Synthesis title: Driver Fatigue

Observatory main category: Drivers

Other relevant topics:

- Drink Driving
- Drug Driving
- Fitness to Drive
- Older Drivers
- Buses, Minibuses and Coaches

Keywords:
Driver fatigue, Driver sleepiness, Driver alertness, Fatigued drivers, Driving performance, Sleep-related vehicle accidents, Cognitive functions, Motor functions, Impairment, Accident risk, Restorative rest, Fatigue countermeasures

Key facts

- Driving while fatigued or sleepy leads to impairment of driving performance by increasing reaction times, reducing attention and compromising the driver's ability to control their vehicle (Bartlett, 1953; Friswell & Williamson, 2008)
- Sleep-related vehicle accidents are more common on long monotonous roads due to the lack of stimulating scenarios (Horne & Reyner, 2001)
- Fatigued drivers are more likely to be involved in an accident resulting in the fatal injury of themselves or their vehicle's occupants than non-fatigued drivers (HVCIS database – Parkes, Gillan & Cynk, 2009)
- Research has found that a person who drives after being awake for 17 hours has impaired driving skills comparable to a driver with a 0.05 mg/ml blood alcohol level. A driver who has gone without sleep for 24 hours has impaired driving skills comparable to a driver with an illegally high blood alcohol concentration of 0.1 mg/ml (Dawson & Reid, 1997; Williamson & Feyer, 2000)
- Research shows that there are two daily peaks when fatigue accidents are most prevalent due to a dip in cognitive and motor function performance. The first is in the early hours of the morning, commonly accepted as 2.00am to 6.00am. The second peak occurs between 2.00pm and 4.00pm (Brown, 1994; Pack et al., 1995; Horne & Reyner, 1995; Eskandarian et al., 2007)
- The behavioural effects of caffeine that have been empirically demonstrated include increased alertness, faster reaction times, improved accuracy on choice reaction, improved vigilance and improved tracking accuracy (Brice & Smith, 2002)
- Use of energy drinks have shown significant improvement in driving performance, demonstrated by less varied speed, better lane keeping, fewer critical incidents and faster reaction times when compared with a placebo (Horne & Reyner, 2001; Parkes et al. 2005). It is worth noting however that these effects are quite small and the authors have concluded that functional energy drinks should not be used as a perceived cure for driver sleepiness.
- A simulator study found that the alerting effects of a rumble strip only lasted for up to five minutes before sleepiness returned (Anund et al., 2008)
- Drivers with sleep apnoea are at a statistically significant increased risk of involvement in motor vehicle accidents, potentially two to three times higher than other drivers (Ellen et al., 2006)

- Continuous positive airway pressure (CPAP), a treatment that uses mild air pressure, via a ventilator, to treat Obstructive Sleep Apnoea by keeping the airways open, has been consistently shown to improve driving performance and reduce the accident risk of sufferers of this condition (Ellen et al., 2006; Tregear, Reston, Schoelles & Phillips B., 2010)
- Prophylactic (preventative) naps, taken in the afternoon between 2pm and 5pm and before sleep loss is accrued, have been shown in a study by Macchia et al. (2002) to be particularly advantageous for night time truck drivers. There were limitations to the study; only eight drivers were used in a lab-based simulator, and data from three of these had to be discounted). Nonetheless, naps were demonstrated to lead to faster and more consistent reaction times, reduced accident risk, and higher night time alertness up to 14 hours later (Macchia et al., 2002).

Summary

Fatigue can result in both cognitive and motor function impairment caused through a reduction in physiological and psychological reductions in performance. Driving while fatigued or sleepy can lead to increased reaction times, reduce attention and compromise a drivers' ability to control their vehicle (Bartlett, 1953; Friswell & Williamson, 2008).

After 17 hours of sustained wakefulness, a driver's psychomotor performance decreases to a level equivalent to that of a driver with a blood alcohol concentration of 0.05mg/ml (Dawson & Reid, 1997). A driver who has gone without sleep for 24 hours has impaired driving skills comparable to a driver with an illegally high blood alcohol concentration (0.1 mg/ml) (Dawson & Reid, 1997; Williamson and Feyer, 2000). Fatigued drivers are more likely to be involved in an accident resulting in the fatal injury of themselves or their vehicle's occupants than drivers involved in non-fatigue related accidents (HVCIS database – Parkes, Gillan, Cynk, 2009).

In the UK during 2016, fatigue was recorded by police as a contributory factor in 4% of fatal accidents and 2% of serious injury accidents (RRCGB, DfT, 2017). However, research suggests that sleep-related vehicle accidents are under-reported and in fact are more likely to account for 16% to 20% of all vehicle accidents in the UK (Horne & Reyner, 1995).

Sleep-related vehicle accidents are more common on long monotonous roads due to the lack of stimulating scenarios that are experienced in urban driving environments (Horne & Reyner, 2001).

Research shows that there are two daily peaks when fatigue accidents are most prevalent. The first is in the early hours of the morning; commonly accepted as 2.00am to 6.00am. The second peak occurs between 2.00pm and 4.00pm (Brown, 1994; Pack et al., 1995; Horne and Reyner, 1995; Eskandarian et al., 2007). A dip in cognitive and motor function performance at these times contributes to driver fatigue accident risk.

85% of sleep-related vehicle accidents involve male drivers (Flatley, Reyner & Horne, 2004). Drivers under 30 years are most at-risk of being involved in a sleep-related vehicle accident (Horne & Reyner, 1995; Flatley, Reyner & Horne, 2004). A more recent study (Filtness, Reyner & Horne, 2011) reinforces the risk associated with fatigue and young drivers. This study also concludes that effects of sleepiness take longer to develop in older drivers, indicating that they are less vulnerable to sleep-related driving impairment.

An analysis of over 600 truck accidents in Europe identified fatigue as the main cause in 6% of the accidents investigated, with 37% of these resulting in a fatality (International Road Transport Union, 2007). Accidents involving HGVs show an increased level of severity when the driver is fatigued (1.26 fatalities per accident involving a fatigued driver) in comparison with all HGV accidents (1.11 fatalities per accident involving a fatigued driver). PSV accidents involving a fatigued driver also show a high level of severity (2.00 fatalities per accident involving a fatigued driver) than for all PSV accidents (1.11 fatalities per accident involving a fatigued driver) (Parkes et al., 2009).

Countermeasures

Despite evidence that they are ineffective, many drivers persist in using use a number of ad-hoc measures that they believe (erroneously) will combat fatigue, including opening the window, turning on the radio and talking to a passenger (Nordbakke & Sagberg, 2007; Oran-Gilad & Shinar, 2000). None of these measures have been shown to have a restorative effect on fatigued driving, and their continued use means that drivers tend to avoid measures that are effective (e.g. stopping and taking a nap).

Many vehicle manufacturers have implemented accident avoidance features in some of their vehicles. These systems provide opportunities to minimise the impact of an accident, which may result from severe fatigue or distraction. Although a review of technologies has already been made, an independent evaluation of their effectiveness has not been completed.

Cotter, Reed & Wright (2006, cited in Charman, 2009) conducted a review of eleven sleepiness detection devices. These included devices based on measurements of eye movements, driver behaviour (including steering and lane deviations), fatigue models, and on a combination of these approaches. The review showed that detection technologies available at the time of the review were being used to warn drivers of unexpected sleepiness rather than keep the driver awake. Jackson et al. (2011) further discuss this issue, suggesting that these types of devices only respond once a driver's performance is already significantly impaired and that drivers may continue to drive until devices are activated, rather than acting responsibly when recognising that they are fatigued. Therefore, use of such devices should be treated with caution.

A study into the use of a lane monitoring system in Germany concluded that implementation would lead to a 35% reduction in lane changing related accidents (a significant proportion of which were a result of fatigue). This would equate to a 2.9% reduction in all vehicle accidents in Germany. These types of systems may also provide safety benefits within the UK.

The consumption of caffeine, through tea, coffee, cola or an energy drink, helps to increase alertness, produce faster reaction times, improve accuracy of decision making, improve vigilance and improve tracking accuracy (Brice & Smith, 2002). In addition, the use of an energy drink also results in significant improvement in driving performance, demonstrated by less varied speed and fewer critical incidents (Parkes et al., 2000).

Research in the USA showed that continuous hard shoulder rumble strips, also used along motorways in the UK, can reduce single-vehicle run-off road accidents by approximately 20% (Griffith, 1999; Hanley et al., 2000). However, the effect of rumble strips on approach to a change in speed limit, a roundabout, or road toll has only proven to be effective for up to five minutes (Anund et al., 2008). Research also suggests that drivers proactively rely on these features with 63% of surveyed drivers believing that rumble strips would wake them if they fall asleep Nordbakke & Sagberg (2007).

Studies in the USA, Australia and Sweden have indicated that Obstructive Sleep Apnoea is prevalent in 12% to 17% of professional drivers (Talmage et al., 2008; Parks et al., 2009; Howard et al., 2004; Carter et al., 2003). Estimates suggest that, in the UK, approximately 80% of people with sleep apnoea are either unaware or do not seek diagnosis (Gibson, 2005).

Continuous positive airway pressure (CPAP) is a treatment that uses mild air pressure, via a ventilator, to treat Obstructive Sleep Apnoea by keeping the airways open. This has consistently been shown to improve the driving performance and reduce the accident risk of sufferers of OSA by helping to reduce daytime sleepiness within two to seven days of treatment (Ellen et al., 2006; Tregear, Reston, Schoelles & Phillips B., 2010).

Work-related driving poses a considerable risk on UK roads and fatigue is a primary contributory factor. To combat driver fatigue the European Union has implemented a number of regulations and directives (Regulation EC 561/2006, Directive 2002/15/EC and Directive 2003/88/EC). Regulations and directives attempt to provide a standardised approach to limits on driving time and requirements on drivers to take minimum breaks and rest periods. An assessment of the effectiveness of these regulations and directives shows that some Member States suspect that certain employers maintain a system of double recording, falsifying records to allow drivers to work longer hours (European Union, 2012).

