higher among patients with sleep spells whilst driving, compared to controls. A study on heavy vehicle drivers in the UK [77] showed that drivers who reported snoring regularly whilst sleeping at night or who were obese or who had a noticeably large collar size had higher accident liabilities than those not exhibiting these characteristics. Accident liability increased with increasing scores on the Epworth daytime sleepiness scale. Truck drivers with sleep-disordered breathing had a two-fold higher accident rate per mile than drivers without sleep-disordered breathing [66]. Connor et al. [49] showed that being sleepy while driving increased the risk of a serious injury crash by eight-fold.

Treating OSAS normalizes the rate of RA [70,78]. However, performance may remain impaired in patients with severe OSAS even after treatment [79]. A growing body of evidence indicates that some neurobehavioral deficits in patients with severe OSAS are not fully reversed by treatment. One of these may be resistance to monotonous driving conditions. With a normal night’s sleep, effectively treated older men with OSAS drive as safely as healthy men of the same age. However, after restricted sleep, driving impairment is worse than that of controls. This suggests that, although successful CPAP treatment can reverse the potentially detrimental effects of OSAS on monotonous driving following normal sleep, these patients remain more vulnerable to sleep restriction [80].

Despite the available scientific evidence, most countries in Europe do not include OSAS or EDS among the specific medical conditions to be considered when judging whether or not a person is fit to drive. There is no consistency in the way OSAS is considered by the national ‘Physical Fitness to Drive’ legislation within the 27 member countries of the European Union (EU), and most ignore OSAS. This is further reflected by the absence of any reference to OSAS in Annex III of the Directive 91/439/EEC, harmonizing Driving Licence regulations in the EU [81]. A common European Directive seems desirable.

**Individual prevention of drowsy driving crashes**

Experts agree that there is no substitute for sleep, so to prevent crashes; drivers should ensure they are well rested. Being aware of signs of drowsiness might be helpful, but only if drivers act on those signs by pulling off the road and getting sufficient sleep. If that is not possible, studies suggest two useful interventions: taking a short 20-minute nap, and/or drinking two cups of coffee or other equivalently caffeinated beverages. Caffeine will improve alertness only for a short period of time, and should not be relied upon to make up for a sleep deficit.

The use of drugs to ward off sleepiness has many drawbacks. There is no evidence that modafinil, the alertness enhancing drug, can reduce drowsy driving. In one small study in which sleep-deprived individuals were given the drug and then tested on a driving simulator, modafinil reduced lane deviation but had less effect on speed deviation, off-road incidents and reaction time, while self-assessments indicated that the drug gave the sleep-deprived participants false confidence in their driving abilities [82].

Patients receiving armodafinil had significantly greater improvements in late-in-shift clinical condition and in wakefulness and overall global functioning than did placebo-treated patients, regardless of shift duration [83].

There is also no evidence for anecdotal reports that opening car windows, stopping to stretch, or turning up the volume of a car radio can prevent drowsy driving crashes. In conclusion, drowsy driving is a prevalent and serious public health issue that deserves more attention and specific initiatives designed to educate drivers, save a significant number of lives and avert disability due to RA.

Recent data suggest that continuous blue light exposure during nocturnal driving resulted in significantly reduced ILC and weaving compared with caffeine placebo, and that it was similar to caffeine (a countermeasure reference) in improving driving ability [84].

Nowadays, the old saying that “only sleep can make up for a loss of sleep” is still true: napping before driving or stopped during driving for a nap is an effective countermeasure to alertness and performance deterioration associated with night work and sleepiness at the wheel [85].

**References**

1. http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2013_en.htm
2. Williamson A, Friswell R (2011) Investigating the relative effects of sleep deprivation and time of day on fatigue and performance. Accid Anal Prev 43: 690-697.
3. http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm
4. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Transport_accident_statistics
5. http://ec.europa.eu/transport/roadsafety_library/publications/final_programme_report.pdf
6. Dawson D, Searle AK, Paterson JL (2014) Look before you (s)leep: evaluating the use of fatigue detection technologies within a fatigue risk management system for the road transport industry. Sleep Med Rev 18: 141-152.
7. Magnaniva N (2013) The risk management of sleep disorders using the method ASIA. G H Med Lav Ergon 35 (Suppl 4): 20-21.
8. Anstey KJ, Wood J, Lord S, Walker JG (2005) Cognitive, sensory and physical factors enabling driving safety in older adults. Clin Psychol Rev 25: 45-65.

J Ergonomics Driver Safety ISSN: 2165-7556 JER, an open access journal
9. Anstey KJ, Horswill MS, Wood JM, Hatherly C (2012) The role of cognitive and visual abilities as predictors in the Multifactorial Model of Driving Safety. Accid Anal Prev 45: 767-774.

