

SLEEPINESS

AT

THE WHEEL

WHITE PAPER

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Improving road safety is a priority of the French Government.

Among the various causes of road accidents, one of them is especially common on motorways: lack of alertness, which leads to inattention and sleepiness.

Lack of alertness is responsible for one in three collisions resulting in deaths on the motorway network, although it is the safest of all road networks!

This phenomenon is not fully grasped by the public. Therefore, it is essential to gain knowledge and raise the public's awareness as regards sleepiness at the wheel.

In more general terms, sleepiness at the wheel remains underestimated both socially and culturally speaking, which is a major issue for road safety and public health.

This white book, put together by the French Motorway Companies (ASFA) and the National Institute of Sleep and Vigilance (INSV), presents the most recent knowledge on the subject at both the French and European levels and provides a number of recommendations.

By contributing to a better understanding of sleepiness at the wheel, this work will help promote the implementation of new prevention strategies, to further reduce the number of victims on the road. Our objective is to cut down to less than 2000 the number of deaths per year on French roads by 2020.



Manuel VALLS
French Minister of Interior

ASFA and INSV would like to express their deep thanks to the panel of European sleep experts who author this book. Most of them also participate in the research on traffic accidents associated with sleepiness in their own country and thus have contributed to enrich our knowledge and proposals for preventing from the consequences of sleepiness at the wheel.

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PROFESSIONAL ASSOCIATION OF TOLL ROAD COMPANIES

ASFA is the French professional association comprising all actors involved in motorway exploitation and concession. Company members operate about 9000 km of high safety and service level infrastructures.

Its corporate purposes are to:

- Defend the interests of the French toll-road industry
- Communicate on issues relevant to the profession as a whole
- Negotiate on employment and social issues
- Develop non-commercial international relations
- Carry out research and conduct surveys

Since becoming the first cause of motorway accidents, sleepiness at the wheel represents a major stake as regards to road safety. Consequently, ASFA and motorway operators have placed fighting this phenomenon at the heart of their safety program.

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The French Institut of Sleep and Vigilance (INSV) was launched in 2000 by the French Sleep Society (SFRMS).

Its vocation is to promote sleep and its disorders as part of public health. Its missions are to raise awareness, inform and educate on sleep and vigilance disorders.

As a federative body, it brings together the entire sleep community: Learned societies, patient associations and healthcare professionals. Its board of directors is made up of doctors and researchers –all sleep experts and leaders in their field.

This genuine French communication and prevention interface has invested much of its energy, during the past 12 years, into having sleep acknowledged as a central factor for individual and collective health.

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The aim of the current booklet is to complement and update the data of “Sleepiness at the wheel”, Eranet transport - ENT Action Group 15, 2009, coordinated by Pr René Amalberti, Health care Adviser at HAS and Scientific director at the MACSF insurance group.

EXECUTIVE SUMMARY

Sleepiness at the wheel is one of the recently uncovered reasons behind a large proportion of fatal car crashes around Europe. Although it is often difficult to determine precisely how much responsibility can be attributed to sleepiness in certain traffic accident situations, it is estimated to underlie about 20% of car crashes in Europe. In this regard, national statistics have been put forward by a few European countries. In France, a preliminary report published in 2011 stated that from a total of 3970 fatal accidents that took place on French roads, 732 cases occurred on straight roads, 85% of which were related to sleepy driving.

In the United Kingdom, the national database indicates a low incidence of drowsy driving (around 4%) but this estimate is most certainly largely underestimated, probably due to the mode of reporting. In Germany, drowsiness is reportedly implicated in 25% of all fatal road accidents. In Italy, although recent data are missing, sleepiness is estimated to be involved in about 22% of road accidents. In Scandinavian countries, a recent Swedish pilot study found that drivers admitted experiencing sleepiness in 15% of road crashes. In Finland, an analysis of the national database on road accidents from 1991 to 2001 found that 15.3% of accidents were related to fatigue/sleepiness.

While the loss of human lives and disability are the most afflicting consequences, sleepiness-related collisions also have a major economic impact. It is thus indispensable to better understand how and when sleep-related traffic accidents occur, and to anticipate new strategies to prevent them as effectively as possible.



In order to understand how sleepiness occurs, it is important to acknowledge certain central aspects of its biology. Sleep and wakefulness are essentially determined by two independent regulatory mechanisms: the 'body clock' and 'sleep pressure.' Both mechanisms can be involved in sleepy driving. The body clock is responsible for the 24-hour rhythm that regulates sleep and wakefulness: sleepiness peaks between 2 and 6 am and to a lesser extent between 2 and 4 pm, which explains the surge of sleep-related traffic accidents that occur during those particular time slots. In parallel, sleep pressure progressively increases during the day: the longer the trip, the higher the risk of sleepiness. Overall, the sleep/wake cycle is a response to the dynamic balance between both mechanisms.

When drivers are affected by sleepiness or fatigue, their performance can become seriously impaired, especially at attention and decision-making on the road. Several objective and subjective methods exist to measure sleeping at the wheel, but all have their limits: objective methods are able to reliably detect sleepiness but most of them need to be conducted in specific conditions -such as a sleep lab- that do not accurately reproduce real-life driving conditions. Subjective methods can help detect the risk of sleepiness in certain situations of day-to-day life and are easier to set up, but they cannot be used directly at the wheel.

Besides the individuals' internal sleep/wake mechanisms, a variety of external factors also influence sleepiness at the wheel and tend to add up exponentially. Some of them are behavioural: sleep deprivation, irregular working hours, length of time spent at the wheel, driving in monotonous environments.

Sleep disorders like sleep apnoea, insomnia or narcolepsy, may severely impact daytime vigilance, but also pathologies that have the potential to trigger sleep disorders, such as depression for example. Certain medications (hypnotics, anxiolytics, antiallergic and antiepileptic drugs) also reduce alertness. Psychoactive substances such as alcohol or cannabis add their deleterious effects to sleep deprivation and fatigue in young drivers, thus further increasing the risk of sleepiness.

Certain populations are considered particularly at risk since they combine several risk factors: shift workers, professional drivers and young drivers. To combat sleepiness at the wheel, several types of measures have been put in place and need to be expanded globally:

- On the manufacturer side, in-vehicle mechanisms have been invented to detect and inform drivers of signs of sleepiness or vigilance impairment. For instance: lane departure warning systems, but also systems monitoring driver-behaviour directly. Because the safety and the full-reliability of these devices has yet to be established, drivers should not depend entirely on them but rely on their own insight to evaluate their sleepiness. Indeed, the driver is responsible for his state of alertness at the wheel.
- On the side of road infrastructure: rumble strips, resting areas and less monotonous road designs are tools that have proven effective at keeping drivers alert.
- On the side of employers of commercial drivers: regulations concerning hours of service have been put in place.
- Concerning driver behaviour: it is important to avoid sleep deprivation before taking the wheel, to choose certain times of the day rather than others if possible when hitting the road (for instance avoiding early morning hours -2 to 6 am -and mid-afternoon hours -2pm to 4pm), to take regular breaks and naps. These are effective measures on which the public needs to be further educated.

The legal aspects associated with sleepiness comprise another area that needs to be actively revisited. In this context, the role physicians can play in alerting patients at risk of sleepiness at the wheel because of pathology or medication they are on is essential, and more training is definitely needed to keep health care practitioners up to date on applicable driving laws. Researchers and physicians should establish fair and accurate performance criteria to predict patients' driving ability with various conditions: this may reduce the risk of motor vehicle crashes and protect others from arbitrary and possibly unfair licence revocation.

More campaigns targeting drivers, especially the at-risk populations, also need to be deployed, in combination with other interventions, such as enforcement of traffic laws and regulations. Such campaigns have recently been conducted in a few European countries and have proven to be effective at improving drivers' knowledge on sleepiness and its risks.

However, they have not appeared to significantly impact the rate of sleep-related car crashes – which is the ultimate goal. Other campaigns involving several European Union (EU) countries are currently on-going and have been designed to determine the efficacy of new in-car systems and to evaluate the behaviour of drivers using these systems.

In all these domains, new approaches still need to be proposed and investigated. Hereunder are some of the authors' proposals:

On campaigns/communication

- Educational campaigns focusing on at-risk populations such as adolescents, professional drivers and shift workers
- Display of information on highways, especially during the most dangerous driving hours (e.g. afternoon, early morning hours), but also broadcasted on radio stations focusing on traffic information

On training

- Training of (future) drivers in driving school, through instructors
- In case of psychoactive drug use, information must be clearly provided by the physician on whether or not it is safe to drive. If sleepiness is a common adverse effect of the drug, patients must think of asking for alternative medication that does not impair driving

On legal aspects

- Work on European legislation regarding drivers who suffer from diagnosed and acknowledged sleep disorders
- Detection and management of sleepiness among professional drivers, especially lorry-drivers

On new directions

- Improved detection of sleepiness
- Better knowledge of determinants of dangerous behaviour

INTRODUCTION

Claudio Bassetti and Damien Léger

According to the European Commission's Directorate General for Mobility and Transport, road deaths have been decreasing year by year across the whole European Union, with a 43% drop since 2001. However, traffic accidents were still responsible for 30,900 road fatalities and 1.7 million injuries in 2010. To continue lowering these numbers, it is indispensable to better understand how and when traffic accidents occur and to anticipate new strategies to prevent them.

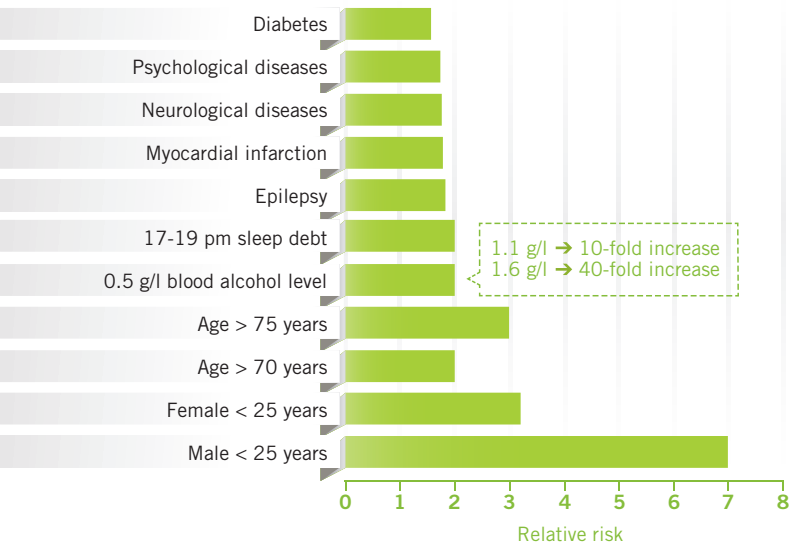
One of the reasons behind fatal car crashes includes sleepiness at the wheel, a phenomenon to which this report is dedicated.

Experts like to compare the effect of sleepiness at the wheel to those of alcohol (which itself is legally punished when associated with driving): studies have shown that driving following a sleepless night is equivalent to hitting the road with an alcohol blood concentration of 0.9 g/l, which exceeds legal limits in all EU-countries.

Road accidents caused by a driver falling asleep at the wheel are particularly severe: they are very likely to result in death because of the uncontrolled speed of the car during the impact and the driver's failure to brake.

...

Probability of an accident according to different risk factors



This table highlights that a blood alcohol level of 0.5 g/l doubles the risk of accidents compared to a blood alcohol level of a sober driver. A blood alcohol level of 1.1 g/l is associated with a 10-fold increased risk of accident and a blood alcohol level of 1.6 g/l is associated with a 40-fold increased risk of accident. Male drivers 25 years old and under are also at a significantly higher risk of accident.

Source: Epilepsy and driving in Europe. Final report of the Working Group on Epilepsy. Project UE IMMORTAL, Publications R1.1 et R1.2. Adapted with permission.