However, when identified, serious offences are reported immediately, which lead to a penal order or notification to the occupational safety and health authorities, who then determine whether more stringent monitoring of the company is required (European Union, 2010).

The most effective and efficient solution to fatigue is restorative rest, which must include sleep (BMA, 2004). Whilst short breaks have shown to improve performance and reduce subjective fatigue (Rosekind, Co & Gregory, 2000; Neri, Oyung % Colletti, 2002), other studies have shown that rest breaks for people suffering from fatigue '*can decrease fatigue but not necessarily accident risk or errors*' (Rogers, Hwang & Scott, 2004).

Prophylactic (preventative) naps taken before sleep loss is accrued have been shown to be particularly advantageous in one study (Macchia et al., 2002), especially for night time truck drivers. There were limitations to the study; only eight drivers were used in a lab-based simulator, and data from three of these had to be discounted). Nonetheless, a three hour nap in the afternoon, between 2pm and 5pm, was shown to reduce the effects of fatigue during the following night's shift resulting in faster and more consistent reaction times, reduced accident risk, and higher night time alertness up to 14 hours later Macchia et al. (2002).

Methodology

A detailed description of the methodology used to produce this review is provided in the Methodology section of the Observatory website at http://www.roadsafetyobservatory.com/Introduction/Methods .

This synthesis was compiled during November 2013.

Searches were carried out on the pre-defined research (and data) repositories. Search terms used to identify relevant papers included:

- Driver fatigue;
    - Accidents
    - Detection
    - Prevention
    - Signs
- Driver sleepiness
- Driver drowsiness;
    - Detection
- Driving tired statistics;
    - Fatal
    - Serious (where possible)
    - Slight (where possible)
    - Damage only (where possible)
- Drowsy driving statistics;
    - Fatal
    - Serious (where possible)
    - Slight (where possible)
    - Damage only (where possible)
- Medical conditions and driving;
    - Detection
    - Medication
- Driver alertness
- Driving while fatigued
- Road fatigue

Review of Research

A total of 916 pieces of potentially relevant research were identified using these search terms. Given the size of the literature, a decision was made to focus on references from 2000 onwards, although key research undertaken prior to 2000 was also included where judged relevant by the authors. Titles and abstracts were examined using the selection criteria below. However, given the size of the literature, as a starting point the following documents were used as a guide to providing a broad understanding of driver fatigue and directing the authors to the most relevant literature within the issues presented:

- Jackson, P., Hilditch, C., Holmes, A., Reed, N., Merat, N. & Smith, L. (2011). Fatigue and Road Safety: A Critical Analysis of Recent Evidence. Road Safety Web Publication No. 21. Department for Transport. London.
- Eskandarian, A., Sayed, R., Delaigue, P., Blum, J. & Mortazavi, A. (2007). Advanced Driver Fatigue Research. U.S. Department of Transportation. Federal Motor Carrier Safety Administration, Office of Research & Analysis. Washington, DC.
- Charman, S. (2009). Driver fatigue and driving hours: Reducing collision risk through the effective management of fatigue. CPR554. Transport Research Laboratory. Wokingham.
- Parkes, A.M., Gillan, W. & Cynk, S. (2009). The relationship between driver fatigue and rules limiting hours of driving and work. PPR413. Transport Research Laboratory. Wokingham.
- Parkes, A.M., York, I., Burton, S. & Luke, T. (2005). An evaluation of energy drinks containing glucose and caffeine, using the TRL driving simulator. PPR059. Transport Research Laboratory. Wokingham.
- McKernon, S. (2008). A literature review on driver fatigue among drivers in the general public. NZ Transport Agency research report 342. 62 pp.

Selection criteria

Research articles were scored on their relevance and quality. A rating of ‘high’, ‘medium’ and ‘low’ as given to each article under the following criteria.

For relevance

- ‘High’= refers to data on a metric clearly relevant to the topic under investigation
- ‘Medium’= refers to data on a metric that is probably relevant to the UK (e.g. interventions targeting driver fatigue with a similar prevalence to the UK)
- ‘Low’= does not refer to data relevant to the topic under investigation

For quality

- ‘High’= from a high-quality peer-reviewed publication, with clear and appropriate methods
- ‘Medium’= from an academic source (e.g. book chapter, conference) but without peer-review, and/or possessing some methodological weakness (e.g. some possible confounding factors)
- ‘Low’= from a more ‘general’ source (e.g. conference, trade paper) and/or clearly being methodologically weak or inappropriate (e.g. failing to address random variability by use of appropriate statistical techniques)

A high proportion of the research used in this review derives from outside of the UK, but has been included because it is relevant to UK road safety. Key findings were extracted from the identified research to highlight pertinent road safety issues relating to driver fatigue.

Key statistics

The bullet points below provide a summary of the statistical evidence relating to driver fatigue. It should be noted that these statistics do not provide a comprehensive summary of all of the evidence surrounding driver fatigue and that the whole synthesis should be read.

Scale of the problem

- According to UK government figures, in 2012 a total of 1,754 people were killed and 23,039 were seriously injured on Britain's roads (Department for Transport, 2013). Of the accidents that were attended and reported by the police in the UK in 2012, fatigue was recorded as a contributory factor in 4% of fatal accidents and 2% of serious injury accidents (Department for Transport, 2013)
- In the UK during 2012, fatigue was recorded by the police as a contributory factor in 6% of all motorway accidents, 2% of accidents occurring on A roads, 1% of all accidents on B roads and 2% on other roads (Department for Transport, 2013)
- Research suggests that sleep-related vehicle accidents are under-reported and in fact are more likely to account for 16% to 20% of all vehicle accidents in the UK (Horne & Reyner, 1995). This is supported when comparing overseas data, concluding that fatigue is a (partial) cause in 10% to 15% of all severe accidents (Schagen, 2003)

Driver fatigue by age and gender

- An analysis of police fatal road accident records found that 85% of sleep-related vehicle accidents (those accidents conforming to a specific set of criteria based on research by Horne & Reyner, 1995) involve male drivers, with 38% of all sleep-related vehicle accidents involving drivers under 30 years of age (Flatley, Reyner & Horne, 2004)

Road conditions

- Studies in the USA show that sleep-related vehicle accidents are more common on long stretches of un-stimulating, monotonous highway and may account for up to 40% of fatal accidents (Shafer, 1993).

Commercial vehicles and drivers

- An analysis of over 600 truck accidents in Europe identified fatigue as the main cause in 6% of the accidents investigated, with 37% of these resulting in a fatality (International Road Transport Union, 2007).

- Accidents recorded in the Department for Transport's Heavy Vehicle Crash Injury Study Fatal Accident Database determined that fatigue was recorded as a contributory factor in 4.1% of fatal accidents involving an HGV, 5.5% of fatal accidents involving an LCV, and 1.1% of fatal accidents involving a PSV (Parkes et al., 2009)

- Accidents involving an HGV shows an increased level of severity when the driver is fatigued (1.26 fatalities per accident involving a fatigued driver) in comparison with all HGV accidents (1.11 fatalities per accident involving a fatigued driver) (Parkes et al., 2009)

- PSV accidents involving a fatigued driver show a higher level of severity (2.00 fatalities per accident) than for all PSV accidents (1.11 fatalities per accident) (Parkes et al., 2009)

Reaction times

- A within-participants design study (whereby the participants complete the same tasks, once when drunk and once when fatigued) showed a person driving after being awake for 17 hours has impaired driving skills comparable to a driver with a 0.05 mg/ml blood alcohol concentration level. In addition, driver response time was up to 50% slower (Williamson & Feyer, 2000)

- A study in New South Wales concluded that over 60% of drivers experiencing fatigue whilst driving reported '*that it impaired their driving, mostly by slowing reactions, reducing attention to the external driving environment, and disrupting steering skills*' *(p.413)* (Friswell & Williamson, 2008)

Sleep Apnoea

- Estimates suggest that approximately 80% of people with sleep apnoea are either unaware or do not seek diagnosis (Gibson, 2005; Finkel et al., 2009)
- Studies in the USA suggest that between 10% and 20% of the adult population suffer from chronic insomnia (Doghramji, 2006; Ancoli-Israel, 2006)
- Studies in the USA, Australia and Sweden have indicated that Obstructive Sleep Apnoea is prevalent in 12% to 17% of professional drivers (Talmage et al., 2008; Parks et al., 2009; Howard et al., 2004; Carter et al., 2003). Hack, Choi & Vijayapalan et al. (2001) identified that Obstructive Sleep Apnoea can grossly fragment sleep, which in turn produces excessive daytime sleepiness that is likely to result in increased road traffic accident rates

Effectiveness of countermeasures

Fatigue detection devices

- A study in Germany estimated the implementation of a fatigue detection system would lead to a 35% reduction in lane changing related accidents (a significant proportion of which were a result of fatigue), which would equate to a 2.9% reduction in all accidents (eSafety Forum, 2005)

Highway measures

- Research in the USA shows that continuous hard shoulder rumble strips, also used along motorways in the UK, can reduce single-vehicle run-off road accidents by approximately 20% (Griffith, 1999; Hanley et al., 2000)

- The effectiveness of rumble strips on the approach to a change in speed limit, roundabout or toll has not been proven. However, research also suggests that drivers proactively rely on these features with 63% of surveyed drivers believing that rumble strips would wake them if they fell asleep (Nordbakke & Sagberg, 2007).

Research findings

Summaries of key findings are given below. Further details of the studies reviewed, including methodology and key findings, and links to the reports are given in the References section.