10. Fittoess AJ, Reyna LA, Horne JA (2012) Driver sleepiness-comparisons between young and older men during a monotonous afternoon simulated drive. Biol Psychol 89(3):580-3.

11. Gillberg M, Kecklund G, Arkestedt T (1996) Sleepiness and performance of professional drivers in a truck simulator—comparisons between day and night driving. J Sleep Res 5: 12-15.

12. Pizza F, Contardi S, Mondini S, Cirignotta F (2012) Impact of sleep deprivation and obstructive sleep apnea syndrome on daytime vigilance and driving performance: a laboratory perspective. G Ital Med Lav Ergon 34: 375-377.

13. Arkestedt T, Peters B, Anund A, Kecklund G (2005) Impaired alertness and performance driving home from the night shift: a driving simulator study. J Sleep Res 14: 17-20.

14. Howard ME, Jackson ML, Swann P, Berlowitz DJ, Grunstein RR, et al. (2014) Deterioration in driving performance during sleep deprivation is similar in professional and nonprofessional drivers. Traffic Inj Prev 15: 132-137.

15. Reyner LA, Wells SJ, Mortlock V, Horne JA (2012) ‘Post-lunch’ sleepiness during prolonged, monotonous driving - effects of meal size. Physiol Behav 105: 1088-1091.

16. Ojeda DA, Niño CL2, López-León S3, Camargo A2, Adan A4, et al. (2014) A functional polymorphism in the promoter region of MAOA gene is associated with daytime sleepiness in healthy subjects. J Neurol Sci 337: 176-179.

17. Van Dongen HP, Caldwell JA Jr, Caldwell JL (2011) Individual differences in cognitive vulnerability to fatigue in the laboratory and in the workplace. Prog Brain Res 190: 145-153.

18. Kosilowski M, Babkoff H (1992) Meta-analysis of the relationship between total sleep deprivation and performance. Chronobiol Int 9: 132-136.

19. Jackson ML, Gurzelmann G, Whitney P, Hinson JM, Belden G, et al. (2013) Deconstructing and reconstructing cognitive performance in sleep deprivation. Sleep Med Rev 17: 215-225.

20. Owsley C, Ball K, Sloane ME, Roemer RN, Bruni JR (1991) Visual/cognitive correlates of vehicle accidents in older drivers. Psychol Aging 6: 403-415.

21. Stutta J, Feaganes J, Reinfurt D, Rodgeman E, Hamlett C, et al. (2005) Driver’s exposure to distractions in their natural driving environment. Accid Anal Prev 37: 1093-1101.

22. Arnett JT, Geddes MA, MacLean AW (2005) Comparative sensitivity of a simulated driving task to self-report, physiological, and other performance measures during prolonged wakefulness. J Psychosom Res 58(1):61-71.

23. McKnight AJ, McKnight AS (1999) Multivariate analysis of age-related driver ability and performance deficits. Accid Anal Prev 31: 445-454.

24. Dingess DF, Pack F, Williams K, Gillen KA, Powell JW, et al. (1997) Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep 20: 267-277.

25. Van Dongen HP, Maislin G, Mullington JM, Dingess DF (2003) The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 26;5(2):117-26

26. Bauk SD, Biggs SN, Reid KJ, van den Heuvel CJ, Dawson D (2008) Chasing the silver bullet: measuring driver fatigue using simple and complex tasks. Accid Anal Prev 40: 396-402.

27. Lundqvist A (2001) Neuropsychological aspects of driving characteristics. Brain Inj 15: 981-994.

28. Sztylik JP, Myers L, Zhang Y, Wetzel L, Shapiro R (2002) Development and assessment of a neuropsychological battery to aid in predicting driving performance. J Rehabil Res Dev 39: 483-498.

29. Williamson AM, Feyer AM (2000) Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. Occup Environ Med 57(10):649-55.

30. van Steveninck AL, van Berckel BN, Schoemaker RC, Bremer DD, van Gerven JM, et al. (1999) The sensitivity of pharmacodynamic tests for the central nervous system effects of drugs on the effects of sleep deprivation. J Psychopharmacol 13: 10-17.

31. Daigneault G, Joly P, Frigon JY (2002) Executive functions in the evaluation of accident risk of older drivers. J Clin Exp Neuropsychol 24: 221-238.

32. Griffith HR, Okonkwo OC, Stewart CC, Stoeckel LE, Hollander JA, et al. (2013) Lower hippocampal volume predicts decrements in lane control among drivers with amnestic mild cognitive impairment. J Geriatr Psychiatry Neurol 26: 256-266.

33. Jackson ML, Howard ME, Barnes M (2011) Cognition and daytime functioning in sleep-related breathing disorders. Prog Brain Res 190: 53-68.