Unfortunately, sleepiness at the wheel is not uncommon. In France, for instance, a 2010 epidemiologic survey, based on telephone interviews of nearly 4,800 French drivers, showed that 1 in 3 participants reported experiencing at least one episode of severe sleepiness at the wheel during the previous year. More than 1 in 10 reported at least one “near-miss accident” in the previous year, half of which were sleep-related.

Collecting objective data concerning car crashes due to sleepiness is difficult, the main issue being it is often hard to estimate the state of a driver right before a crash. Consequently, the proportion of fatigue-related accidents in police reports and accident databases from different jurisdictions varies greatly.

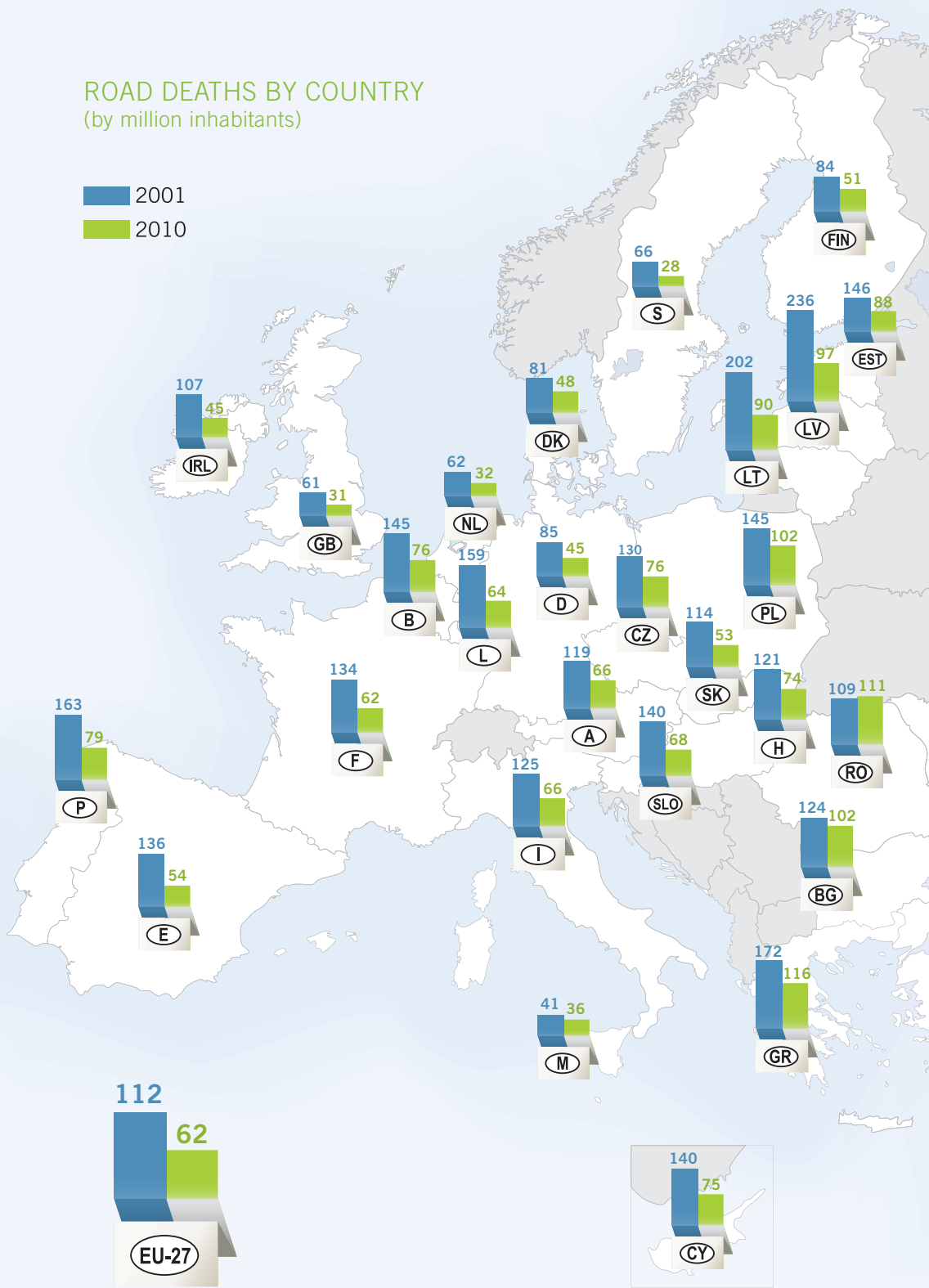
Here are some of the most recent statistics issued by a few European countries:

FRANCE

A preliminary report on traffic accidents published in 2011 stated that from a total of 3970 deaths on French roads, 732 cases occurred on straight roads. Among them, 85% were related to sleepy driving, the remaining 15% to distraction.

ROAD DEATHS BY COUNTRY
(by million inhabitants)

2001
2010



Source: European Commission, State: July 2011.
Adapted with permission.

THE UK

Data are scarce in the UK. In the national database, drowsy driving is reported in about 4% of all road crashes. However, the term “fatigue” is only used in very specific unequivocal situations by UK police officers. Thus, it is most probable that its incidence is largely under-estimated. In a 2004 publication, authors found that 17% of road traffic collisions were sleep-related.

GERMANY

Drowsiness is currently implicated in 25% of all fatal road traffic accidents in the country. In 2009, 4154 deaths were recorded on German roads, which is the lowest estimate since 1950. The figures peaked in 1970 with 21,332 road fatalities. Since then, the number of deaths on the road has fallen by around 80 per cent. According to scientific studies, material-damage amounting to some five billion euros is caused by sleepy drivers each year in Germany.

SPAIN

In a 2010 publication, authors reported the results of a survey, carried out by the Spanish Institute of Health and Safety in the Workplace, showing that 45% of road accidents are due to distraction, recklessness, absent-mindedness and lack of attention, which are all often related to a lack of rest/sleep.

ITALY

Recent data are scarce. Based on numbers put forward by the Italian National Institute of Statistics, a 2001 publication reported that between 1993 and 1997, 21.9% of road accidents were sleep-related.

SWEDEN

A recent pilot study found that in approximately 15% of crashes, drivers admitted experiencing sleepiness. When considering the most significant risk factors (i.e. remaining awake during more than 16 hours in a row, sleeping less than 6 hours during the 24 hours prior to departure, taking the road at 2-6 am or 2-4 pm, presenting sleep disturbances), around 35% of drivers fulfilled at least one of the criteria. In order to estimate the prevalence of driving while sleepy, the Swedish Transport Administration has been screening, on a yearly basis, a random sample of 11 000 people, asking if they had experienced severe sleepiness or if they had almost fallen asleep while driving in the past 12 months. The most recent results, dating from the 2011 survey, state that more than 15% of individuals reported experiencing sleepiness. The group reporting the highest prevalence was that of young drivers.

FINLAND

An analysis of the national database including about 1400 car drivers held legally responsible for a fatal road accident between 1991 and 2001 showed that 15.3% of cases were considered fatigue-related accidents. During the years 2006 to 2010, 17% of fatal motor vehicle accidents were due to fatigued drivers, which were responsible for 18% of deaths on the road.

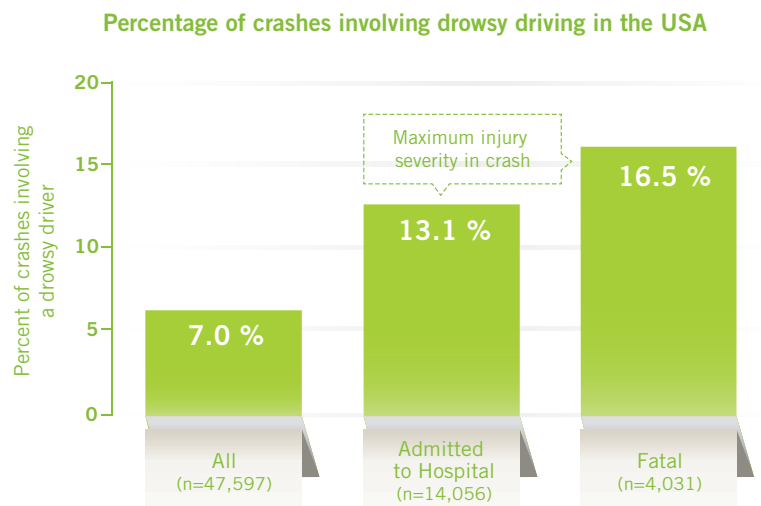
EUROPE

Overall, sleepiness at the wheel is considered responsible for 20 to 25% of traffic accidents occurring on European roads.

While the loss of human lives and disability are the most afflicting consequences, sleepiness-related collisions also have a major economic impact. There have been occurrences of commercial-vehicle sleepiness collisions destroying bridges over interstate motorways, causing major disruption to the transportation system and to the economy in the USA. In 2011, the United States reported a \$230 billion societal cost for motor vehicle crashes. Direct and indirect costs of car accidents amounted 160 billion in 2007 for the whole European Union.

This cost is phenomenal and several experts share the opinion that sleepiness is not sufficiently recognized and reported as a causal factor for road accidents, and that more efforts need to be deployed in this area.

The following figure shows the weight of drowsy driving in fatal road accidents (up to 16.5%) in the 1999-2008 period in the USA.



Estimated proportion of crashes involving a drowsy driver, by maximum injury severity in crash. Study population: crashes that involved a passenger vehicle that was towed from the scene, United States, 1999–2008.

Adapted from BC Tefft. Prevalence of motor vehicle crashes involving drowsy drivers, United States, 1999–2008. Accident Analysis & Prevention, 2012, vol 45, 180–6 with permission.

How do we analyse sleepiness at the wheel –what causes it, how do we measure sleepiness, and who are the populations most at risk? These are some of the questions chapter 1 explores. It also goes through several of the behavioural factors influencing alertness –such as sleep deprivation, irregular working schedules, timing and length of driving –but also factors such as medical conditions or the use of psychoactive substances and medication.

Chapter 2 summarizes some of the countermeasures that have been put forward so far to fight against sleepiness at the wheel. After focusing on in-vehicle detection and warning devices that have been put in place in recent years, the report goes into describing measures targeting road infrastructure, driver behaviour and employer awareness.

In Chapter 3, some of the major legal aspects that are still necessary to bring forward are presented, as well as examples of European-wide and national campaigns, which can serve as bases for upcoming initiatives.

To conclude, lead European sleep experts present 15 proposals to implement effective new countermeasures to further decrease the prevalence of sleep-related-accidents in Europe.

Chapter I

ANALYZING SLEEPINESS AT THE WHEEL

A. Sleep/wake characteristics and methods for measuring sleepiness

Fabio Cirignotta, Thomas Penzel and Markku Partinen

1. THE SLEEP/WAKE CYCLE

Sleep provides the body and mind with the necessary time to rest, recuperate and reenergize for the next day. In the adult general population, seven to eight consecutive hours are considered a healthy length of time spent asleep. During the wake period, signs of sleepiness indicate the likelihood of falling asleep.

Sleep and wakefulness are essentially determined by two independent regulatory mechanisms: the 'body clock' and 'sleep pressure' (also known as sleep homeostasis):

- The body clock, physically located in the brain, is responsible for 24-hour rhythms, known as circadian rhythms, which control several functions including sleep and wakefulness. The circadian rhythm in sleepiness peaks in the early hours of the morning (2-6 am), with another rise mid-afternoon (2-4 pm).
- Sleep pressure is the amount of fatigue that accumulates progressively throughout the day, due to daytime cerebral/mental activity mainly. As waking duration increases, sleep pressure increases, which progressively increases the feelings of daytime sleepiness.



The sleep/wake cycle is thus a response to the dynamic balance between both regulatory mechanisms. On top of these integrated factors of influence, sleepiness can be influenced by a variety of external factors, which tend to add up exponentially.