Driver Fatigue

Driving while fatigued or sleepy leads to impairment of driving performance by increasing reaction times, reducing attention and compromising the drivers' ability to control their vehicle (Bartlett, 1953; Friswell & Williamson, 2008). Research undertaken by Williamson & Feyer (2000) (using a within-subjects design methodology – meaning that study participants completed the same tests while drunk and separately when fatigued), found that a person who drives after being awake for 17 hours has impaired driving skills comparable to a driver with a 0.05 mg/ml blood alcohol level. A driver who has gone without sleep for 24 hours has impaired driving skills comparable to a driver with an illegally high blood alcohol concentration of 0.1 mg/ml (Williamson & Feyer, 2000).

Symptoms of fatigue can result in both cognitive and motor function impairment caused through a reduction in physiological and psychological reductions in performance.

Symptoms of cognitive impairment include:

- A narrowing of the perceptual field (Easterbrook, 1959)
- Reductions in attention levels (Bartlett, 1953; Friswell & Williamson, 2008)
- Heightened stress and anxiety levels (Brookhuis & de Waard, 2001, in Hancock & Desmond, 2001)

Symptoms of motor function impairment include:

- Reductions in reaction times (Bartlett, 1953; Friswell & Williamson, 2008)
- Difficulty coordinating different parts of the body (Froberg, 1977)

Definition of terms

Although sleepiness and fatigue are different concepts, driver fatigue literature throughout the world has used them interchangeably in a number of related contexts. This is understandable in the sense that fatigue and sleepiness interact, whereby fatigue can promote sleepiness and sleepiness can elevate feelings of fatigue (Philip et al., 2005).

Throughout this synthesis, the terms fatigue and sleepiness are used as reported in the literature.

Fatigue

According to Grandjean (1979), Lal & Craig (2001) and Boksem et al. (2005), fatigue relates to a gradual disinclination towards effort that accumulates over time and results in a reduction in performance levels. In other words completing the task wears out the person completing it (Broadbent, 1953).

Sleepiness

Sleepiness is different from fatigue in that it is not necessarily task-dependent and relates to a difficulty in remaining awake, even when carrying out activities (Dement & Carskadon, 1982, as cited in Mitler, Miller, Lipsitz, Walsh & Wylie, 1998).

Sleepiness is related to circadian (or body clock) effects. The body clock generates and maintains biological rhythms which control sleep (Philip et al., 2005). In the daytime, there is a drop in vigilance in the mid-afternoon and a peak in alertness towards the end of the afternoon (Lavie, 1986). At night time the body is geared towards sleep and so there is a drop in vigilance.

Borbély (1982) developed a model of sleep regulation based on the homeostatic and circadian processes. Borbély suggested that these processes have a dominant role in sleep regulation, with the homeostatic process being dependent on sleep, and the circadian process being independent of sleep. Sleep propensity and duration are proposed to be determined by the combination of the two processes. Akerstedt & Folkard (1987) built on Borbély's two-process model to develop a three-process model of regulation of alertness, expanding the previous model to capture the transient effect of sleep inertia.

How much sleep do you need?

The US Department of Health and Human Services (2011) states that '*if you have several nights in a row of fewer than 7–8 hours of sleep, your reaction time slows. Restoring that reaction time to normal can take more than one night of good sleep, because a sleep debt accumulates after each night you lose sleep. It may take several nights of being well rested to repay that sleep debt and make you ready for driving on a long road trip*' *(p.17)*.

The quality and quantity of sleep is important. People whose sleep is frequently interrupted or cut short may not get enough of both non-rapid eye movement sleep and rapid eye movement sleep. These types of sleep are vital elements for learning and memory performance.

Van Dongen et al. (2003) studied the effects of restricting sleep to four, six or eight hours per night for two weeks. Restriction of sleep to four or six hours per night resulted in cognitive performance deficits that were equivalent to up to two nights of total sleep deprivation. The authors concluded that '…*even relatively moderate sleep restriction – if sustained night after night – can seriously impair waking neurobehavioural functions in healthy young adults.*' (p.124).

Sleep needs vary between individuals. Sleep patterns also change over time. As people get older, the time spent in the deep sleep stages reduces and is replaced by light sleep. This can result in excessive daytime sleepiness, requiring a person to sleep or nap in the day.

Difference between chronic and acute fatigue

Fatigue is generally categorised as acute or chronic (Mohren et al. 2007; Brenu et al., 2010).

Chronic fatigue

Due to the lack of restorative sleep over a sustained period of time, drivers can become chronically fatigued. The lack of restorative sleep can occur for a variety of reasons, such as disruption to sleep patterns experienced by shift workers, insomnia or a lack of sleep after becoming a new parent.

Studies in the US suggest that between 10% and 20% of the adult population suffer from chronic insomnia (Doghramji, 2006). However, there is a lack of literature assessing the effects of chronic fatigue on drivers.

Acute fatigue

Whereby chronic fatigue develops over a longer period of time, acute fatigue can occur as a result of a single event; for example one bad night of sleep.

How Can Sleepiness Be Measured?

Tests to measure sleepiness have focussed on identifying different levels of sleepiness. There are many different tests and this section describes those tests that have been commonly used to assess sleepiness in a research context.

Subjective measures

Karolinska Sleepiness Scale

The Karolinska Sleepiness Scale (KSS) is a measure designed to assess how sleepy a person is feeling at a given point in time. It is a self-rating measure and patients are asked to rate their feelings during the five minutes prior to the test on a nine point scale ranging from 1, '*very alert*' to 9, '*very sleepy, fighting sleep*'. The KSS is often used in research to track participant's introspective sleepiness over time.

Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Philips & Dement, 1973)

The Stanford Sleepiness Scale (SSS) is very similar to the Karolinska sleepiness scale in that it also measures sleepiness/alertness at a given point in time. SSS uses a seven point scale to rate levels of sleepiness, ranging from 1, '*Feeling active, vital, alert, or wide awake*' to 7, '*No longer fighting sleep, sleep onset soon; having dream like thoughts*'. The SSS also includes an X rating for when people have actually fallen asleep. In this respect the SSS goes further than the KSS in that its highest ratings describe a state that is closer to sleep than the highest ratings of the KSS.

Epworth sleepiness scale (Johns, 1991)

The Epworth sleepiness scale is a measure used to assess typical daytime sleepiness. It is a questionnaire which requires an individual to rate the likelihood that they will doze off or fall asleep during eight different common activities, such as reading or riding as a passenger in a car. Respondents make their ratings on a scale of 0 to 3, where 0 indicates that they would never fall asleep while doing the activity and 3 indicates that they would be very likely to fall asleep doing the activity. Each rating is added to form a total ESS score ranging between 0 and 24. Scores of less than 10 indicate normal levels of daytime sleepiness. Higher scores may be indicative of a sleep disorder or other condition affecting sleep.

It should be noted that self-assessments of fatigue and sleepiness have proven to be inaccurate, in particularly in the simulated environment (Harrison & Horne, 2000; Philip et al 2005).

Objective measures

The most frequently used objective measures are the electroencephalogram (EEG) which measures brain activity, the Psychomotor Vigilance Test (PVT) and the electrooculogram (EOG) which measures eye movements. The EEG and the EOG are physiological measures which have been used in both controlled laboratory and practical driving studies (Åkerstedt & Kecklund, 2000).

The studies aim to identify levels of sleepiness through low levels of alpha activity (4-12 Hz) and eye movement. The PVT tests response times against a rolling clock presented to subjects. This method has proven to be a reliable indicator of sleepiness when using a 10 minute test procedure, and somewhat reliable using a 5 minute test procedure (Loh, et al., 2004).

How Much of a Problem is Driver Fatigue?

Fatigue and sleepiness have been studied extensively by road safety researchers across the world because of the high number and severity of accidents where fatigue is classified as a causation factor. Horne & Reyner (1995) suggest that sleep-related vehicle accidents are likely to account for at least 16% of all urban road accidents to 20% of all motorway accidents. More recent research by Horne & Reyner (1999) confirms that sleep-related accidents are uncommon in urban environments due to the presence of stimulating scenarios and more common on motorways due to the monotonous driving environment.

According to UK government figures, in 2012 a total of 1,754 people were killed and 23,039 were seriously injured on Britain's roads (Department for Transport, 2013). Of the accidents that were attended and reported by the police, fatigue was recorded as a contributory factor in 4% of fatal accidents and 2% of serious injury accidents (Department for Transport, 2013).

In the UK during 2012, fatigue was reported by the police as a contributory factor in 6% of all motorway accidents, 2% of accidents occurring on A roads, 1% of all accidents on B roads and 2% on other roads (Department for Transport, 2013).

A comparison of research and STATS19 data highlights a potential disconnect between reported accident data, which is based on a judgement of contributory factors provided by the police, and the results of scientific research. It is possible that the method of reductive reasoning (an attempt to explain a complex effect through a simple cause) used by Horne & Reyner (1995), could overestimate the problem of driver fatigue.

Equally, as has been shown across the world, reported accident figures could underestimate the driver fatigue problem due to a range of factors, such as the lack of a standardised methodology for recording information about driver fatigue; differences between investigating officers in their understanding of driver fatigue; and difficulties associated with proving driver fatigue as a cause (Robertson et al., 2009).

Whilst there is some variance in the results of the research undertaken in this area, the growing body of evidence suggests that reported accident figures underestimate the problem of driver fatigue. Following a detailed literature study of international research, Schagen (2003) states that, *'when the various foreign data sources are combined, it must be concluded that fatigue is a (partial) cause in 10-15% of all severe accidents*' *(p.3)*.

Estimates of prevalence in different age and gender groups

85% of all drivers involved in sleep-related vehicle accidents assessed by Flatley, Reyner & Horne (2004) were male. In addition, 38% of all drivers involved in sleep-related vehicle accidents were between 17 and 30 years old. A more recent study, undertaken by Filtness, Reyner & Horne (2011) reinforces the risk associated with fatigue and young drivers. This study also concludes that effects of sleepiness take longer to develop in older drivers, indicating that older drivers are less vulnerable to sleep-related driving impairment.