34. Jackson ML, Croft RJ, Kennedy GA, Owens K, Howard ME (2013) Cognitive components of simulated driving performance: Sleep loss effects and predictors. Accid Anal Prev 50: 438-444.

35. Ohayon MM, Lemoine P, Arnaud-Briant V, Dreux M (2002) Prevalence and consequences of sleep disorders in a shift worker population. J Psychosom Res 53: 577-583.

36. Léger D, Bayon V, Ohayon MM, Philip P, Ement P, et al. (2014) Insomnia and accidents: cross-sectional study (EQUINOX) on sleep-related home, work and car accidents in 5293 subjects with insomnia from 10 countries. J Sleep Res 23: 143-152.

37. Connor J, Whitlock G, Norton R, Jackson R (2001) The role of driver sleepiness in car crashes: a systematic review of epidemiological studies. Accid Anal Prev 33: 31-41.

38. Håkkinen H, Summalta H (2000) Sleepiness at work among commercial truck drivers. Sleep 23: 49-67.

39. Håkkinen H, Summalta H (2001) Fatal traffic accidents among trailer truck drivers and accident causes as viewed by other truck drivers. Accid Anal Prev 33: 187-196.

40. Garbarino S, Nobili L, Beelke M, De Carl F, Ferlini F (2001) The contributing role of sleepiness in highway vehicle accidents. Sleep 24: 203-206.

41. Mitter MM, Carskadon MA, Czeisler CA, Dement WC, Dinges DF, et al. (1988) Catastrophes, sleep, and public policy: consensus report. Sleep 11: 100-109.

42. Costa G, Accottoli MP, Garbarino S, Magnavita N, Roscelli F (2013) [Sleep disorders and work: guidelines for health surveillance, risk management and prevention]. Med Lav 104: 251-266.

43. NTSB National Transportation and Safety Board. (1990) Safety Study. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes.

44. Philip P, Arkestedt T (2006) Transport and industrial safety, how are they affected by sleepiness and sleep restriction? Sleep Med Rev 10: 347-356.

45. Franco EL, Duarte-Francio E, Ferenczy A (2003) Prospects for controlling cervical cancer at the turn of the century. Salud Publica Mex 45 Suppl 3: 3367-375.

46. Pack AI, Maislin G, Staley B, Pack FM, Rogers WC, et al. (2006) Impaired performance in commercial drivers: role of sleep apnea and short sleep duration. Am J Respir Crit Care Med 174: 446-454.

47. Horne JA, Reynar LA (1995) Sleep related vehicle accidents. BJM 310: 565-567.

48. Philip P, Vervialle F, Le Breton P, Taillat J, Horne JA (2001) Fatigue, alcohol, and serious road crashes in France: factorial study of national data. BMJ 322: 829-830.

49. Connor J, Norton R, Ameratunga S, Robinson E, Civil I, et al. (2002) Driver sleepiness and risk of serious injury to car occupants: population based case control study. BMJ 324: 1125.

50. Herman J, Kafoa B2, Niño CL2, López-León S3, Camargo A2, Adan A4, et al. (2014) A cmvfatiguestudy.htm#intro

51. http://www.fmcsa.dot.gov/facts-research/research-technology/publications/cmffatiguestudy.htm#intro
54. NTSB. Factors that affect fatigue in heavy truck accidents. National Transportation Safety Board, Safety Study, 1995,NTSB/SS-85/01.

55. http://www.nhtsa.gov/Driving+Safety

56. Quera Salva MA, Barbot F2, Hartley S3, Sauvagnac R4, Vaugier I2, et al. (2014) Sleep disorders, sleepiness, and near-miss accidents among long-distance highway drivers in the summertime. Sleep Med 15:23-26.

57. Kircher K, Andersson J (2013) Truck drivers’ opinion on road safety in Tanzania—a questionnaire study. Traffic Inj Prev 14:103-111.

58. Phillips RO, Sagberg F (2013) Road accidents caused by sleepy drivers: Update of a Norwegian survey. Accid Anal Prev 50:139-146.

59. Papadelis C, Chen Z, Kourtidou-Papadeli C, Bamidis PD, Chouvarda I, et al. (2007) Monitoring sleepiness with on-board electrophysiological recordings for preventing sleep-deprived traffic accidents. Clin Neurophysiol 118:1906-1922.

60. Papadelis C, Lihhari C, Kourtidou-Papadeli C, Bamidis PD, Portouli E, et al. (2009) Monitoring driver’s sleepiness on-board for preventing road accidents. Stud Health Technol Inform 150:485-489.

61. Mathis J, Hess CW (2009) Sleepiness and vigilance tests. Swiss Med Wkly 139:214-219.

62. Howard ME, Jackson ML, Berlowitz D, O’Donoghue F, Swann P, et al. (2014) Specific sleepiness symptoms are indicators of performance impairment during sleep deprivation. Accid Anal Prev 62:1-8.