Behavioural factors (such as a disturbed sleep-wake schedule), sleep disorders (for instance sleep apnoea syndrome), drugs (for instance hypnotics or anxiolytics) or alcohol intake –all account for increased sleepiness.

When drivers are affected by sleepiness or fatigue, their performance can become seriously impaired, especially at attention and decision-making. They are prone to a loss of alertness, difficulty keeping their eyes in focus, loss of concentration and wandering thoughts, reduced awareness of the environment and memory lapses. Individuals starts failing to check their rear view mirrors as frequently as they should, they present unconscious variations in speed, and erratic changing, drifting out of lanes. It is thus critical to identify the external factors influencing sleepiness to learn how to best manage them and reduce the likelihood of human error.

Before going into the details of the various factors influencing sleepiness, here is a short summary of the most common methods currently used to measure sleepiness at the wheel. This evaluation of sleepiness is indeed indispensable to better understand its pattern of occurrence, and to establish effective countermeasures for road safety. A variety of strategies have been proposed to evaluate the risk of drowsy-driving accidents. Some methods are cheap and easy to perform on a wide number of subjects, like the Epworth Sleepiness Scale (see page 26), while others are more expensive and time-consuming. Some are performed in the laboratory, others can be performed in real-life situations, or in a driving simulator. The choice of method depends on the circumstances and purpose of those measurements.

2. MEASUREMENT TOOLS OF DAYTIME SLEEPINESS

Objective methods

Objective methods for measuring daytime sleepiness use a variety of physiological variables as indicators of an individual's drowsy state. These objective measurement tools are useful in that they are not influenced by possible self-reporting biases.

The Multiple Sleep Latency Test and the Maintenance of Wakefulness Test

Two objective clinical measures, The Multiple Sleep Latency Test (MSLT) and Maintenance of Wakefulness Test (MWT), are sensitive predictors of daytime sleepiness and driving performance. The main difference between both methods is that MSLT involves lying in a dark room where the participant is instructed to initiate sleep, whereas the MWT involves sitting on a comfortable chair in a semi-dark room where the participant is instructed to try to avoid falling asleep. The sooner participants enters sleep, the higher their objective sleepiness rating. Brain activity is recorded during the test.

One limitation in these approaches is that both tests provide a very different environment to that of driving, and do not require participants to conduct tasks similar to driving. Nonetheless, the MSLT and MWT have been found

to correlate with subjective sleepiness measures, driving performance indicators, and have shown sensitivity to sleep deprivation.

Electroencephalography

Brain activity recorded via electroencephalography (EEG) can also be used out of the laboratory to evaluate sleepiness without the need for participants to actually fall asleep to achieve a measurement. This type of objective sleepiness measure may be more indicative of a participant's current state of sleepiness when at the wheel, and has been used in a number of sleep-related on-road and simulated driving studies.

Video recording of eye movements

In recent years, new methods based on eyelid movement and eye-closure have been specifically developed to measure drowsiness while driving. An increase in eye blink duration is associated with an increase in sleepiness. Similarly, an increase in slow eye movements and eye blink frequency are also associated with increasing sleepiness. One such method uses video recordings to determine the percentage of time an eye-lid remains closed at approximately 80% of total closure. A commercial drowsiness detector based on this technique is now available on the market. Its sensor is placed on the dashboard and measures eyelid closure. In the commercial trucking industry, drivers using this detector not only receive a warning when they start becoming sleepy, this information can also be instantly relayed to fleet managers. However, the sensitivity of this sensor is still questionable.

An alternative method uses infrared reflectance oculography to measure the relative velocity and duration of eyelid movements during blinks and especially the short-term variability of those characteristics. This relatively new drowsiness monitor is also commercially available. The system requires drivers to wear a special set of glasses that send and receive infrared light pulses to measure the velocity of the drivers' eyelids. A computer system is installed to process this information and provide feedback on drowsiness in the form of a score displayed on the dashboard. Here again, the sensitivity of the system needs to be further established.

Psychomotor Vigilance Test

Another approach is based on the measurement of the drivers' reaction time. One such test, the Psychomotor Vigilance test (PVT), is often used to assess commercial driver sleepiness in the United States. The PVT is based on a simple task where the subject presses a button as soon as a stimulus -such as a light- appears. The stimulus will turn on randomly every few seconds for 5–10 minutes. The purpose of the PVT is to measure sustained attention, and give a numerical measure of sleepiness by counting the number of lapses in attention of the tested subject.

Limitations of current measurement tools

These objective measures of sleepiness present important technical issues, which need to be addressed in further research to improve their use. Of major importance is the difficulty in differentiating levels of sleepiness and the specificity of recordings, i.e., whether sleepiness, rather than attention, is actually being measured. In addition to these issues, physiological measures can be more time consuming, difficult to set up, and can be highly costly and relatively easily damaged.

Subjective methods

The Epworth Sleepiness Scale

One of the most commonly used methods for measuring sleepiness, the Epworth Sleepiness Scale (ESS), is quite different from the other methods described above, as it is based on a subjective approach. It is a scale intended to evaluate daytime sleepiness, measured using a short questionnaire. Subjects are asked to rate their likelihood of dozing off in different daily life situations. The higher the score, the higher the individual's level of daytime sleepiness. While this test does not provide a diagnostic in itself, the ESS score can indicate the need to seek for expert medical advice.

Tests such as the ESS have the advantage of not influencing the behaviour of the driver –they do not constantly draw attention to his sleepiness. Thus the ESS has been extensively used as a research tool in studies of road crashes and driver impairment, however is less useful for the development of in-car sleepiness countermeasures.

The Epworth Sleepiness Scale

- 0= no chance of dozing
1= slight chance of dozing
- 2= moderate chance of dozing
3= high chance of dozing

SITUATION	CHANCE OF DOZING
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	
TOTAL	

- A score ≥ 10 indicates a significant reduction of alertness requiring a medical consultation.
- A score ≥ 16 indicates a pathological level of sleepiness.

Other scales measuring sleepiness are the Stanford Sleepiness Scale and the Karolinska Sleepiness Scale, which are less frequently used. Validity and reliability have been reported for both.

***Tests specially designed for evaluating sleepiness during driving:
Measurement of standard deviation of lateral position***

Measuring the standard deviation of lateral position (SDLP) reflects how well subjects maintain their lane position. It provides an index for each subject's road tracking error and ability to control the lateral motion of the vehicle. This test has a high test-retest reliability, and thus can provide useful information on increasing sleepiness and decreasing attention at the wheel. SDLP is measured in centimetres, using an electro-optical device mounted on the rear of the vehicle that continuously records lateral position relative to lane-line delineation.

As each measurement tool provides different types of information, they should be considered complementary. Researchers should use these various approaches keeping the limits of each one in mind, choosing depending on their research objectives, time and resources.

In conclusion, objective measurement tools are useful in that they are not influenced by possible self-reporting biases. However, some of these approaches, because they require participants to actually fall asleep to achieve a measurement, are impossible to implement in real-life situations. Others can be cumbersome, time-consuming and expensive to set up. Subjective methods such as the Epworth Sleeping Scale are easier to execute but do not provide a diagnostic per se. Again, one of the major issues at play is whether sleepiness or another related concept is the dimension actually being measured. Studies have pointed out that this issue is already difficult at the individual level: subjective assessments made by drivers do not robustly relate to actual driving performance either in terms of judgments about alertness before the drive or ratings of performance after the drive.

B. Behavioural factors influencing alertness

Tobjorn Akerstedt and Pierre Philip

Among the different types of factors influencing sleepiness, behavioural factors are the most common to occur in the general population. Lack of sleep, long working hours and working during time-slots of low alertness, insufficient rest between work periods and excessive work load are among the main factors that can cause fatigue.

1. SLEEP DEPRIVATION

Sleep deprivation is considered to be one of the primary causes of fatigue and sleepiness. Consecutive nights of sleep deprivation -partial or total- lead to what is called a "sleep debt." If an individual's sleep debt becomes too important, he eventually goes to sleep, involuntarily. While it has long been known that total sleep loss can have a devastating impact on driving

performances, recent research has shown that even one night of partial sleep deprivation (where sleep duration is restricted to four hours for instance) can significantly impair driving performance, as assessed by lane drift and the number of line crossings.

In the mid-nineties, French sleep specialists reported that 50% of drivers reduced their sleep duration the night prior to a departure, while 10% didn't sleep at all. Interestingly, sleep reduction was associated with the duration of driving: the longer the trip was, the shorter the sleep episode during the night before departure. In 2002, a study showed that, for drivers having slept less than 5 hours in the past 24 hours, their risk of accidents increased by 2.7 compared to drivers who respect a normal sleep schedule.

A driver's sensitivity to sleep deprivation varies with age. A 2012 study in the United States found that younger male drivers (between the ages of 20 and 25) are more susceptible to the effects of sleep restriction than older male drivers (aged 50 to 75).

Sleep complaints are indeed common during adolescence. Adolescents are physiologically predisposed to developing chronic sleep deprivation because of maturation changes in their circadian and homeostatic regulation systems. This leads to a delay in the timing of sleep and a consequent accumulation of chronic sleep debt. Adolescents' complaints may also reflect lifestyle factors affecting sleep quality. Despite sleep-research data indicating that adolescents require 9 to 10 hours of sleep per night, youths sleep significantly less. Moreover, studies led in 2010 have suggested that even if young people are aware of sleepiness-related risks, they do not correctly perceive sleepiness while driving.

As a consequence, younger drivers are more at risk for sleep-related accidents. According to a 2011 study led by the American Automobile Association's Foundation for Traffic Safety, drivers aged 16-24 are nearly twice as likely to be involved in a drowsy driving crash than drivers aged 40-59. In addition to their high sensitivity to sleep deprivation, young drivers may also accumulate inadequate experience at wheel, a tendency to adopt ineffective strategies against drowsiness, a propensity for enhanced risk-taking behaviours.

2. IRREGULAR WORKING SCHEDULES

About 20% of the working population is engaged in shift work and other irregular working hour arrangements. A number of shift workers suffer from what is known as "Shift Work disorder." The main diagnostic criteria for this disorder are insomnia during daytime, sleep and excessive sleepiness during working hours. The fixed programming of the human body clock is the key reason as to why it can be harder to sleep during the day than at night. External factors such as noise, light, etc. can be other influencing factors. The prevalence of this disorder is estimated to reach 2 to 5% of the general population, which is probably an under-estimate.

Studies led in 2009 have reported that shift workers have a high risk of falling asleep behind the wheel, of near-miss accidents and actual accidents, compared to regular daytime workers. Especially night shift workers, rotating

shift workers and those working extended shifts are at risk. A 1999 study led by the American Automobile Association's Foundation for Traffic Safety found that for night shift workers, the risk of having a sleep related accident was almost six times higher than having a non-sleep related accident. The most extreme findings come from focus group interviews on intensive care nurses working 12h shifts. An alarming 95% reported automobile-related injuries and near-miss accidents that occurred during their commute to and from work.

Major findings on commuting shift workers

- High prevalence of sleepiness and nodding off when driving home after night shifts and rotating shifts
- Struggle to stay awake at work, exhaustion and number of consecutive shifts can predict drowsiness and near-miss accidents after shift-work
- Extended shifts increase the risk of crashes and near-miss accidents
- The risk of falling asleep behind the wheel increases with the number of extended shifts per month
- Long driving distances after shift-work are related to severe sleepiness
- Sleep durations below 6-7 hours are associated with sleep-related crashes

Adapted from Mets M A J et al Shift work and traffic safety, 2010, 80-89 with permission.

3. TASK-RELATED FATIGUE

Most studies concerning driver fatigue -and consequent sleepiness- focus on sleep deprivation or circadian rhythm effects, but require drivers to perform driving tasks during monotonous conditions. This confounds the effects of sleep-related fatigue (SR fatigue) and what is known as task-related fatigue (TR fatigue).