Philip et al. (2004) examined the effect of 24 hours of total sleep deprivation on driving reaction time in young (20-25 years old) and older (52-63 years old) people. Performance under sleep deprived conditions was compared with a rested condition where participants were permitted to sleep between 23:00 and 07:30. Self-ratings of instantaneous fatigue, sleepiness and predicted reaction time performance were also collected. The main dependent variable was the number of reaction time lapses (a response time exceeding 500 milliseconds). Participants were tested six times at two hour intervals between the times of 09:00 and 19:00.

When analysing the results, the research team found that in the younger group, sleep deprivation increased the risk of lapse by 1.9 times, but in the older group sleep deprivation did not significantly increase the risk of lapses.

This may suggest that older people are more resistant to the debilitating effects of sleep deprivation. Both young and older participants predicted a reduction in their performance in the sleep deprived condition. However, where older subjects overestimated their expected reduction in performance, younger subjects underestimated it. Philip et al. (2004) argue that this may leave younger drivers more susceptible to sleep-related road accidents.

Estimates of prevalence in different road conditions

McBain (1970) defined a road as monotonous '*when the stimuli remain unchanged*'. Studies in the USA show that sleep-related vehicle accidents are more common on long stretches of highway and may account for up to 40% of fatal accidents (Shafer, 1993). Drivers are more likely to fall asleep on straight monotonous roads where '*boredom*' is likely to occur (Sagberg, 1999).

Other studies confirm the results of McBain & Sagberg. Desmond & Matthews (1998) state that '*driving performance degrades at a faster rate on straight road sections than on curves*', and a simulator study undertaken by Thiffault & Bergeron (2003) suggests that fatigue is likely to occur much earlier when driving in a monotonous, low demanding road environment.

Estimates of prevalence in commercial and passenger carrying vehicles

An analysis of DfT's Heavy Vehicle Crash Injury Study Fatal Accident Database undertaken by Parkes et al. (2009), aimed to assess the number and proportion of drivers where behavioural factors were reported and where fatigue and excess hours were reported as contributing to the accident. This study determined that fatigue was recorded as a contributory factor in 4.1% of fatal accidents involving a heavy goods vehicle (HGV), 5.5% of fatal accidents involving light commercial vehicles (LCV), and 1.1% of fatal accidents involving a bus, coach or minibus (PSV). For accidents involving an HGV, the data shows an increased level of severity when the driver was fatigued (1.26 fatalities per accident involving a fatigued driver) in comparison to all HGV accidents (1.11 fatalities per accident involving a fatigued driver). For PSV accidents involving a fatigued driver, the severity is much higher (2.00 fatalities per accident involving a fatigued driver) than for all PSV accidents (1.11 fatalities per accident involving a fatigued driver). For LCVs the severity is the same for fatigue related and non-fatigue related accidents.

Furthermore, the data suggests that fatigued HGV, LCV or PSV drivers are more likely to be involved in accidents where the occupants of their vehicle are fatally injured.

The European Commission and the International Road Transport Union joined together to launch the European Truck Accident Causation (ETAC) study to identify the main cause of accidents involving trucks (International Road Transport Union, 2007). The database included in-depth data on over 600 truck accidents that included at least one injury, across 7 European countries.

Of the four main accident configurations identified in the ETAC study, fatigue was a major cause in three of them. The analysis of over 600 truck accidents identified fatigue as the main cause in 6% of the accidents investigated, with 37% of these resulting in a fatality. Most accidents that resulted from fatigue happened between 02.00 to 02.59 and 15.00 to 15.59, when the circadian rhythm is known to be at a low point (International Road Transport Union, 2007).

Estimates of prevalence in different injury classifications

A review of literature on behalf of the US Federal Motor Carrier Safety Administration highlighted that accidents where drivers have fallen asleep are on average very serious in terms of injury severity (Pack et al., 1995). In addition, it was concluded that accidents involving fatigued drivers have a high fatality rate '*because the perception, recognition, and vehicle control abilities of the driver reduces sharply while falling asleep*'.

Whilst there are studies that refer to the impact of fatigue on accidents resulting in fatal injuries, research into the impact of fatigue on serious injuries is limited and on slight injuries non-existent.

Estimates of prevalence at different times of day and week

There has been decades of research highlighting the importance of time of day on performance of tasks. The basis of the time of day effect is our 24 hour physiological rhythm known as the '*circadian rhythm*' which is geared up to support action in the daytime, and rest during the night.

Generally, research shows that there are two daily peaks when fatigue accidents are most prevalent due to a dip in cognitive and motor function performance. The first is in the early hours of the morning; commonly accepted as 2.00am to 6.00am. The second peak occurs between 2.00pm and 4.00pm (Brown, 1994; Pack et al., 1995; Horne & Reyner, 1995; Eskandarian et al., 2007). This has been shown to be consistent in studies undertaken in the UK (Horne & Reyner, 1995), USA (Pack et al., 1995), Israel (Zomer & Lavie, 1990), Finland (Summala & Mikkola, 1994), Sweden (Kecklund & Akerstedt, 1993) and France (Philip et al., 1996).

Additional research by Horne & Reyner (2001) goes further in suggesting that time-of-day is a more consistent predictor of fatigue-related accidents than duration of driving (time-on-task).

Night shifts are reported to result in greater loss of total sleep time than evening and slow rotating shift schedules (Pilcher, Lambert & Huffcutt, 2000). Night shift workers and those rotating between shifts on a regular basis rarely obtain optimal amounts of sleep. Research shows that night shift workers obtain 1 to 4 hours less sleep than normal when they were working nights (Czeisler, Weitzman & Moore-Ede, 1980). Sleep debt (the cumulative loss of sleep) resulting from shift work can result in significant impairment on decision making, integration of information and vigilance (Krueger, 1989).

What Type of Behaviour Does Driver Fatigue Produce?

Several studies (Dinges, 1995 and Philip et al., 2005) have shown that fatigue influences driving behaviour in specific ways:

- Slower reaction times: fatigue increases the time taken to react in an emergency

- Reduced vigilance: subjects perform worse on attention-based tasks when sleep-deprived (e.g. a fatigued driver will be slower to notice oncoming hazards, such as road works or a railway crossing)

- Reduced information processing: fatigue reduces both the ability to process information and the accuracy of short-term memory (e.g. a fatigued driver may not remember the previous few minutes of driving)

Brown (1994) states that the main effect of fatigue on drivers is withdrawal from the demands of the road and traffic.

Overt behaviours

Parkes, York, Burton & Luke (2005) identified a number of additional behaviours/indicators that are indicative of fatigue, particularly in drivers. These are:

- Blinking
- Yawning
- Head jerking
- Slouching
- Sighing
- Face/eye rubbing
- Body shifts
- Scratching

During episodes of severe fatigue, other behaviours may be observed including prolonged eye closures and microsleeps.

Observable signs of fatigue

Both cognitive and visual distractions can be identified through eye movements. Eyelid closures, slow rolling eye movement and more frequent blinking have all been found to be reliable indicators of the onset of sleep (Wierwille, Wregget, Kirn, Ellsworth & Fairbanks, 1994).

Research undertaken by (Roepke & Ancoli-Israel, 2010) identified that in older drivers fatigue may result from the increased incidence of sleep disorders, including rapid eye movement.

What Impact Does Driver Fatigue Have On Driving?

Fatigue impairs the driver's cognitive and motor performance by slowing reaction times, reducing attention to the external driving environment, and disrupting steering skills (Friswell & Williamson, 2008).

When impaired by fatigue *'a fatigued driver's ability to respond effectively to unusual, unexpected or emergency situations is reduced. Occurrences of these factors pose a risk to the safety of the drivers themselves and to other road users.*' (Akerstedt & Haraldsson, 2001, as cited in Lal & Craig, 2001).

Reaction times

When comparing the effects of fatigue and alcohol, research by Williamson & Freyer (2000) shows that a person who drives after being awake for 17 hours has impaired driving skills comparable with a driver with a 0.05 mg/ml blood alcohol level. In addition, driver response times were up to 50% slower.

In Friswell & Williamson's study (2008), long and short haul drivers in New South Wales, Australia completed a self-reporting survey about their work and experiences of fatigue. Driver fatigue was defined as feeling drowsy or sleepy, being tired, lethargic, bored, unable to concentrate, unable to sustain attention, and being mentally slowed. Analysis of the surveys showed that over 60% of drivers experiencing fatigue felt that '*it impaired their driving, mostly by slowing reactions, reducing attention to the external driving environment, and disrupting steering skills*' *(p.416.)*.

Tracking accuracy

There have been several studies that have assessed the effect of fatigue on tracking ability or lane deviation. Mast et al. (1996) found that lane tracking ability decreases as the time on task increases.

Skipper et al. (1984) found that measures related to vehicle lane position could be used to detect sleepiness. This was reinforced by Dingus et al. (1985), who found that the number of lane deviations, the standard deviation of lane position, and the maximum lane deviation are intrinsically linked with the number of eye closures.

When studying the effect of impairment on driving performance in truck drivers using a simulator experiment, Stein (1995) found that deviation of vehicle lane position '*increases remarkably*' at the point at which drivers have been driving for 13 hours.

Situation awareness

In the USA, it has been identified that monotonous road environments can have a detrimental effect on a driver's awareness of the situation ahead of them (NHTSA, 2007). As such, the surroundings presented to drivers can affect fatigued or alert drivers.

Brown (1994) stated that under conditions of partial sleep deprivation, performance of tasks that are long, familiar, monotonous, uninteresting and complex deteriorates more than that of short, novel, variable, interesting and simple tasks.

Brown (1994) argues that there is a specific state induced by highly repetitive and predictable visual demands. In this state, the visual sampling of the environment is gradually reduced to a point where it is determined by an expectancy of unchanging task demands rather than by current and anticipated task demands. This is termed '*driving without awareness*' and drivers in this state are supposedly oblivious to impending accidents, though they will continue with routine steering corrections.