63. Powell NB, Chau JK (2010) Sleepy driving. Med Clin North Am 94:531-540.

64. Herrmann US, Hess CW, Guggisberg AG, Roth C, Gugger M, et al. (2010) Sleepiness is not always perceived before falling asleep in healthy, sleep-deprived subjects. Sleep Med 11:747-751.

65. Young T, Palta M, Dempsey J, Skatrud J, Weber S, et al. (1993) The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 328(17):1230–5.

66. Strohs RA, Bingham LA, Ito A, Guilleminault C, Dement WC (1995) Sleep and sleep-disordered breathing in commercial long-haul truck drivers. Chest 107:1275-1282.

67. Chayon MM, Caulet M, Philip P, Guilleminault C, Priest RG (1997) How sleep and mental disorders are related to complaints of daytime sleepiness. Arch Intern Med 157:2645-2652.

68. Cramm F, Cameron PA, Swann P, Kossmann T, Naughton MT (2008) Prevalence of sleepiness in surviving drivers of motor vehicle collisions. Intern Med J 38:769-775.

69. Philip P, Sagaspe P, Lagarde E, Leger D, Ohayon MM, et al. (2010) Sleep disorders and accidental risk in a large group of regular registered highway drivers. Sleep Med 11:973-979.

70. Alonderis A, Barbe F, Bonsignore M, Calverley P, De Backer W, et al. (2008) Medico-legal implications of sleep apnoea syndrome: driving license regulations in Europe. Sleep Med 9:362-375.

71. Young T, Blustein J, Finn L, Palta M (1997) Sleep-disordered breathing and motor vehicle accidents in a population-based sample of employed adults. Sleep 20:608-613.

72. Garbarino S, Magnavita N (2014) Obstructive sleep apnea syndrome (OSAS), metabolic syndrome and mental health in small enterprise workers. Feasibility of an action for health. PlosOne, 2014 (in press)

73. Engleman HM, Hirst WS, Douglas NJ (1997) Under reporting of sleepiness and driving impairment in patients with sleep apnoea/hypopnoea syndrome. J Sleep Res 6:272-275.

74. Strohs RA, Guilleminault C, Ito A, Dement WC (1994) Traffic accidents in commercial long-haul truck drivers: the influence of sleep-disordered breathing and obesity. Sleep 17:619-623.

75. Findley LJ, Unverzagt ME, Suratt PM (1988) Automobile accidents involving patients with obstructive sleep apnea. Am Rev Respir Dis 138:337-340.

76. Haraldsson PO, Carenflett C, Diderichsen F, Nygren A, Tingvall C (1990) Clinical symptoms of sleep apnoea syndrome and automobile accidents. ORL J Otorhinolaryngol Relat Spec 52:57-62.

77. Maycock G (1997) Sleepiness and driving: the experience of heavy goods vehicle drivers in the UK. J Sleep Res 6:238-244.

78. Sassani A, Findley LJ, Kryger M, Goldlust E, George C, et al. (2004) Reducing motor-vehicle collisions, costs, and fatalities by treating obstructive sleep apnea syndrome. Sleep 27:453-458.

79. Vakulin A, Bauld SK, Catcheside PG, Antic NA, van den Heuvel CJ, et al. (2011) Driving simulator performance remains impaired in patients with severe OSA after CPAP treatment. J Clin Sleep Med 7:246-253.

80. Filtness AJ, Reyner LA, Home JA (2011) Moderate sleep restriction in treated older male OSA participants: greater impairment during monotonous driving compared with controls. Sleep Med 12:838-843.

81. Rodenstein D Cost-B26 Action on Sleep Apnoea Syndrome (2008) Driving in Europe: the need of a common policy for drivers with obstructive sleep apnoea syndrome. J Sleep Res 17:281-284.

82. Gurtman CG, Broadbear JH, Redman JR (2008) Effects of modafinil on simulator driving and self-assessment of driving following sleep deprivation. Hum Psychopharmacol 23:681-692.

83. Harsh J, Yang R, Hull SG (2014) The impact of shift duration on the efficacy and tolerability of armodafinil in patients with excessive sleepiness associated with shift work disorder. Curr Med Res Opin.

84. Taillard J, Capelli A, Sagaspe P, Anund A, Akerstedt T, et al. (2012) In-car nocturnal blue light exposure improves motorway driving: a randomized controlled trial. PLoS One 7:e46750.

85. Garbarino S, Mascialino B, Penco MA, Squarcia S, De Carlì F, et al. (2004) Professional shift-work drivers who adopt prophylactic naps can reduce the risk of car accidents during night work. Sleep 27:1295-1302.