Task-related fatigue is caused by driving itself and by the driver's environment. Experts make a difference between active and passive task-related fatigue. Active fatigue is the most common form of task-related fatigue, occurring when demanding situations accumulate, such as high-density traffic, poor visibility or the need to complete an auxiliary task (i.e. searching for an address) in addition to driving.

Passive fatigue develops when a driver is mainly monitoring an uneventful, predictable, and repetitive driving environment over an extended period of time. While safe handling of a vehicle requires sustained attention, monotony leads to the opposite: arousal levels decline and are replaced by inattention and sleepiness.

According to a French study published in 2010, this type of vigilance impairment has been identified as one of the main contributing factors to road crashes, and is estimated to be involved in 20 to 30% of these crashes. The authors report that the effects of monotony occur in the 40 minutes

following initiation of task. The results show that driving performance impairment increased most during the first 10 to 15 minutes for a range of metrics (heart rate variability, speed and skin conductance for instance), while other were impacted constantly throughout the experiment (lane lateral positioning, steering wheel movement and blink frequency for instance).

4. LENGTH OF TASK AND TIME OF DAY

Long periods of uninterrupted driving have been associated with higher rates of accidents. More precisely, studies have shown that the duration of driving seems to significantly increase the risk of accidents at night and in the early hours of the morning.

5. SITUATIONS COMBINING SEVERAL RISK FACTORS

In most cases, road accidents combine several factors: a lack of sleep, the length of the trip, a monotonous road, driving during the times of day when sleepiness peaks, bad environmental conditions, such as poor visibility and/or use of psycho-active substances or medications. Some sub-populations are more prone than others to accumulate risk factors for daytime sleepiness and are therefore at a higher risk of accidents: professional drivers and youngsters are good examples.

Professional drivers

Because of increasing productivity requirements, professional drivers (drivers of lorries, coaches and company cars) are highly exposed to sleep deprivation, to a modification of their sleep-wake schedule, to long uninterrupted periods of driving and to task-related fatigue and sleepiness. For instance, a 2002 study reported that 12% of truck drivers sleep less than six hours a day and that 17% of them stay awake for more than 16 hours.

A UK study led in 2010 analysed the prevalence of excessive daytime sleepiness and accident rates among bus drivers. The results show that 20% of all bus drivers had an Epworth sleepiness score >10, which represents a significant level of sleepiness. 8% of drivers reported falling asleep at the wheel at least once a month, 7% reported experiencing a sleep-related accident and 18% a near-miss accident due to sleepiness while driving.

The period in the 24-hour when the risk of traffic accidents is at its highest for a truck driver is during times of postprandial drowsiness. It is even greater outside normal working hours and, in particular, at the end of the night.

Young drivers

According to the authors of an Italian study published in 2011, road crashes are considered to be the first cause of death in people aged 10-24 years in developed countries. Indeed, young drivers tend to accumulate several risk factors. First of all, they represent the population most prone to sleep deficiency. A study led in 2010 on about 340 adolescents reported that 19% percent of the sample complained of bad sleep, 64% complained of daytime sleepiness, and 40% reported sleepiness while driving. Their analyses confirmed the high prevalence of sleep-related complaints among high-school

adolescents and highlighted their independent role on self-reported crash risk. Youngsters also tend to overestimate their driving abilities. Finally, it is common knowledge that they also tend to engage more frequently in certain risky behaviours, such as drunk driving and driving under the influence of cannabis (see E). Studies have indicated that younger age, lack of experience driving and consumption of alcohol and illegal drugs, especially on weekend evenings, are the main risk factors of sleep related traffic crashes.

C. Morbidities affecting alertness

Thomas Penzel, Markku Partinen and Damien Léger

All sleep disorders –whether they generate a lack of sleep, an excess of sleep or bad quality sleep –end up affecting daytime alertness. In 2007, a study led by ASFA (published in December 2009 in the journal *Sleep Research*) evaluated at the impact of sleep disorders on driving skills. The researchers had 35 000 questionnaires filled out by a population of frequent motorway users in France. Results show that 16.9% of drivers complained of at least one sleep disorder (5.2% obstructive sleep apnoea, 9.3% insomnia, 0.1% narcolepsy and hypersomnia). 8.9% of drivers reported at least one episode per month of sleepiness at the wheel so severe they had to stop driving. The highest risks of accident were found among subjects suffering from narcolepsy and hypersomnia or multiple concomitant sleep disorders.

Different sleep disorders are presented in this section, but other non-sleep-related pathologies can lead to sleep disorders and this also affect sleepiness.

1. SLEEP APNOEA

According to a 2008 epidemiological study, obstructive sleep apnoea is present in approximately 3% to 7% of adult men and 2% to 5% of adult women in the general population, in Europe and in the United States. Disease prevalence is higher in certain subsets of the population, including overweight individuals and the elderly.

Sleep apnoea is characterized by the frequent occurrence of abnormal pauses in breathing during sleep. These pauses may last from ten seconds to one or two minutes. Subjects with severe forms of sleep apnoea have more than 30 apnoea events per hour of sleep, and they can appear up to 90 times an hour.

These pauses frequently generate awakenings, or so called “micro-awakenings,” which lead to non-restorative sleep and eventually to a reduction of attention, alertness and sleepiness during the day, resulting in an increased risk of sleep-related accidents. In 2008, a large US study showed that the risk of being in a car crash is two to five times higher in individuals with sleep apnoea.

Individuals with sleep apnoea are rarely aware of their ailment, due to the sleepiness itself, and symptoms may be present for years or decades before they are identified. The problem is usually brought forward by a bed companion disturbed by the loud snorts or choking sounds that follow each

breathing pause. A test using polysomnography in a sleep laboratory enables to diagnose the disorder. Several studies have shown that treating sleep apnoea by Continuous Positive Air Pressure (CPAP) reduces sleepiness and the risk of motor vehicle collisions.

2. INSOMNIA

Insomnia is the most common sleep disorder affecting millions of people as either a primary or comorbid –secondary to another pathology- condition. Epidemiological studies have shown that it is reported by 20% to 30% of the adult general population.

Insomnia is defined as a difficulty in falling asleep and/or maintaining sleep, occurring at least three times a week for at least one month and resulting in daytime impairment. It is “primary” when no other cause is found for these symptoms. In many cases though, insomnia accompanies another disease, which may be somatic (pain, metabolic disease) or psychiatric, such as anxiety or depression. Insomnia can also be the result of medication side effects or have a toxic origin (alcohol). Whatever the cause, patients with insomnia are affected by persistent difficulty falling asleep, staying asleep or by sleep of poor quality. This debt in restorative sleep inevitably leads to impairments in daytime functioning and to sleepiness, which again have a negative influence behind the wheel.

The 2007 “Sleep in America” poll reported that individuals with insomnia are three to five times more prone to accidents in general, and two and half times more in case of motor vehicle accidents. The connection between insomnia and the risk of road accidents has been well documented.

Finally all types of pathologies leading to sleep restriction or deprivation can, as a consequence, give rise to somnolence and drowsy driving.

3. NARCOLEPSY

Narcolepsy is a rare disease affecting less than 0.01% of the general population. Its main characteristic is excessive daytime sleepiness even after an adequate night sleep. A person with narcolepsy is likely to have unavoidable episodes of sleepiness and to fall asleep several times throughout the day, often in inappropriate times and places. Daytime naps occur with little warning and can become physically irresistible. Patients fall quickly into what appears to be very deep sleep, and wake up suddenly with a strong disorientation feeling. These naps are typically refreshing, but only for a few hours and drowsiness may persist for prolonged periods of time. Another typical feature of narcolepsy is cataplexy, which is characterized by sudden loss of muscle tonus. It is triggered by emotions and can lead to sudden falls. It may also dangerously affect driving.

The authors of “Narcolepsy: A Clinical Guide,” published in 2010, report that driving simulator studies and psychological tests have proved that untreated narcolepsy can significantly impair driving performance and lead to an increased risk of car crashes. However, studies in real traffic remain scarce.

D. Effect of psychoactive medications

Joris C. Verster and Diego García-Borreguero

Many psychoactive medications can seriously affect one's ability to drive safely, and are thus the indirect cause of a significant number of road accidents. The drugs concerned can be prescribed medications or drugs bought "over the counter". They include anxiolytics, hypnotics, certain anticonvulsants, most muscle relaxing and anti-allergic drugs and antidepressants.

However, the effects of any drug vary from person to person, and individuals may not always be able to predict whether a particular medication will affect their driving or not. Alternatively, under the influence of certain medication, drivers may not even be aware that their driving is affected until they find themselves in a situation they need to respond to quickly and accurately to avoid a crash.

In general, adverse effects of medications are most pronounced during the first weeks after treatment initiation. Thus, physicians, dentists and pharmacists need to tell patients about any risk associated with medication they prescribe or provide. Moreover, if a patient wants to drive a car, prescribers should aim at prescribing a medicinal drug that has shown not to affect driving –if available.

Some countries, like France, have labelled all treatment boxes with logos allowing to understand if the treatment may affect alertness.

1. MINOR TRANQUILIZERS

Minor tranquilizers belong to the benzodiazepines (BZD) chemical family and are most commonly prescribed to relieve stress and anxiety, to help people sleep, or are used as anticonvulsants and muscle relaxants. They are known to slow down the activity of the central nervous system and messages traveling between the brain and the body. BZDs can be categorized as either short-, intermediate- or long-acting.

How BZDs affect patients depends on several aspects, including the dosage but also the patient's age, size, weight and health, and whether the individual is used to taking BZDs. The effects may start to be felt within 15-20 minutes and, depending if they are short-, intermediate- or long-acting, they can last from 2½ to 160 hours. Some of the adverse effects following the administration of BZDs may include drowsiness, reduced alertness, and sleepiness. Given the long duration of action of many BZDs, these adverse effects can also be experienced in the morning, after taking sleep medication at bedtime.

A 2008 study led in the UK showed that the different types of BZDs (short-, intermediate-, long-acting) are associated with different levels of risk. Compared with BZD-free drivers, drivers (aged 25 to 55) taking intermediate or long-acting BZDs showed an increased odd of unsafe driving behaviours. Other studies showed that accident risks are highest after treatment initiation and are lower as tolerance develops when these drugs are used chronically. Several epidemiological studies have also shown that the use of BZDs increases one's chances of having an accident.

A 2011 review of the literature on the link between BZDs and road accident showed that BZD use was associated with a significant increase in responsibility for accidents. The authors found that this association was more pronounced in younger drivers and that the accident risk was markedly increased when drivers were at the same time under the influence of alcohol.

2. ANTIPSYCHOTICS

Anti-psychotics –also known as neuroleptics –are primarily used to manage psychosis in schizophrenia and bipolar disorders, but are also increasingly used to manage non-psychotic disorders. For example, one such neuroleptic, called metoclopramide, is used to treat nausea and vomiting.

Antipsychotics are all potentially sedative and can decrease reaction time and thus represent a danger for traffic safety.

In the early 1990s, a UK study analysed the effects of the anti-vertigo anti-psychotic drug prochlorperazine on driving skills. Patients on the drug were compared to normal controls when performing a driving task (to estimate weaving) and two psychomotor tasks (to evaluate reaction time). Their results showed that prochlorperazine impaired driving performance and increased carelessness. Moreover, patients under prochlorperazine had little subjective appreciation of their impairments.

Although driving research on anti-psychotics is scarce, there is consensus that the sedative effects of these drugs are likely to impair driving.

3. ANTIDEPRESSANTS

Tricyclic antidepressants (TCAs), traditionally, have been prescribed for the treatment of depression. Some of the frequent side effects associated with TCAs include blurry vision and cognitive impairment, drowsiness and confusion, which have an evident impact on one's driving abilities. On-the-road driving studies have shown that TCAs significantly impair driving performance and that their use significantly increases the chance of having a traffic accident.