How to Identify a Fatigue Related Accident

Building on the research of Horne & Reyner (1995) and Reyner et al. (2001), Flatley, Reyner & Horne (2004) conducted an analysis of sleep-related crashes causing death or injury, based on analyses ('audits') of all road traffic crashes from 15 sections of road in the UK. The sections of road used for the study included motorways that were both lit and unlit, that differed in traffic density and the number of lanes, and were urban and rural. Sleep-related vehicle accidents on specific monotonous 'A' roads with lit and unlit dual and single carriageways, as well as a 'B' single carriageway were also studied. Accidents were classified as sleep-related if they conformed to slightly modified criteria from those previously established in Horne & Reyner, 1995:

- Good weather conditions and clear visibility
- Breathalyser/blood alcohol levels below the legal driving limit
- No mechanical defects to the vehicle
- Elimination of 'speeding' and 'driving too close to the vehicle in front'
- Driver had no known medical disorder to cause the accident
- Vehicle either ran off the carriageway or ran into another vehicle that was clearly visible for several seconds beforehand
- No signs of pre-impact emergency swerving or braking
- The police officer at the scene suspected 'sleepiness'

If the accident conforms to the first seven of these criteria, then it was deemed 'possible' that the accident was sleep-related. If the accident conformed to all eight criteria, then it was deemed 'probable' that the accident was sleep-related.

Similarly in the USA, the National Highway Transportation Safety Administration (NHTSA) characterises a fatigue-related accident when:

- The problem occurs during late night/ early morning or mid-afternoon
- The accident is likely to be serious
- A single vehicle leaves the roadway
- The accident occurs on a high-speed road
- The driver does not attempt to avoid an accident
- The driver is alone in the vehicle

How Effective?

Distinguishing Between Effective and Ineffective Countermeasures

Drivers use a number of ad-hoc measures to attempt to overcome the symptoms of fatigue (Nordbakke & Sagberg, 2006; Oran-Gilad & Shinar, 2000). Maycock (1995) found that 30% of drivers try listening to the radio, 68% open a window, 57% try stopping and taking a walk, 25% rely on talking to a passenger and 14% consume a caffeinated drink. Although the majority of these measures have not been proven to be very effective, they remain popular with drivers as they allow them to continue driving.

'*What many drivers fail to appreciate is that sleepiness portends sleep, which can come on more rapidly than they realise, especially if the driver has reached the more profound stage of fighting off sleep. This involves acts such as opening the vehicle's window, turning up the radio, the driver often moving around in the driving seat—actions whereby the driver must fully realise that he or she is very sleepy. At which point the driver should stop driving as soon as possible and take a break for at least 30 minutes, drink caffeinated coffee, and if feasible, take a brief nap*' (Reyner & Horne, 1998).

Fatigue detection devices

In-vehicle fatigue detection devices can provide an insight into the driver and their behaviour whilst driving. In-vehicle systems can monitor the lateral position of the vehicle, the speed at which the driver is travelling (including acceleration levels), movement of the steering wheel and lane deviation. Behaviours such as eye movement, steering wheel grip and in some cases brain waves can also be assessed.

The European eSafety Forum (2005) attempted to calculate the benefit of lane changing monitoring systems used in Germany. It was estimated that if 70% penetration of the passenger vehicle fleet can be achieved, then 50% of all fatigue-related accidents would be affected by such a system. If this figure is correct, the study estimates that implementation of the lane changing monitoring system in vehicles would lead to a 35% reduction in lane changing related accidents (a significant proportion of which were a result of fatigue), which would equate to a 2.9% reduction in all accidents.

The European AWAKE project (http://www.transport-research.info/web/projects/project_details.cfm?id=15255) has developed guidelines for fatigue warning systems. These guidelines recognise that in order for on-road driver fatigue detection systems to be successful, they have to combine driver state (eye and eye lid movements, rate of blinking, eye closures) and driver performance measures (lane and headway tracking), as concluded by Williamson & Chamberlain (2005).

The AWAKE project has produced a set of design guidelines for assessing driver vigilance and warning signals. While these are useful in the development of fatigue detection devices, the project concludes that '*there is no single method that is commonly accepted to detect driver fatigue*'.

Wright, Stone, Horberry & Reed (2007) have undertaken a study to evaluate the sensitivity, intrusiveness, operational and market status of fifteen sleepiness detection devices. Devices assessed came under one of five categories:

- Sleepiness detection devices based on physiological measures
- Sleepiness detection devices based on measures of physical activity
- Sleepiness detection devices based on behavioural measures
- Sleepiness detection devices that used model-based predictions of sleepiness
- Sleepiness detection devices based on combination measures

Following assessment of the devices, Wright, Stone, Horberry & Reed (2007) concluded that while many fatigue detection devices are available for use, the majority of these are '*unsuitable for detecting sleepiness in drivers*' *(p.14)*.

- No single method exists that is commonly accepted to detect driver fatigue in an operational context
- Devices based on physiological measures were too intrusive
- Devices based on physical measures are not sufficiently sensitive
- Devices measuring eye activity were most suitable for detecting sleepiness, although effectiveness is dependent on how the measurements are taken
- Devices using a model-based approach offer some promising results, although further research is required

Rest breaks and sleep hygiene

The most effective and efficient solution to fatigue is a period of restorative rest (BMA, 2004) wherein the individual spends time sleeping (rather than simply having a break from driving but not falling asleep). Breaks, where there has been a period of restorative sleep, have been shown to improve performance and reduce subjective fatigue (Rosekind, Co & Gregory, 2000; Neri, Oyung & Colletti, 2002).

However, there is no guarantee that a rest period will restore performance to the initial level and there is little evidence regarding the necessary duration of rest periods to maintain performance. There is evidence that the restorative effect of rest periods for professional drivers declines throughout a shift.

Prophylactic (preventative) naps taken before sleep loss is accrued have been shown to be particularly advantageous for night time truck drivers (Macchia et al., 2002). There were limitations to the study; only eight drivers were used in a lab-based simulator, and data from three of these had to be discounted). Nonetheless, a three hour nap in the afternoon, between 2pm and 5pm, was shown to reduce the effects of fatigue during the following night's shift in terms of both subjective and physiological measures. Drivers demonstrated faster and more consistent reaction times, reduced accident risk, and higher night time alertness. Macchia et al. (2002) suggest that preventative naps (taken before sleep loss has accrued) are much more effective than recuperative napping (taken when already tired) due to the improvement in performance up to 14 hours later.

Public awareness campaigns

While the relevant cross-sector literature reviewed in the development of this synthesis suggests that driver fatigue awareness campaigns are an important countermeasure, Jackson et al. (2011) states that '*there are currently very few peer-reviewed published journal articles which have systematically assessed the effectiveness of road safety campaigns, designed specifically to target driver fatigue*' *(p.56)*.

Jackson et al. (2011) also highlight that while regular surveys are undertaken by the UK's Department for Transport to evaluate the extent to which drivers rate various driving behaviours as unacceptable, a research study is required to explore the effectiveness of driver fatigue *Think!* campaigns to measure their impact on driving behaviour and/or on driver-fatigue incidents.

The 2013 survey undertaken on behalf of the Department for Transport shows that 68% of people surveyed agreed completely that it is dangerous to carry on driving when they are too tired (TNS BRMB, 2013). This has remained relatively static since 2006.

Caffeine

Caffeine is a naturally occurring chemical that stimulates the central nervous system. It is present in many popular drinks such as tea, coffee, cola and many energy drinks. Brewed coffee has the highest caffeine content, approximately 100-150 mg/180ml; instant coffee has 60-80mg/180ml. Tea has the highest variability in caffeine content with 40-100 mg/180 ml and cola drinks have 17-55 mg/180 ml (Parkes et al. 2005).

Caffeine has numerous positive and negative physiological and psychological effects. Low doses of caffeine can increase alertness and decreased fatigue, although caffeine as a stimulant will only provide short-term benefits, somewhere in the region of two to five hours (Penetar, McCann & Thorne, 1993).

Doses of 100-200 mg of orally administered caffeine can produce more rapid and clearer thought flow and increased wakefulness and cortical arousal (the state of being awake). At very high doses caffeine can affect the cardiovascular system and result in increased heart rate, force of heart contraction and cardiac output.

Smit & Rogers (2000) demonstrated that low doses of caffeine, such as those found in a single serving of tea, coffee or cola, can enhance cognitive performance. This effect is robust for both high and low caffeine consumers. However, Smit & Rogers (2000), as cited in Parkes et al. (2009), also found that the highest doses of caffeine in the study (100mg) seemed to result in a negative effect in the mood of study participants with a higher level of habitual caffeine intake, with subjects showing signs of anger, distress and anxiety.

Brice & Smith (2002) listed more positive behavioural effects of caffeine that have been empirically demonstrated; increased alertness, faster reaction times, improved accuracy on choice reaction, improved vigilance and improved tracking accuracy (although these cannot be relied upon to offset sleep beyond the short term). All of these effects could result in improved driving performance. Increased alertness is of particular interest as it could counteract the negative impact of fatigue on driving.

Functional energy drinks

Several studies have examined the effects on driver performance of functional energy drinks. These drinks contain differing levels of caffeine, glucose and taurine, as well as glucuronolactone and a vitamin B complex.

In one study, Horne & Reyner (2001) examined lane keeping performance and reaction times of sleep deprived subjects (sleep limited to 5 hours) after the administration of 500ml of one energy drink (i.e. 160mg of caffeine). The energy drink counteracted the effects of fatigue and both lane keeping and reaction time in a low-fidelity part-task driving simulator were improved.

Parkes et al. (2001) evaluated the effects of a different energy drink on driving performance after a normal night's sleep. Performance was evaluated during the post lunch dip in vigilance and during the evening. The drink provided 75mg of caffeine and 37.5g of glucose. This formulation was compared with a placebo which was matched for colour, taste and temperature. Both drinks were administered in a single 250ml dose.