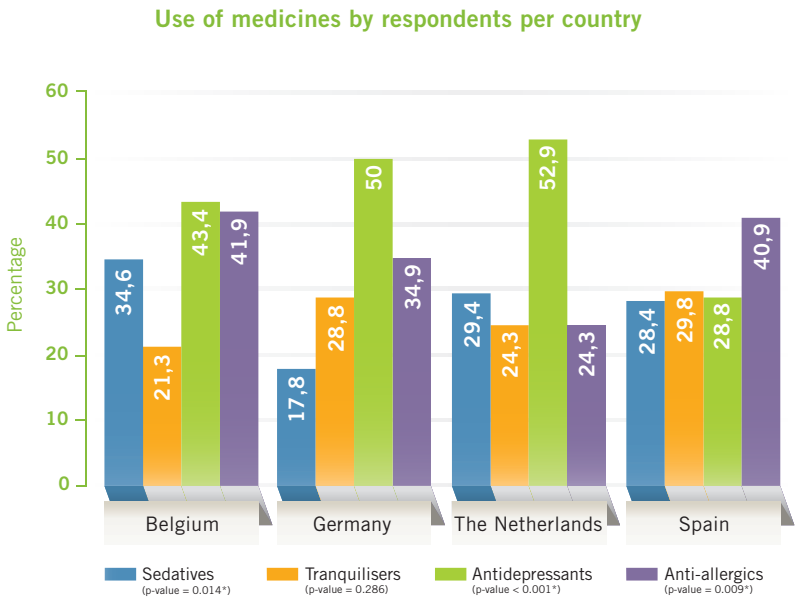
Today, TCAs have been largely replaced by newer antidepressants that typically have more favourable side effect profiles (however, for certain indications, TCAs are still sometimes prescribed). Most of these newer antidepressants belong to the family of Selective Serotonin Reuptake Inhibitors (SSRIs). These drugs generally do not trigger driving impairment when tested in simulators and on-road studies. However, recent epidemiological evidence suggested that despite the seemingly absence of performance impairment in experimental studies, increased risks of having a traffic accident were found for patients using SSRIs.

4. ANTIHISTAMINE DRUGS

Anti-allergic drugs (a.k.a. “antihistamines”) are considered relatively safe even for self-treatment, which is why they are often readily available as over-the-counter medication. The most common adverse effect of anti-allergic drugs is drowsiness, especially when using older medications such as diphenhydramine, chlorphenamine and promethazine, which are, in fact, also used to help patients fall asleep. Many driving studies have shown that these drugs impair driving.

For newer versions of anti-histamine drugs, the effects on driving are much less pronounced or even absent. Physicians must therefore prescribe newer and safer anti-allergic drugs to patients who want to drive a car.

As part of the DRUID (DRiving Under the Influence of Drugs, alcohol and medicines) project, a survey was conducted in 4 European countries to assess knowledge and behaviour when driving under the influence of medicines. Pharmacists handed out questionnaires to drivers aged 18-75 years and using any psychotropic drug. Hereunder are the impressive percentages of use of psychotropic drugs.



Belgium n= 136 Germany n= 146 The Netherlands n= 136 Spain n= 215
Global results of this survey are exposed in Chapter 3 European Initiatives.

Adapted from Monteiro et al, BMC Public Health, 2012, 12:59 with permission.

E. Effects of psychoactive substances

Diego García-Borreguero and Joris C. Verster

The negative impacts of alcohol and illegal drug use on cognitive abilities (which become impaired first) result in a deterioration of attention, memory, logical reasoning and visual perception. Other components of driving performance, such as danger perception, are altered as well. In young drivers, who are the greatest consumers of substances such as alcohol and cannabis, but also the sub-population most prone to sleep restrictions, the deleterious effects add up.

Finally, there is good evidence to suggest that using cannabis and alcohol together, even at low doses, has a worse effect on driving than either cannabis or alcohol used alone.

The availability and use of alcohol and illicit drugs have increased dramatically during the 2nd half of the 20th Century. Alcohol is the most consumed psychoactive substance in the Western world, but illicit substances such as cannabis are also gaining ground since the 1960s. Since the number of vehicles on the road has also increased exponentially, one should expect a considerable increase in driving while intoxicated.

According to the European Commission's Directorate General for Mobility and Transport, Road Safety Unit, 25% of road accidents involve alcohol, medicines or illicit drugs. These accidents are directly responsible for the loss of 10 000 lives due to car crashes in Europe every year.

1. ALCOHOL

Although recent statistics indicate that total alcohol consumption in Europe is decreasing, European citizens are still the highest consumers of alcohol in the world. According to the European Commission's 2006 statistics, total alcohol consumption in the EU amounts to an average of 11 litres of pure alcohol consumed per adult each year. Furthermore, alarming trends are emerging in relation to drunk-driving. Again, the European Commission 2006 statistics report that more than 1 in 4 traffic accident deaths on EU roads is caused by drunk-driving (approximately 10 000 per year), costing about 10 billion Euros a year (in 2003).

Epidemiological data have revealed a relationship between the amount of alcohol consumption and the risk of having a traffic accident. In 2011, researchers led a study across Italy, Belgium, Spain, Bulgaria, Latvia and Poland, in which they evaluated brake reaction time, comparing it to alcohol blood concentrations in over 4500 young adults (aged 16-35) driving to and from recreational sites during weekend evenings. The authors found a significant worsening in reaction time with increasing alcohol intake. The increase in reaction time initiated with blood alcohol levels equal or over 0.5 g/l, corresponding to the legal limit of many European countries for driving after consuming alcohol.

The danger with alcohol is that, after its initial stimulant effects (euphoria, vigor, talkativeness and excitement), very rapidly, as concentrations in the bloodstream increase, stimulation gives way to sedation.

A great number of experimental studies also show that alcohol can impair skills and abilities related to driving. For instance, on-the-road driving studies measuring the weaving of a car during a 100-km motorway driving test in actual traffic showed that driving performance is significantly impaired in drivers with blood alcohol levels ≥ 0.5 g/l.

2. CANNABIS

After alcohol, cannabis is the most commonly detected psychoactive substance in impaired drivers. A 2008 review on 'drug use, impaired driving and traffic accidents,' led by the European Monitoring Centre for Drugs and Drug Addiction, revealed that between 0.3% and 7.4% of drivers tested positive for cannabis across seven roadside surveys conducted between 1997 and 2007 in Australia, Denmark, the Netherlands, Norway, the United Kingdom, and the United States.

Cannabis has noticeable effects on skills required to drive safely: alertness, the ability to concentrate, coordination, and the ability to react quickly. According to a 2004 review of the literature, laboratory studies examining the effects of cannabis on driving skills detected impairments in tracking, attention, reaction time, short-term memory, hand-eye coordination, vigilance, time and distance perception, decision-making and concentration. A study led in 2008 also suggested that cannabis impairs tasks of selective attention, time estimation, and executive function. Although most of these studies examined the effects of low doses of cannabis, recent research has suggested that decrements in performance are generally dose-related and typically persist for two to four hours.

Epidemiological studies conducted between 1993 and 2008 also confirm that cannabis use increases the chances of having a traffic accident. A 2004 study on culpability (responsibility) in fatal driving crashes concluded that cannabis users were significantly more culpable than non-cannabis users, and that the likelihood of being responsible for a crash increased with cannabis dosage.

The latest evidence reports that driving under the influence of cannabis appears to increase the risk of motor vehicle crashes by a factor of two to three.



Chapter II

METHODS TO FIGHT SLEEPINESS AT THE WHEEL

A. On the manufacturer side: In-vehicle detection and warning devices

Jim Horne

Driver Vigilance Monitoring', 'Drowsiness Detection Systems', 'Fatigue Monitoring Systems' –all these terms refer to in-vehicle systems designed to monitor driver and/or vehicle behaviour and provide alerts or set up security automatisms if a driver seems impaired.

In this section, we will first present some of the monitoring systems that focus on the vehicle itself, then examples of recent developments in systems monitoring driver behaviour especially.

1. SYSTEMS MONITORING THE VEHICLE

As automation technology has progressed, more and more functions have been added to automobiles to assist drivers in controlling their vehicles. These include: pre-crash systems, advanced automatic collision notification, automotive night vision with pedestrian detection, lane departure systems, vehicle tracking systems, adaptive cruise control, adaptive headlamps, etc. Only those with the potential to detect or minimize the consequences of sleepy driving will be covered here.



Autonomous cruise control

Autonomous cruise control (ACC) is an optional cruise system based on information detected by on-board sensors. These sensors, either radar or laser-based, inform the vehicle to slow down when approaching another vehicle ahead, and to accelerate again to a pre-set speed when traffic allows. Single radar systems are the most common.

Many luxury, mid- size and small cars in Europe are now fitted with an adaptive cruise control (ACC) system. ACC technology is widely regarded as a key component of any future generations of so-called intelligent cars.

Pre-crash systems

Pre-crash systems are designed to reduce the severity of accidents. Also known as forward collision warning systems, they use radar and sometimes laser sensors to detect an imminent crash. Depending on the system, they may warn the driver, pre-charge the brakes, inflate seats for extra support, move the passenger seat, position head rests to avoid whip lash, tension seat belts and automatically apply partial or full braking to minimize impact. This type of system has been sold on some EU vehicles since 1999.

An example is the Pr-Sense Plus system introduced in 2010, which works in four phases. In the first phase, the system provides warning of impending accident, while the hazard warning lights are activated, the side windows and sunroof close, front seat belts are tensioned. In the second phase occurs light braking, strong enough to catch the driver's attention. The third phase initiates autonomous partial braking at a rate of 3 m/s^2 . The fourth phase decelerates the car at 5 m/s^2 followed by automatic deceleration at full braking power, roughly half a second before the projected impact. Many common brands offer such option.

Lane departure warning systems

A lane departure warning system is a mechanism designed to warn a driver when the vehicle begins to move out of its lane on freeways and arterial roads. The first lane departure warning system introduced in Europe was developed in 2000, and is now available on most trucks sold in Europe. Since then, most brands have designed their own system.

These systems are designed to minimize accidents by addressing the main causes of collisions: driver error, distractions and drowsiness. For instance, in the Lane Keep Assist System launched in 2003, a camera, mounted at the top of the windshield just above the rear-view mirror, scans the road ahead in a 40-degree radius, picking up the dotted white lines used to divide lane boundaries on the motorway. The computer recognizes that the driver is "locked into" a particular lane, monitors how sharp a curve is and uses factors such as vehicle speed to calculate the steering input required. However, absence of lane markings and/or bad weather impairs their performance.

There are two main types of systems: systems that warn the driver (lane departure warning) if the vehicle is leaving its lane (visual, audible, and/or vibration warnings), and systems that warn the driver and, if no action is taken, automatically take steps to ensure the vehicle stays in its lane (lane keeping system).

In 2009, the United States National Highway Traffic Safety Administration began studying whether to make frontal collision warning systems and lane departure warning systems mandatory.

Intelligent cars for the future

Engineers are working to design vehicles that can rely completely on automation, called robotic or autonomous. Autonomous vehicles would be capable of sensing their environment and navigating on their own to minimize the consequences of sleepy driving. The driver could choose a destination, but would not be required to perform any mechanical operation on the vehicle.

A method to automate cars without having to modifying them as much as in the case of robotic cars is the Automated Highway Systems (AHS), which aims to construct lanes on motorways that would be equipped with, for example, magnets to guide vehicles. Motorway computers would manage traffic and direct cars to avoid crashes without driver intervention.

In 2006, the European Commission established a smart car development program called the Intelligent Car Flagship Initiative.

2. DRIVERS' SLEEPINESS DETECTION-BASED SYSTEMS

In this section some of the existing in-vehicle systems that attempt to monitor driver-behaviour directly, such as eye movement, facial feature movement, brain waves (using electroencephalography recordings, a.k.a. EEG) and steering wheel grip will be presented.

Camera-based systems

Camera-based systems are most established in the detection of sleepiness and are used in several applications. As described in the previous chapter, cameras can be used to detect eyelid movements, but also pupil size changes. The speed of eyelid movements depends much on the person's alertness and can be used for vigilance classification.

New processing algorithms are trying to improve recognition of pupil size changes as the driver becomes drowsy. It is also possible to monitor the direction of drivers' gaze and, this way, establish whether drivers actually see what is happening in front of the car or whether they are distracted.

EEG (Electroencephalography)

The best-established technique to detect sleepiness is based on recording brain activity from an EEG, similar to that in a sleep laboratory experiment. EEG recordings are captured using one or several electrodes that detect local vigilance changes. The recorded EEG signal is analysed for changes indicative of sleepiness (which it distinguishes from those indicative of distraction). However, to date, such a system is impractical as drivers are restricted and the complex electrode system may cause discomfort. Another obstacle is that other in-vehicle electronics can interfere with these EEG signals.

Capacitive Foils

Driver behaviour can also be monitored using “capacitive foils” located in the roof of cars. These foils detect head position and movements. This technique can help identify sleepy drivers when their heads drop due to sleepiness or when head movements become irregular.

However, this method is new and needs further evaluation. For example, depending on the angle of the driver’s seat, head dropping does not always accompany drowsiness.

Steering wheel grip and other driving inputs

In 2009, a system called Attention Assist was developed, which attempts to monitor drivers’ fatigue level and drowsiness based on their driving inputs. It monitors speed, longitudinal and lateral accelerations, pressure and movements on the steering wheel and accelerator pedal. It issues a visual and audible alarm to alert drivers if they are too drowsy to continue driving safely. However, wheel grip has yet to be shown to be a valid index of sleepiness, and the effectiveness of this system has yet to be established.

3. ADVANCED INTEGRATED SYSTEMS

More sophisticated, integrated, remote sensing systems present a more intelligent and obvious approach to detecting driver drowsiness. For example, they incorporate lane drifting with the detection of monotonous road conditions liable to promote sleepiness, coupled with the time of day when a driver is more likely to be sleepy (the circadian “body clock”), together with some driver input as to whether they have had adequate sleep during the previous 24 hours. An example of this is the Advisory System for Tired Drivers (ASTiD).

Another example is the Coyote Sleepiness Prevention tool. Created in France in 2005, Coyote is a geolocation information solution which makes it possible to share real-time, among a community of about 1.9 million users, any changes in traffic information. Coyote is based on a participative system that relies on the contribution of individual users for the benefit of all. Equipped with GPS, GPRS and GSM technologies, the system is in constant communication with a central server, which transmits the relevant information to user. One recently added application to the Coyote system is its “sleepiness prevention” tool. Based on four parameters -variations in speed, in direction, departure hour and length of trip- the system interrogates the driver on his or her physical state. Depending on the response, the Coyote system can suggest the need to take a pause. This portable device is now available in several countries around Europe.

Although encouraging, the safety and reliability of these devices has yet to be fully established and, currently, drivers should not depend entirely on these devices to tell them when not to drive –they should rely on their own insight, especially as drivers do not spontaneously fall asleep at the wheel. There is invariably a feeling of increased sleepiness beforehand when drivers consciously attempt to stay awake (e.g. opening the window, turning up the radio, etc).

It is a very important aspect to emphasize since, in the case of accidents

linked to sleepiness at the wheel, studies have revealed that drivers tend not to accept responsibility for the consequences of driving while sleepy, even when the consequences are severe. However, a driver is the prime responsible for his or her state of alertness while driving, and cannot relegate this responsibility to any driving-assistance device.

B. Measures focusing on road infrastructure

Jim Horne

Improving road infrastructures is one of the many ways to increase traffic safety. Here are some examples of approaches that help fight against sleepiness at the wheel.

1. RUMBLE STRIPS

Longitudinal rumble strips are milled or raised elements on the pavement that cause vibration and sound, serving to warn inattentive drivers that their vehicles have left the travel lane. They are also known as sleeper lines.

In France, since 2012, highways are mandatorily equipped with rumble strips on the outside edge of the road to prevent sleepy drivers from drifting off into the emergency lane. These systems are usually made up of so-called “raised” strips (with protruding pavement markers), but the use of “milled” strips (strips milled directly into the asphalt or concrete pavement) is also being studied. Indeed, milled rumble designs have been shown to be more effective at producing both noise and vibrations and are credited with higher crash reduction factors. According to preliminary results, lorries tend to drift off the road twice as less often when strips are milled compared to raised.

According to statistics released recently by the US Federal Highway Administration, centre line rumble strips on rural two-lane roads can reduce head injury on fatal crashes by 44%. On urban two-lane roads, they can reduce head injury on fatal crashes by 64%.

According to a 2010 report collecting testimonies, rumble strips are responsible for waking up 64% of those drivers who had fallen asleep at the wheel. In a 2012 field study evaluating the effectiveness of rumble strips on lateral position, these also had a significant effect on driving, with drivers tending to drive closer to the centre of the lane when rumble strips were present.

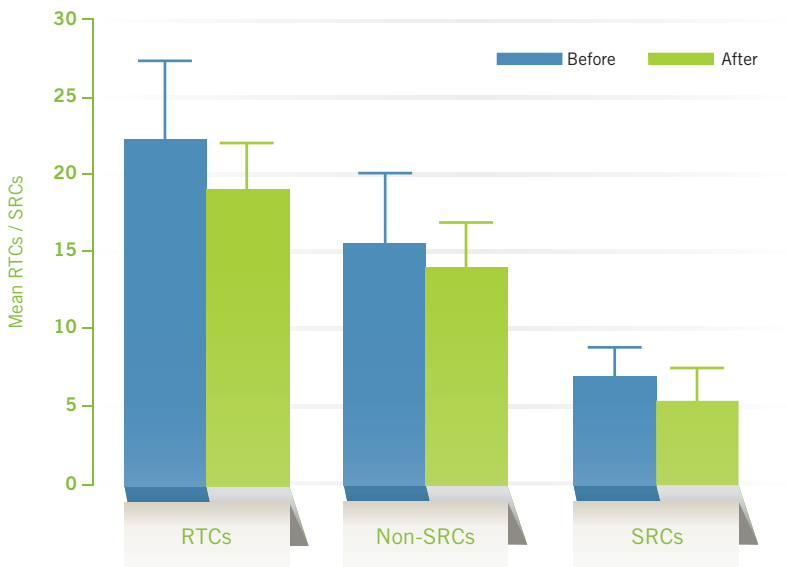
Since driver errors occur on all types of roadway systems, rumble strips are most effective when deployed in a systemic manner, and can be incorporated on many kilometers of road but more cost-efficacy studies have to be launched before.

2. THE PRESENCE OF RESTING AREAS

In 2009, a study indicated that the number of both fatigue and non-fatigue collisions decreased significantly on motorway sections containing resting areas. More specifically, the authors showed that the number of collisions due to fatigue significantly decreased over 16 km sections following each

rest area of a major motorway, as shown in the following figure. Beyond this distance, the number of fatigue related accidents increased again. Non-fatigue collisions were reduced to a lesser extent and the reduction was not significant. Again, such findings prove the utility of including rest areas on motorways and the necessity to increase their number.

Road traffic collisions before and after rest areas in the UK



Means (s.d. error bars) of all road traffic collisions (RTCs) and road traffic collisions sub-divided into non-sleep-related collisions (non-SRCs) and sleep-related collisions (SRCs) in 16 km sections before and after the 14 motorway service areas.

Adapted from Reyner L A et al, *Accident Analysis and Prevention*, 2010, 42, 1416-18 with permission.

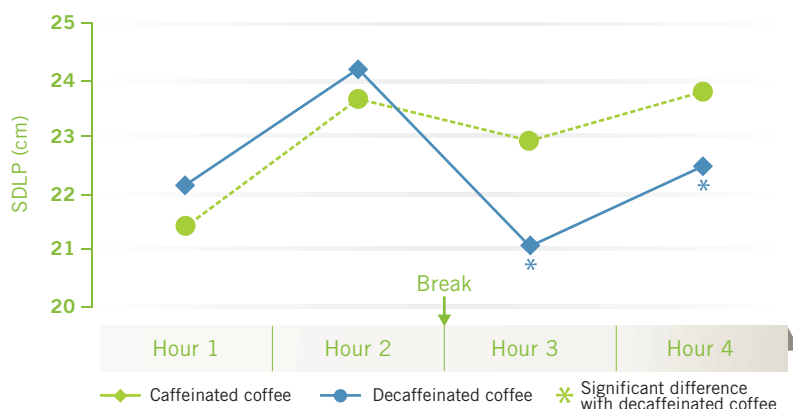
C. Behavioural approaches to fighting sleepiness

Pierre Philip and Jim Horne

When it comes to driving on monotonous roads, sleep-related accidents are more likely to occur at certain times of the day, when the body clock reaches its daily trough and when sleepiness is at its greatest –as described in chapter 1 (page 23). These intervals extend between midnight and 6 am and, to a lesser extent, in the early afternoon. During the early morning period, for instance, it is said that around half of the accidents that occur on major European motorways are caused by driver sleepiness. Although current public campaigns recommend that individuals take a break from driving for at least 15 minutes every two hours, drivers contemplating long journeys should be particularly aware of the possibility of impaired driving during these periods and may need to take more frequent breaks, especially during the early morning hours. Research has shown that drinking a cup of coffee or another caffeinated drink,

and having this immediately before a 15-minute nap or 'doze', is a very effective way for drivers to overcome sleepiness in a short period of time. Indeed, as caffeine takes about 20 minutes to 'kick in,' this leaves right about the time for the driver to take a power nap, thereby benefiting from both techniques. This is depicted in the following figure. The Standard Deviation of Lateral Position (SDLP) is significantly lower 1 and 2 hours after the break in the group taking caffeinated coffee when compared with the group taking decaffeinated coffee.

Effect of caffeinated coffee consumption on driving performance compared with decaffeinated coffee



No significant differences were observed in Standard Deviation of Lateral Position (SDLP) before the break compared to decaffeinated coffee. However, both in the first and second hours after the break, caffeinated coffee significantly decreased SDLP.
n = 24 non-sleep deprived healthy volunteers.

Adapted from Mets M A J et al, *Psychopharmacology*, 2012 with permission.

'Energy drinks' that lack caffeine are not effective. Although the ingestion of drinks containing high amounts of sugar can lead to a transient feeling of alertness in sleepy drivers, it is soon followed by increased sleepiness.

In addition, drivers should:

- Get plenty of sleep (at least 7 hours) the night prior to a long trip
- Plan their journeys taking sleepiness into consideration
- They shouldn't work all day and then drive all night
- They should consider sharing the task of driving if possible when the journey is long

A recent study has shown that while most drivers acknowledge their increased risk of being involved in a crash when they are drowsy, very few actually take the appropriate precautions to prevent or combat sleepiness. The authors of this Internet-based survey undertaken in Norway reported that 73% of drivers said they continued to drive despite feeling sleepy. While they acknowledged that stopping for a quick nap is an effective countermeasure, they were more likely to resort to less effective methods, such as stopping to eat or drink, or winding down their window for cold air (see the following table).

These findings confirm previous studies reporting that drivers frequently fail to follow recommended countermeasures, as demonstrated in the following table. This is especially true for young male drivers, who are particularly likely to overestimate their capability to drive while sleepy. Also included are those highly motivated drivers who continue to drive while ignoring their own subjective feelings of sleepiness in order to get to their destination ‘as quickly as possible’, and others who are ‘close to home’. The latter reason is of major concern since fatigue-related crashes commonly occur close to destination. Moreover, drivers tend not to accept responsibility for the consequences of driving while sleepy, even when the consequences are severe.

These findings demonstrate the increasing need to focus education and countermeasure efforts on motivating drivers to adopt safer driving strategies.