Self-reported scales of sleepiness indicated that both drinks had an alerting effect, however, the level and duration of the alerting effect was greater for the energy drink than for the placebo. The energy drink also improved performance in hand-eye coordination resulting in better lane keeping performance during a simulated driving task. Finally, in the placebo condition the drivers tended to drive faster in traffic than in the energy drink condition. The energy drink did not produce any benefits on other performance measures such as speed variability and situation awareness.

It is worth noting that the effects were consistent (statistically significant), but quite small and the authors conclude that functional energy drinks should not be used as a perceived cure for driver sleepiness.

Cold air and use of the radio

Horne & Reyner (1997) evaluated the effects of cold air and having the radio on to maintain driver alertness. Targeting young drivers, subjects were required to drive for 2.5 hours. This included 0.5 hours for adaption to the vehicle and a further 2 hours using a combination of treatments as a control (cold air, radio or nil). They found that the capability of air and radio to counteract driver sleepiness fell below the effects shown by research into the effects of caffeine and a short nap (15 minutes). Results demonstrated that radio had a marginally better and sustained effect than cold air, although it was concluded that neither treatment was suitable as a sustained counteraction of sleepiness. Finally, it concluded that in practical terms, these treatments may serve to allow drivers to find a suitable place to stop and take an appropriate break.

Work organisation

Work-related driving poses a considerable risk on UK roads and fatigue is a primary contributory factor (Jackson et al., 2011). Research studies and analyses of crash data show that many professional drivers, in particular drivers of large goods vehicles, often obtain inadequate sleep, report elevated levels of sleepiness, and are involved in a disproportionately high number of fatigue-related accidents (Parkes, Gillan & Cynk, 2009).

To combat driver fatigue the European Union has implemented a number of regulations and directives (Regulation EC 561/2006, Directive 2002/15/EC and Directive 2003/88/EC). Regulations and directives attempt to provide a standardised approach to limits on driving time and requirements on drivers to take minimum breaks and rest periods. For example, key requirements of the Regulation EC 561/2006 are:

- Daily driving time should not exceed more than 9 hours per day, with the exception of two days per week where the maximum driving time can increase to 10 hours
- The maximum weekly driving time should not exceed 56 hours, although driving time of two consecutive weeks should not exceed 90 hours
- Drivers should not drive for more than 4.5 hours without a break of 45 minutes (separable into 15 minutes followed by 30 minutes)
- In every 24 hour period, the driver must take at least 11 hours rest, although this can be reduced to 9 hours no more than three times per week
- A driver is required to have 45 hours of continuous rest in any 7 day period

Every two years the European Commission compiles a report on the effectiveness of working time rules across member states. The 2012 report, analysing data from 2009-2010 (European Commission, 2012) states that '*Member States have emphasised that enforcement of working time rules for mobile workers is in practice a very complex, burdensome and labour-intensive process. Checks on drivers that work for several employers are even more challenging*' *(p.17)*.

In relation to offences against working time rules, the EU reported that '*If the offence is not regarded as very serious, the first step is to issue instructions to the employers…If the employer does not comply with such requirements within the given period, the responsible inspection authorities will report this as an offence. However, serious offences are reported immediately, which would lead to a penal order or notification to the occupational safety and health authorities, who will determine whether monitoring of the company needs to be stepped up*' *(p.15)*.

Parkes et al. (2006) report on an Australian scheme designed to manage driver fatigue. In September 2008 regulations for drivers hours changed in Australia, with the introduction of the Heavy Vehicle Driver Fatigue Reform (HVDFR). Because Western Australia and the Northern Territories are large, sparsely populated areas, some rules are not practical. Therefore, drivers in these areas operate under a Fatigue Management Code of Practice. This allows organisations to adopt standard hours, Basic Fatigue Management (BFM) or Advanced Fatigue Management (AFM).

Most organisations adopt the standard hours option (Parkes et al., 2006). This is despite the fact that adoption of either BFM or AFM would provide a greater degree of flexibility in the driver's hour's rules in return for the implementation of improved fatigue management systems. The 2008 regulations for drivers hours made all parties (from the driver, the employer and operator) in the '*chain of responsibility*' responsible for managing driver fatigue. As such, reasonable steps must be taken by all parties to prevent fatigue. This includes:

- Developing an industry code of practice
- Use of accreditation schemes
- Review business practices
- Adopting a risk management approach

Technology

Many vehicle manufacturers have implemented accident avoidance features in some of their vehicles. For example, Ford's '*Accident Warning with Brake Support*' system provides a warning; if the driver does not react, the system will apply the brakes accordingly. Volvo's '*Accident Warning with Auto Brake*' system ensures that the car brakes by itself if the system considers that an accident is imminent and there is no intervention from the driver. These systems provide opportunities to minimise the impact of an accident resulting from severe fatigue or distraction.

Cotter, Reed & Wright (2006), as cited in Charman (2009), conducted a review of eleven sleepiness detection devices. These included devices based on measurements of eye movements, driver behaviour (including steering and lane deviations), fatigue models, and on a combination of these approaches. The review assessed the scientific validity of the technologies, their intrusiveness, their availability, their cost and their suitability for alerting drivers to fatigue.

The review showed that detection technologies available at that time were being used to warn drivers of unexpected sleepiness rather than keep the driver awake. This was a concern raised by Jackson et al. (2011) who suggest that these types of devices only respond once a driver's performance is already significantly impaired due to fatigue. As such drivers may continue to drive until devices are activated, believing that activation of the device will allow them to react appropriately if necessary, rather than acting responsibly when identifying the signs that they are fatigued. Jackson et al. (2011) advise caution in the use of such devices.

Although there are many devices available on the market, there is little comparative research quantifying the effectiveness of the devices. Cotter, Reed & Wright (2006), as cited in Charman (2009), identified the need for independent studies evaluating the utility, costs and benefits of such devices to determine whether or not these technologies represent a good opportunity for managing fatigue across the UK road network. Such research has not yet been completed.

Highway design

A number of highway safety features exist relevant to alerting fatigued drivers of an impending danger by causing the vehicle to vibrate and generate an audible rumbling noise. These include rumble strips and patterned road markings.

Literature provides no clear evidence of the effectiveness of rumble strips on the approach to a change in speed limit, roundabout or toll. However, research undertaken in the USA shows that continuous hard shoulder rumble strips, as are also used on motorways in the UK, can reduce single-vehicle run-off road accidents by approximately 20% (Griffith, 1999; Hanley et al., 2000).

Negatively, research shows that drivers proactively rely on these features to protect themselves against the effects of fatigue. Nordbakke & Sagberg (2007) found that 63% of surveyed drivers believed that rumble strips will wake a driver who has fallen asleep. This is despite a simulator study that found that the alerting effects of a rumble strip only lasted for up to five minutes before sleepiness returns (Anund et al., 2008).

Special focus on sleep apnoea

Sleep apnoea is a disorder where an individual has one or more pauses in breathing while asleep. Pauses can last from a few seconds to minutes, and may occur over 30 times an hour. It is usually a chronic condition that disrupts sleep and sleep quality. Studies in the USA, Australia and Sweden have indicated that Obstructive Sleep Apnoea (OSA) is prevalent in 12% to 17% of professional drivers (Talmage et al., 2008; Parkes et al., 2009; Howard et al., 2004; Carter et al., 2003).

Estimates suggest that approximately 80% of people with the disorder are either unaware or do not seek diagnosis (Gibson, 2005; Finkel et al., 2009). Hack, Choi & Vijayapalan et al. (2001) identified that OSA can grossly fragment sleep, which in turn produces excessive daytime sleepiness that is likely to result increased road traffic accident rates.

Ellen et al. (2006) and George (2001) established that untreated OSA results in a higher accident risk, potentially two to three times higher than other drivers. Since around 25% of commercial motor vehicle drivers are estimated to suffer from OSA, organisations should seek to educate their drivers and carry out OSA screening programs to help reduce the effects of the condition.

Continuous positive airway pressure (CPAP), a treatment that uses mild air pressure, via a ventilator, to keep the airways open, has consistently been proven to improve driving performance and reduce accident risk by reducing daytime sleepiness with two to seven days of treatment (Ellen et al., 2006; Tregear, Reston, Schoelles & Phillips, 2010). Despite the success of CPAP, studies have shown that approximately 25% of patients with OSA discontinue therapy in the long-term (de Zeeuw et al., 2007).

Gaps in the evidence

Despite the growing concern for driver fatigue in Great Britain there are a number of limitations or gaps in the evidence. The key areas include:

- An accurate calculation of the driver fatigue problem
- The current prevalence of driver fatigue in all injury classifications
- The level of restorative sleep required to re-establish sustainable levels of cognitive and motor function performance
- The need for independent studies to evaluate the utility, costs and benefits of sleep detection devices to determine suitability for managing driver fatigue across the UK

References

The following list of references is not comprehensive given the size of research in this area. The references provided are intended to offer the reader with a sound basis for clarification and further research in the topics discussed in this synthesis.

Title:	**Exploratory study of fatigue in light and short haul transport drivers in NSW, Australia**
Published:	Friswell, R. and A. Williamson (2008) "Exploratory study of fatigue in light and short haul transport drivers in NSW, Australia." Accident Analysis & Prevention 40(1): pp 410-417.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457507001224 $41.95
Objectives:	Identify relationships between work characteristics and fatigue experiences among light and short haul road transport drivers.
Methodology:	321 driver surveys. Stepwise logistic regression analysis
Key Findings:	• 38% of participants experienced fatigue at least once a week while driving for work and 45% had nodded off while driving during the preceding 12 months. • Fatigue is an issue for some light and short haul road transport drivers and identifies work characteristics that should be investigated further.
Keywords:	Driver fatigue, Light transport, Short haul trucking, Working hours, Workload
Comments:	An exploratory study seeking to identify relationships between work characteristics and fatigue experiences among light and short haul road transport drivers. The study supports earlier US work in suggesting that fatigue is a safety issue for light and short haul transport drivers.

Title:	**Fatigue, alcohol and performance impairment**
Published:	Dawson, D. & Reid, K. (1997) Fatigue, alcohol and performance impairment. Nature 388, 235 (17 July 1997)
Link: **Free/priced:**	https://www.eurocockpit.be/sites/default/files/Dawson-Reid-1997.pdf Free
Objectives:	To equate the performance impairment caused by fatigue with that due to alcohol intoxication.
Methodology:	Forty subjects participated in two counterbalanced experiments. In one they were kept awake for 28 hours (from 08.00 until 12.00 the following day), and in the other they were asked to consume 10-15mg of alcohol at 30 minute intervals from 08.00 until their mean blood alcohol concentration reached 0.10%. The study measured the cognitive psychomotor performance at half-hourly intervals using a computer-administered test of hand-eye coordination (an unpredictable tracking test). Results were expressed as a percentage of performance at the start of the session.
Key Findings:	• The key finding of this study shows that moderate levels of fatigue produce higher levels of impairment than the proscribed level of alcohol intoxication.
Keywords:	Fatigue, alcohol, performance impairment, alertness, psychomotor performance
Comments:	Dawson and Reid's study begins by recognising that up to the point of their research, the risks associated with fatigue had not been sufficiently quantified. This research set out to rectify this. The study was used later by Williamson and Feyer (2000) as a basis to further quantify the impact of fatigue on drivers.

Title:	**Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication**
Published:	Williamson, A.M. & Feyer, A-M. (2000) Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. Occup Environ Med2000;57:649-655 doi:10.1136/oem.57.10.649
Link: **Free/priced:**	http://oem.bmj.com/content/57/10/649.short Free
Objectives:	To compare the relative effects on performance of sleep deprivation and alcohol
Methodology:	Performance effects were studied in the same subjects over a period of 28 hours of sleep deprivation and after measured doses of alcohol up to about 0.1% blood alcohol concentration (BAC). There were 39 subjects, 30 employees from the transport industry and nine from the army.
Key Findings:	• After 17–19 hours without sleep, corresponding to 2230 and 0100, performance on some tests was equivalent or worse than that at a BAC of 0.05%. • Response speeds were up to 50% slower for some tests and accuracy measures were significantly poorer than at this level of alcohol. • After longer periods without sleep, performance reached levels equivalent to the maximum alcohol dose given to subjects (BAC of 0.1%).
Keywords:	Long distance driving, sleep restricted, fatigue, sleepiness, performance, driver impairment
Comments:	The findings of this study reinforce the evidence that the fatigue of sleep deprivation is an important factor likely to compromise performance of speed and accuracy of the kind needed for safety on the road and in other industrial settings.

Title:	**Assessment of drivers' workload: Performance and subjective and physiological indices**
Published:	Brookhuis, K. A., & De Waard, D. (2001) Assessment of drivers' workload: Performance and subjective and physiological indices. In P. A. Hancock & P. A. Desmond (Eds.), (2001). Stress, workload and fatigue (pp. 321 – 333). Mahwah, NJ: Lawrence Erlbaum Associates
Link: **Free/priced:**	http://trid.trb.org/view.aspx?id=683356 (Abstract)
Objectives:	To establish an exact measurement between mental workload and accident causation.
Methodology:	Unknown
Key Findings:	• Although stability of primary measures of driving performance over time is what the drivers' goals are, the conditions are variable and sometimes strongly demanding and require effort in variable amounts that at times are beyond capacity. • The accident proneness that follow such conditions is the rationale for measurement of driver's mental workload.
Keywords:	Accident cause; Attention; Driver performance; Driving; Measurement; Methodology; Perception; Physiology
Comments:	Brookhuis and de Waard demonstrate here that a driver's mental ability can sometimes be stretched beyond its capacity, which can increase the likelihood of an accident.

Title:	**Fatigue, Sleepiness, and Performance in Simulated Versus Real Driving Conditions**
Published:	Pierre Philip, MD, PhD; Patricia Sagaspe, PhD; Jacques Taillard, PhD; Cédric Valtat, CRA; Nicholas Moore, MD, PhD; Torbjorn Åkerstedt, MD, PhD; André Charles, PhD; Bernard Bioulac, MD, PhD (2005) Fatigue, sleepiness, and performance in simulated versus real driving conditions. SLEEP 2005;28(12): 1511-1516.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/0301051177900084 $39.95
Objectives:	To determine whether real-life driving would produce different effects from those obtained in a driving simulator on fatigue, performances and sleepiness.
Methodology:	Cross-over study involving real driving (1200 km) or simulated driving after controlled habitual sleep (8 hours) or restricted sleep (2 hours).
Key Findings:	• Fatigue can be equally studied in real and simulated environments but reaction time and self-evaluation of sleepiness are more affected in a simulated environment. • Real driving and driving simulators are comparable for measuring line crossings but the effects are of higher amplitude in the simulated condition. • Driving simulator may need to be calibrated against real driving in various conditions.
Keywords:	Driving, sleep restriction, simple reaction time, driving simulator, real driving, sleepiness scale, young adult, fatigue
Comments:	A study that recognises the differences and similarities between fatigue and sleepiness. The study combines real and simulated driving and measured sleepiness using the Karolinska Sleepiness Scale. One important finding in this study confirmed the lack of effect of the duration of the drive on performance and sleepiness. This goes against the common notion that the driving time is an important factor that needs to be controlled in order to promote road safety.

Title:	**Predicting duration of sleep from the three process model of regulation of alertness**
Published:	Akerstedt, T. & Folkard, S. (2005) Predicting duration of sleep from the three process model of regulation of alertness. Occupational and Environmental Medicine 1996;53: 136-141
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1128427/pdf/oenvmed00074-0064.pdf Free
Objectives:	Present a modification of the quantitative computerised three process model of regulation of alertness to predict duration of sleep in connection with irregular sleep patterns.
Methodology:	The model uses a circadian "C" (sinusoidal) and homeostatic "S" (exponential) component (the duration of previous periods awake and asleep), which are summed to yield predicted alertness (on a scale of 1-16). It assumes that waking from sleep will occur at a given alertness level (S' + C') when recuperation is complete. Variables of electroencephalographic duration of sleep from two studies of irregular sleep were used to model the S and C variables in a regression approach to maximise prediction. The model performance was cross validated against published field and laboratory data.
Key Findings:	• The model parameters were defined with a high degree of precision R2 = 0O99 and the validation yielded similar values R2 = 0O98-095, depending on the acrophase. • The paper also describes a simplified graphical version of the computation model seen as a two dimensional duration of sleep nomogram.
Keywords:	Sleep, prediction, shift work
Comments:	

Title:	**The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation**
Published:	Van Dongen, H.P.A., Maislin, G., MA, M.S., Mullington, J.M. & Dinges, D.F. (2003) The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. SLEEP 2003;2:117-126.
Link: **Free/priced:**	http://www.med.upenn.edu/uep/user_documents/dfd16.pdf Free
Objectives:	To inform the debate over whether human sleep can be chronically reduced without consequences, we conducted a dose response chronic sleep restriction experiment in which waking neurobehavioral and sleep physiological functions were monitored and compared to those for total sleep deprivation.
Methodology:	The chronic sleep restriction experiment involved randomisation to one of three sleep doses (4 hour, 6 hour, or 8 hour time in bed per night), which were maintained for 14 consecutive days. The total sleep deprivation experiment involved 3 nights without sleep (0 h time in bed). Each study also involved 3 baseline (pre-deprivation) days and 3 recovery days.
Key Findings:	• Chronic restriction of sleep periods to 4 hours or 6 hours per night over 14 consecutive days resulted in significant cumulative, dose-dependent deficits in cognitive performance on all tasks. • Subjective sleepiness ratings showed an acute response to sleep restriction but only small further increases on subsequent days, and did not significantly differentiate the 6 hour and 4 hour conditions. Polysomnographic variables and δ power in the non-REM sleep EEG—a putative marker of sleep homeostasis—displayed an acute response to sleep restriction with negligible further changes across the 14 restricted nights. • Comparison of chronic sleep restriction to total sleep deprivation showed that the latter resulted in disproportionately large waking neurobehavioral and sleep δ power responses relative to how much sleep was lost. • A statistical model revealed that, regardless of the mode of sleep deprivation, lapses in behavioural alertness were near linearly related to the cumulative duration of wakefulness in excess of 15.84 hours (s.e. 0.73 hours).
Keywords:	Chronic sleep restriction, partial sleep deprivation, total sleep deprivation, cognitive performance, subjective sleepiness, cumulative deficits, sleep debt, wake extension, core sleep, sleep need

Title:	**Fatigue in industry**
Published:	Grandjean, E. (1979) Fatigue in industry. British Journal of Industrial Medicine, 36 (3), 175-186.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1008561/pdf/brjindmed00071-0001.pdf Free
Objectives:	To confirm the concept of fatigue and its impact on industry.
Methodology:	A review of previous field studies in the area of fatigue.
Key Findings:	• Fatigue is a term that usually denotes a loss of efficiency, and a disinclination for any kind of effort, but it is not a single, definite state. • Fatigue in industrial practice has clinical symptoms: psychic instability, fits of depression and increased liability to illness. • Occupations that demand sustained vigilance must be so planned, with working periods and rest periods that the risk of accidents is not increased through fatigue of the operators.
Keywords:	Physical fatigue, mental fatigue, chronic fatigue, clinical fatigue, electrophysiological phenomena, electromyograms, neurophysiological, hormone influences
Comments:	This paper makes the distinction between physical and mental fatigue and discusses each of these separately. Grandjean's research focusses on biochemical changes, the electrophysiological phenomena and electromyograms of fatigued muscle (physical fatigue), and functional states, neurophysiological aspects of mental health, and hormone influences (mental fatigue). Grandjean emphasises that stress and recuperation must balance over the 24-hour cycle, and that if rest is unavoidably postponed this can be done only at the expense of wellbeing and efficiency. Grandjean uses the results of this work to make the case for managing fatigue in the work place.