**Self-reported perception of effectiveness
and practical use of fatigue countermeasures (score 1- 10)**

COUNTERMEASURE	MEAN EFFECTIVENESS	MEAN USE
Stop and sleep somewhere	9.47 (1.60)	5.78 (3.74)
Swap drivers	9.16 (1.80)	6.82 (3.45)
Stop and have a quick nap	8.18 (2.63)	4.04 (3.58)
Stop to eat and drink	7.84 (2.24)	6.73 (3.00)
Stop and get out of car	7.50 (2.55)	5.30 (3.49)
Have a caffeinated drink	5.74 (4.02)	4.16 (3.19)
Wind down window	5.12 (2.85)	4.68 (3.19)
Turn on fan or AC	4.73 (2.98)	4.53 (3.30)
Splash water on face	4.62 (2.85)	3.32 (2.97)
Drink water	4.56 (2.79)	4.56 (3.17)
Put on loud music	4.30 (2.76)	3.90 (3.23)
Drink an energy drink	3.79 (2.64)	2.53 (2.59)
Eat sweets or mints	3.75 (2.60)	3.28 (2.79)
Drive slower	3.29 (2.81)	2.75 (2.65)
Take a caffeine medication	3.25 (2.79)	1.29 (1.33)
Take an alertness medication	3.09 (2.71)	1.78 (1.03)
Drive faster	1.73 (1.54)	1.57 (1.64)
Increase the heat	1.34 (0.97)	1.20 (0.88)

N=305 Studied population consists of members of the Royal Automobile Club of Queensland (RACQ) randomly selected from the RACQ membership database.

In the first column, “Mean effectiveness” represents what subjects consider as the most appropriate way to fight sleepiness while the second column “Mean use” represents what they are practically doing in case of sleepiness. Figures in brackets (SD) are the Standard Deviation.

Adapted with permission by ARRB Group. Armstrong, K, Obst, P, Banks, T, & Smith, S 2010, "Managing driver fatigue: education or motivation? ", Road and Transport Research, vol: 19, no: 3, pp. 14-20.

D. Measures focusing on employers

Damien Léger

A 2010 study found that the likelihood of a driver stopping his vehicle for a nap increases with age. The authors suggest that employment responsibilities may have a partial contribution to this finding. It is possible that older drivers who are retired feel less time pressure, and are thus more responsive than young professionals to countermeasures that are appropriate to their lifestyle, such as stopping to rest during a long drive. For younger drivers who feel more time-pressured and more risk-taking, other approaches need to be carried out. One of these strategies includes targeting employers.

This approach is particularly important in the case of commercial drivers. A laboratory study conducted in 2010 aimed to determine the recuperative effectiveness, in the USA, of the current 34-hour restart provision in the hours of service regulations governing freight carrying commercial motor vehicle drivers. The key finding was that this provision was sufficiently effective to maintain optimal performance in subjects on a daytime work schedule. However, it proved insufficient—and perhaps even detrimental – to maintain performance in subjects on a night-time work schedule. Indeed, the 34-hour restart provision does not take into account the circadian aspect of sleep/wake/work scheduling. Hours of driving regulations in both Europe and the USA could be improved by taking circadian timing into account.



Chapter III

IMPLEMENTATION

A. Legal Aspects

Markku Partinen and Jim Horne

1. DETERMINING LIMITATIONS TO MOTOR VEHICLE USAGE IN CASE OF PATHOLOGIES THAT CAN INDUCE SLEEPINESS

In addition to technical and civic knowledge, drivers must also present the medical capacity to drive. Some disorders represent limits to obtaining or maintaining a driver's license, because of the excessive daytime sleepiness they can induce. These pathologies may be organic, psychiatric, or linked to age. However, various medical problems are overlooked by patients themselves, with a majority of them continuing to drive. This represents a major concern.

The role of physicians

Physicians have a crucial role in evaluating patients ability to drive and to alert them of their heightened risk. They are legally due to inform their patients that their disease represents a potential threat for their own security and that of others on the road. When a severe accident occurs, physicians may encounter legal consequences if there is no proof that the physician has in fact informed his or her patient (the driver) on the potential dangers. In reality, though, physicians have been rarely sued in such cases.

...

Most health care practitioners have little or no training in medico-legal issues, even though they may well be advising their patients on these issues. This has been described in a 2001 study, showing that practitioners may be in a conflict situation where they suspect individuals are driving against their advice. In the United States, many, but not all, states allow the practitioner to report such situations to driving authorities, and with immunity, to ensure public safety, specifically when reported in good faith. Practitioners can remind drivers that they are not immune from civil and possibly criminal prosecution if illegal driving continues. Additionally, it is important to inform the patient that vehicle insurance may not apply if it is determined that the person is driving illegally.

Thus physicians would be well-served by understanding applicable driving laws and factors that affect driving, clearly documenting telephone conversations and consultations when driving is discussed, and periodically revisiting the topic to maximize safety. Often, when the facts are explained, the patient generally follows a prudent course of action. Framing the discussion on a personal level and reminding the individual of the consequences of causing injury or death to another driver, bystander, passenger, or to themselves often helps the patient to arrive at an appropriate decision.

Furthermore, establishing fair and accurate performance criteria to predict ability to drive in patients with various conditions may reduce the risk of motor vehicle crashes and protect others from arbitrary and possibly unfair licensing revocation. Although a clinician is likely able to identify obviously impaired drivers, it is often difficult for physicians to evaluate each case objectively. When should driving be curtailed? A clinician's assessment alone may not be accurate enough to evaluate driving skills in drivers marginally affected by a disorder or a treatment.

2. DETECTING AND SANCTIONING SLEEPY DRIVERS

If there were a reliable device capable of detecting the “true” level of fatigue/sleepiness, legislators would probably make fatigued driving a criminal offence, like drunk-driving. But without the availability of such a detector, how can fatigued drivers be identified and sanctioned appropriately?

One of the approaches that has been put in place consists of courts using data collected and analysed by multidisciplinary investigation teams that assess the cause of any fatal accident. These teams consist of a police officer, an engineer, a traffic engineer, and a physician.

Alerted immediately after the crash, the team arrives at the scene to collect all available information: they interview survivors and eyewitnesses, carry out alcohol and drug tests, analyse vehicle positions, road geometry and signs. The experts perform a primary reconstruction of the accident on the spot, then after their own individualized investigation, meet to exchange their opinions about the possible causes of the accident. They produce a final statement in the form of an explicit decision as to the primary cause, called “the key event” (such as falling asleep). The team also lists the risk factors that contributed to the accident (fatigue, for example).

If we take the case of Finland, for instance, the first permanent team was established in 1968, and since the early 1970s every road accident involving one or more fatalities has been studied in depth by one of the multidisciplinary

investigation teams stationed across Finland. Between 1991 and 2001 they studied 2,980 fatal accidents in depth, and in only ten of these cases the key event remained undecided. In 8% of cases the driver had fallen asleep, among which only 23% had survived.

3. THE CASE OF COMMERCIAL DRIVERS

European legislation has imposed regulations (EU 3820/85 and 3821/85) on the trucking industry to improve driver safety. These regulations limit the amount of time truckers are allowed to drive to a maximum of 9 hours per day, with the possibility of driving 10 hours per day during two days a week. Furthermore, they can be at work, including non-driving (eg loading their vehicle) for another 4 hours, which sums up to 13 hours in total (per 24 hours). Within the 9 hour driving rule, they can drive for up to 4.5 hours straight, prior to having a statutory break of 45 minutes minimum. There is no consideration of the 24h circadian body clock, here. Clearly a driver with an undiagnosed sleep disorder will be particularly vulnerable under these circumstances. After six consecutive working days, drivers are mandated to take a weekly rest period break of at least 45 consecutive hours. This legislation may not be enough, since sleep loss is cumulative and EU law cannot influence sleep behaviour during weekends.

In 2008, the European Transport Safety Council (ETSC) argued that the current European regulations are not effective enough in delivering safety benefits. For example, inasmuch that EU regulations allow a work span up to 13 hours in a day, the crash risk doubles after 11 hours of work. The ETSC concluded that working and driving should be combined more effectively. It is essential to reduce permissible driving time to an extent that will bring total working time within acceptable limits.

B. European initiatives

Damien Léger, Claudio Bassetti and Marta Gonçalves

Public information campaigns may raise awareness about the problem of driver sleepiness and effective countermeasures. Possible campaign themes may include:

- Acknowledgement of the main causes of sleepiness at the wheel
- Educating the community on minimum sleep requirements and fatigue/sleepiness warning signs
- Encouraging drivers to consider fatigue/sleepiness-related driving risk as a personal responsibility
- Targeting specific populations (such as driving schools, university students, sleep disorder clinics, truck driver associations) with direct education
- Challenging existing incorrect beliefs about personal ability to cope with fatigue and sleepiness
- Driving when sleepy is a risk equal to driving drunk
- Tactical use of driver rotation, caffeine, napping
- Awareness of the riskier hours for sleepiness

At the moment, evaluations of campaign efficacy on behaviour and crashes are rare. In general, it is acknowledged that road safety campaigns, by themselves, only have a modest impact on attitudes and behaviour but no significant impact on crashes. Campaigns work best when combined with other interventions, such as enforcement of traffic laws and regulations, or provision of other safety services and products.

A possible reason is that driving while sleepy is not punishable by law for private drivers. It is therefore difficult if not impossible, at least where private drivers are concerned, to link public campaign themes with enforcement or legal consequences. For professional drivers, the case is different since legislations exist concerning work and rest hours. Nonetheless, sleepiness and fatigue awareness campaigns have been deployed in the USA, in Australia, New Zealand, and in Europe.

1. EUROPEAN UNION ORIENTATIONS ON ROAD SAFETY

Recent European Union initiatives

In 2010, the European Commission issued a Communication entitled “Towards a European road safety area: policy orientations on road safety 2011-2020.” It underlines seven strategic objectives regarding education, enforcement, road infrastructures, safer vehicles, emergency and first-aid services, development of intelligent vehicles and vulnerable road users.

The European Parliament stressed that more practical measures should be implemented. It thus proposed a series of actions, 3 of which are related to fatigue/ sleepiness:

- When educating novice drivers, tiredness should be acknowledged as a serious road-crash risk factor, just as speed or alcohol-consumption are.
- The usefulness of installing warning systems against fatigue should be assessed and, if appropriate, made compulsory.
- Special measures should be implemented to ensure that the requirements imposed on commercial vehicles are up to date concerning technological evolution, especially regarding sleepiness - and distraction-warning devices.

In 2012, in the context of the European Driving License Directive, a group of experts was established with the aim of identifying and defining specific actions to implement, in regards to driving ability and sleep apnoea (specific limitations, specific training targets, actions led by doctors etc.)

The DRUID project

In 2007, in the context of an increasing concern about the role medication can play in car crashes, a study co-financed by the European Commission was led across four European countries –Belgium, Germany, Spain and The Netherlands –to define what characteristics can help predict a certain level of risk-knowledge among individuals using driver-impairing medications -benzodiazepines, sedative antidepressants and first-generation anti-histamines, a.k.a. anti-allergics.

This study was part of the European DRUID project (Driving Under the Influence of Drugs, alcohol and medicines). The findings show that patient knowledge regarding the risks associated with driving under the influence of such medications was stronger among younger, higher-educated individuals compared to the rest of the adult population. They also showed that information provided to patients generally did not influence behaviours. Those most inclined to change their driving behaviour were the individuals having experienced negative side effects of these drugs in the past, and who thus already had a bad conception of driving under the influence of medication.

2. NATIONAL CAMPAIGNS IN EUROPEAN UNION COUNTRIES

In 2008, following the guidelines of the CAST research project (European Commission co financed, DG-MOVE), sleepiness road safety campaigns were set up in two countries: Greece and Belgium. Other countries that conducted national campaigns include France and Portugal.

The Belgian Pitstop Campaign

The Belgian “Pitstop” campaign targeted young drivers between 18 and 25 years of age through radio spots, an internet website, small posters, brochures and the distribution of gadgets. It ran during four weeks, its principle aim being to install the knowledge that there is only one effective solution: a 15 minute “powernap” to fight sleepiness at the wheel.

The outcome evaluation of the campaign published the following year reports an increase in the knowledge that a powernap is the best solution against driver sleepiness, especially in the target audience but also in other age groups. Slight decreases were noted in the percentages of youngsters who believed that drinking coffee, opening a window, turning on the radio or talking to passengers are the best solutions against driver sleepiness. After the campaign, youngsters ranked the powernap as best solution to fight sleepiness, while they indicated “opening the windows” as the best solution prior to the campaign.

The campaign was not able to challenge the belief that getting home as soon as possible is most important, which remained especially present in the 18-25 years old targeted audience.

There was a slight increase in personal risk apprehension in the 18-25 years old targeted audience after the campaign; however, there was an increase in the percentage of youngsters who indicated to drive better than the others, even when sleepy.

In terms of behavioural intentions, the percentage of those in the target audience who intended to take a powernap had increased after the campaign, whereas the intentions for taking a short pause to stretch their legs, and opening the window, turning on the radio or talking to passengers had decreased.

However, the authors noted that: “The observed differences were not significant for most of the outcome results. All factors changed in the good direction but a repetition of the campaign is necessary to strengthen these effects”.

The Greek “Eyes on the Road” Campaign

The “Eyes on the Road” campaign was the first sleepiness road safety campaign conducted in Greece. It chose professional drivers as the primary target group and non-professional drivers as the secondary target group. The campaign ran during two months, the main media channels being TV and radio spots, campaign leaflets and the Internet.

The aim here was to make drivers understand that sleepiness does affect them, whomever they are, and to make them start identifying the signs of sleepiness during their daily driving. On posters, radio and TV spots, the slogan was “Sleep, but not at the wheel”. Drivers were then offered a proposal: to rest before they drive, to stop at a safe resting area and take a nap if they feel sleepy. On leaflets, reasons that cause sleepiness were clearly stated, but also the way sleepiness is detected and countermeasures to sleepiness.

The outcome evaluation published the following year didn’t show a great increase in drivers’ knowledge (knowledge of the causes of driving fatigue, knowledge of the effects of driving fatigue, knowledge that the most effective solutions to driving fatigue are to stop and rest or to plan the trip). However, these percentages were already at very high levels before the campaign implementation. Overall, the campaign seemed successful in that there was a significant increase in the number of drivers who stated they would begin stopping and resting when feeling tired, or that they would start better planning for their trips. According to the authors: “the dissemination of the results of the campaign would be a fruitful approach for the next campaigns that will be conducted. There is a large need for comparing these results with those of other (similar) campaigns to improve the design of future campaigns”.

France: INSV poll on “coping with sleepiness at the wheel” 2011

Each year, the French Institut of Sleep and Vigilance (INSV) - a French non-profit public health association -organizes a National Sleep Day to educate the public about the risks associated with lack of sleep or bad quality sleep. In 2011, the theme of this event was “sleepiness” and a national poll enquired on adult knowledge regarding sleepiness at the wheel. Across a representative sample of 1012 French adults, 3% reported they had fallen asleep at the wheel at least once in the past 12 months. 12% said they were forced to stop driving because of sleepiness at the wheel at least once in the last 12 months. Interviewed on “what are the best means to cope with sleepiness at the wheel?” 49% of sources answered “to stop driving”, 27% “to stop driving and take a nap”, 22% “to listen to the radio or to music”. Only 8% responded “to keep on driving” and 6% “to open the window.”

Portuguese campaign “Driving Sleepy can Kill”

In 2011, the “Driving Sleepy can kill” campaign was the first sleepiness at the wheel campaign conducted in Portugal. The aim of this campaign was to increase awareness about the risks of driving sleepy and ways to prevent it. Especially dedicated to young drivers, it lasted for one week with several different approaches including a TV spot in partnership with a public television station, a radio spot in partnership with a public radio station and an educational brochure about Sleepiness at the Wheel which was handed out at gas stations along the main motorways.

This campaign was presented in a media workshop presided by the Secretary of the Portuguese Ministry of Internal Affairs with the support of the National Road Safety Authority (ANSR), Ministry of Internal Affairs, the Portuguese Automobile Club (ACP) and others.

A sleep study “Sleepiness in motor-vehicle accidents in Portuguese drivers” was performed at the same time. This study was meant to determine the role of sleepiness in motor-vehicle accidents in a representative sample of drivers and the most common strategies drivers use to counteract sleepiness. The results were presented on World Sleep Day throughout the media.

3. GOING FORWARD

An on-going European project testing the efficacy of various intelligent in-vehicle systems to detect sleepiness at the wheel is the EUROFOT project or European Field Operational Test on Active Safety Systems. Another project, entitled TELEFOT, is testing the efficacy of road information on drivers. Finally, another interesting project entitled INTERACTION, is studying the interaction between drivers and in-vehicle technologies: why, when and how drivers use such in-vehicle technologies. However, none of these projects are investigating vigilance at the wheel per se.

Here are two projects that focus on this aspect, and that were financed in the context of the European Commission’s Seventh Framework Programme.

The PROLOGUE project

The PROLOGUE project (for “PROMoting real Life Observations for Gaining Understanding of road user behaviour in Europe”) aims to contribute to reducing the number of road casualties by developing and testing what is known as “the naturalistic driving observation methodology”. This approach uses advanced in-vehicle technology to non-obtrusively record driver behaviour during ordinary driving conditions. Many parameters can be studied, such as road safety, driver adaptation to the environment, traffic management but also distraction, inattention and sleepiness. The PROLOGUE project is investigating the feasibility and value of this method across several European countries –Germany, Greece, Norway, Spain, the Netherlands, the UK- and provides safety recommendations.

The ITERATE project

Recently, many driver-support-and-information systems have been designed to improve vehicle safety and performance. These systems have enabled to solve crucial issues from a technical point of view but their influence on driver behaviour remains practically unknown and should be fully investigated, as well as their global impact on traffic safety.

The objective of the European ITERATE project (Information Technology for Error Remediation And Trapping Emergencies) is to develop and validate a unified model to evaluate driver behaviour and performance (errors, reaction time, etc.) -especially how drivers perceive, adapt, make choices and respond to different road and traffic situations. The ITERATE project involves five countries: France, Israel, Italy, Sweden and the UK.



AUTHORS' PROPOSALS

The authors' proposals can be organized according to 4 sections

CAMPAIGNS/COMMUNICATION

- European campaigns for the general public.
- Educational campaigns focusing on at-risk populations such as adolescents, professional drivers and shift workers.
- Display of information on highways, especially during the most dangerous driving hours (e.g. afternoon, early morning hours), but also broadcasted on radio stations focusing on traffic information.
- Information leaflets distributed to patients in sleep centres, especially to patients with suspected sleep apnoea and insomnia.

TRAINING

- Training of (future) drivers in driving school on sleepiness at the wheel, through instructors.
- Training of law enforcement officials to take better account of sleepiness inside accident reports.
- In case of psychoactive drug use, information must be clearly provided by the physician on whether or not it is safe to drive. If sleepiness is a common adverse effect of the drug, patients must think of asking for alternative medication that does not impair driving.
- Prevention: Self-detection of sleep disorders, for instance if sleepiness is present regularly.

LEGAL ASPECTS

- Work on European legislation concerning drivers who suffer from diagnosed and acknowledged sleep disorders but are still not following an adapted treatment, to cancel or at least lower their insurance protection in case of sleepiness-related accidents.
- Forbid driving under psycho-active substance use.
- Generalization of rest areas on European road networks
- Detection and management of sleepiness among professional drivers, especially lorry-drivers.

NEW DIRECTIONS

- Improved detection of sleepiness.
- Better knowledge of determinants of dangerous behavior.
- Improvement of countermeasures, especially vehicle alert systems that notify drivers when they are becoming sleepy and suggest a break in driving.



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LIST OF ABBREVIATIONS

ACC: *Autonomous Cruise Control*

Cruise system relying on information collected through on-board sensors, that adapts a pre-set speed depending on traffic.

AHS: *Automated Highway Systems*

A system aimed at constructing motorway lanes equipped with magnets to guide vehicles.

ASFA: Professional association of toll road companies

BZD: *BenZoDiazepine*

A chemical family of drugs that include hypnotics (inducing sleep), anxiolytics (fighting anxiety), muscle-relaxing and anti-epileptic properties.

CAST: *Campaigns and Awareness-raising Strategies in Traffic safety*

Designs and implements mass media campaigns and evaluates their effect on traffic accidents and other performance indicators.

DRUID: *DRiving Under the Influence of Drugs, alcohol and medicines*

EEG: *ElectroEncephaloGram*

Records brain activity representing specific sleep (and sleepiness) waves.

ESS: *Epworth Sleepiness Scale*

A scale subjectively evaluating sleepiness through the individual's capacity to doze-off in different situations of daily life.

ETSC: *European Transport Safety Council*

A Brussels-based independent non-profit organization dedicated to reducing the numbers of deaths and injuries related to transport in Europe.

EUROFOT: *EUROpean Field Operational Test on active safety systems*

INSV: French Institut of Sleep and Vigilance

ITERATE: *Information Technology for Error Remediation And Trapping Emergencies*

KSS: *Karolinska Sleepiness Scale*

LDA: *Lane Departure Assistance*

LIST OF ABBREVIATIONS

LED detector: *Light-Emitting-Diode detector*

A system located on the dashboard, capable of detecting sleepiness through the measure of eye and eyelid movements.

MSLT: *Multiple Sleep Latency Test*

An objective test measuring the time it takes to initiate sleep when an individual is lying in a dark room.

MWT: *Maintenance of Wakefulness Test*

An objective test measuring the time an individual remains awake when sitting in a comfortable chair in a semi-dark room.

PROLOGUE: *PROMoting real Life Observation for Gaining Understanding of road user behaviour in Europe*

PVT: *Psychomotor Vigilance Test*

SDLP: *Standard Deviation of Lateral Position*

Objective measure reflecting how well an individual maintains his lane position in a driving simulator.

SSRI: *Selective Serotonin Reuptake Inhibitors*

SSS: *Stanford Sleepiness Scale*

TCA: *Tri-Cyclic Antidepressant*

One of the first-generation families of antidepressants with sedative effects.

TELEFOT: *Field Operational Tests of aftermarket and nomadic devices in vehicles*

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Marta Gonçalves is Head of the Psychiatry and Sleep Medicine departments at the Hospital CUF Porto since 2011. She is a member of the Organizing Committee of several national and international congresses. Invited Speaker in various scientific events. She is the president of the Portuguese Sleep Association (2008/2013) and a member of the EU Committee of the European Sleep Research Society and of the executive committee of ANSS (Assembly of National Sleep Societies).

UK

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Jim Horne is at the Sleep Research Centre at Loughborough University, UK. With Dr Louise Reyner, his work on sleep related crashes has led to changes to UK Government policy on driver sleepiness, including new road signs throughout the country.

Until recently he was Editor of the Journal of Sleep Research. His 'popular' book, 'Sleepfaring – a journey through the science of sleep' OUP, covers many issues relating to sleepiness and accidents.

FRANCE

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Damien Léger is the Head of the University Hospital Hotel-Dieu Sleep and Vigilance Centre in Paris, APHP, Paris Descartes, France. He is current President of the French Institute of Sleep and Vigilance (Institut National du Sommeil et de la Vigilance), General Secretary of the French Sleep Society and member of the European Board of the Insomnia European network. He is an expert of the French National road safety board expert council (ONISR) and of the Prévention Routière scientific board. He serves as a consultant to the World Health Organization, the European Community, the French National Health Agency and the French Ministry of Health, Labour, Environment and Transportation. Associate editor of the Journal of Sleep Research and Sleep Medicine Review. Damien Léger is the author of five books and over 80 scientific publications.

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