Title:	**A critical review of the psychophysiology of driver fatigue**
Published:	Lal, S.K. and Craig, A. (2001) A critical review of the psychophysiology of driver fatigue. Biological Psychology, 55 (3), 173-194.
Link: **Free/priced:**	http://acrs.org.au/files/arsrpe/RS020004.PDF Free
Objectives:	Utilize EEG changes during fatigue for development of fatigue countermeasure software and to test the ability of such software in detecting fatigue.
Methodology:	On-line monitoring of physiological signals while driving. EEG was obtained in twenty truck drivers during a driver simulator task till subjects fatigued. Changes found in delta, theta, alpha and beta activity were used to develop algorithms for the software.
Key Findings:	• EEG delta increased during early fatigue in professionals more so than in non-professionals. • Theta and alpha increased in professionals only. • During medium fatigue, theta increased in both groups. • Alpha increased in professional drivers in both the medium and extreme phases and in non-professionals in the extreme phase, while beta increased most in the medium phase.
Keywords:	Fatigue neurophysiology, physiological signals, countermeasures, software, simulator tasks, truck drivers, delta, theta, alpha, beta
Comments:	This was not a sleep deprivation study so subjects were not sleep deprived prior to the study. The results of this study are discussed in light of driver fatigue management and developing a fatigue countermeasure device.

Title:	**Effects of mental fatigue on attention: An ERP study**
Published:	Boksem, M. A. S., Meijman, T. F., Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. Cognitive Brain Research 25 (2005) 107 – 116
Link: **Free/priced:**	http://www.boksem.nl/pdf/boksem2005cbr.pdf Free
Objectives:	To gain insight in the mechanisms that are central to mental fatigue and in the cognitive functions that are most affected by mental fatigue. Examine how mental fatigue affects the attentional processes of bias the processing of incoming information and actively ignoring irrelevant information.
Methodology:	Using visual attention tasks continuously for 3 h, without rest. Subjects were presented with stimulus displays that consisted of two letters at four possible locations. Subjects were to respond when a target letter appeared at one of the locations that were cued as being relevant. Subjects had to focus their attention on the cued relevant positions and had to ignore stimuli presented on the irrelevant positions. The study used the tasks to detect changes in performance on a task that places high demands on the attentional system, while subjects become more and more fatigued. In addition, electroencephalogram (EEG) and event-related potential (ERP) measures were used to examine the physiological changes related to fatigue and attention.
Key Findings:	• The results indicate a dissociation (mild to severe detachment from immediate surroundings) in the effects of mental fatigue on goal-directed (top–down) and stimulus driven (bottom–up) attention: mental fatigue results in a reduction in goal-directed attention, leaving subjects performing in a more stimulus driven fashion. This has some clear implications for driving a car. • When people are fatigued when driving, this results in a decrease in attention for the road and the other traffic. This would not result in major performance decrements if one can rely on automated behavioural patterns. • However, when an unexpected and potentially dangerous situation arises, fatigued people lack the flexibility that is needed to handle the new and unexpected situation in an adequate way, which may result in the high number of traffic accidents that are due to driver fatigue.
Keywords:	N1, N2b, alpha, theta, selectivity, time on task
Comments:	A simulator based study demonstrating how a decrease in selective attention would lead to a decrease in the driver's ability to focus their attention on the task of driving and increase the likelihood of an accident occurring.

Title:	**The sleep of long-haul truck drivers**
Published:	Mitler, M.M., Miller, J.C., Lipsitz, J.J., Walsh, J.K., and Wylie, C.D. (1997). THE SLEEP OF LONG-HAUL TRUCK DRIVERS. N Engl J Med. 1997 September 11; 337(11): 755–761.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2430925/pdf/nihms51819.pdf Free
Objectives:	Determine the most vulnerable time of day for truck drivers.
Methodology:	Round-the-clock electrophysiological and performance monitoring of four groups of 20 male truck drivers who were carrying revenue-producing loads. The study compared four driving schedules, two in the United States and two in Canada.
Key Findings:	• Drivers averaged 5.18 hours in bed per day and 4.78 hours of electrophysiologically verified sleep per day over the five-day study (range, 3.83 hours of sleep for those on the steady 13- hour night schedule to 5.38 hours of sleep for those on the steady 10-hour day schedule). • These values compared with a mean (±SD) self-reported ideal amount of sleep of 7.1±1 hours a day. For 35 drivers (44%), naps augmented the sleep obtained by an average of 0.45±0.31 hour. • No crashes or other vehicle mishaps occurred. • Two drivers had undiagnosed sleep apnoea, as detected by polysomnography. • Two other drivers had one episode each of stage 1 sleep while driving, as detected by electroencephalography. • Forty-five drivers (56%) had at least 1 six-minute interval of drowsiness while driving, as judged by analysis of video recordings of their faces; 1067 of the 1989 six-minute segments (54%) showing drowsy drivers involved just eight drivers.
Keywords:	Electrophysiological, polysomnography, sleep apnoea, drowsiness, long-haul, truck drivers
Comments:	The results of the study determined that long-haul truck drivers obtained less sleep than is required for alertness on the job. The greatest vulnerability to sleep or sleep-like states is in the late night and early morning.

Title:	**Ultrashort sleep-waking schedule. III. 'Gates' and 'Forbidden zones' for sleep**
Published:	Lavie, P. (1986). Ultrashort sleep-waking schedule. III. Gates and forbidden zones for sleep. Electroencephalography Clinical Neurophysiology, 63 (5), 414-425.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/0013469486901239 $35.95
Objectives:	Investigate the 24 h structure of sleepiness after 1 night of sleep deprivation.
Methodology:	Three experiments which utilized an ultrashort sleep-waking cycle were conducted to investigate the 24 h structure of sleepiness after 1 night of sleep deprivation under 2 experimental conditions: instructing subjects to attempt to fall asleep or instructing subjects to attempt to resist sleep. Six subjects participated in experiment 1. At 19.00 h they started a 13 min waking-7 min sleep attempt, or 13 min waking-7 min resisting sleep, until 19.00 h on the next day. Eight subjects were tested in a similar way in experiment 2, which started at 07.00 h after a night of sleep deprivation and lasted for 24 h. Eight subjects were similarly tested in experiment 3 which started at 11.00 h after a night of sleep deprivation and lasted for 36 h until 23.00 h on the next day.
Key Findings:	• The results showed that in spite of the significant between-group differences in total sleep, the temporal structure of sleepiness was very similar in the 3 experiments. • In each there was a bimodal distribution of sleepiness: a major nocturnal sleepiness crest and a secondary mid-afternoon sleepiness peak. These were separated by a 'forbidden zone' for sleep centred at around 20.00–22.0 h. • The onset of the nocturnal sleep period (the sleep gate) was found to be a discrete event occurring as an 'all or none' phenomenon. • Its timing was stable over a 2 week period, and independent of the specific experimental demands; there were no significant differences between the AS and RS conditions with respect to total sleep time or any of the sleep stages.
Keywords:	Sleep-waking cycle, sleep deprivation, ultrashort sleep
Comments:	Lavie's study demonstrates structured variations in sleepiness across the 24-hour period, showing drops in vigilance in the mid-afternoon and at night when the body is geared towards sleep.

Title:	**The Epidemiology and Diagnosis of Insomnia**
Published:	Doghramji, K. (2006). The Epidemiology and Diagnosis of Insomnia. The American Journal of Managed Care. VOL. 12, NO. 8, SUP. May 2006.
Link: **Free/priced:**	http://programs.rockpointe.com/content/online/swsdtoolkit/downloads/Insomnia_Severity_Index.pdf Free
Objectives:	Provide an overview of insomnia, its prevalence and epidemiology, and guidelines for clinical assessment.
Methodology:	A review of relevant field studies.
Key Findings:	• In the absence of comprehensive knowledge about the active intricacies of the "resting" brain, what is known about the high prevalence and socioeconomic burden of insomnia should encourage increased awareness of the prevalence of sleep disturbances and promote effective treatment strategies.
Keywords:	Insomnia, chronic insomnia, sleep, treatment strategies
Comments:	A review of relevant field studies highlighting the lack of research into the relationships between abnormal sleep patterns predict lower life expectancy, and that insomnia frequently co-occurs with affective disorders, substance abuse, and other physical and psychological comorbidities. The review also discusses the impact of insomnia on fatigue, irritability, decreased memory and concentration and determines that more needs to be done to identify effective treatments.

Title:	**Vehicle accidents related to sleep: a review**
Published:	Horne, J. & Reyner, L. (1999). Vehicle accidents related to sleep: a review. Occup Environ Med1999;56:289-294 doi:10.1136/oem.56.5.289
Link: **Free/priced:**	http://oem.bmj.com/content/56/5/289.full.pdf+html Free
Objectives:	How can sleep-related vehicle accidents be reduced.
Methodology:	A review of studies relating to vehicle accidents, clinical causes of sleepiness, forewarnings of sleepiness, in-vehicle warning devices, symptoms of falling asleep and countermeasures.
Key Findings:	• Falling asleep while driving accounts for a considerable proportion of vehicle accidents under monotonous driving conditions. • Circadian factors are as important in determining driver sleepiness. • Sleep does not occur spontaneously without warning. • Drivers falling asleep are unlikely to recollect having done so, but will be aware of the precursory state of increasing sleepiness. • Putative counter measures to sleepiness, adopted during continued driving (cold air, use of car radio) are only effective for a short time. • The only safe counter measure to driver sleepiness, particularly when the driver reaches the stage of fighting sleep, is to stop driving, and—for example, take a 30 minute break encompassing a short (<15 minute) nap or coffee (about 150 mg caffeine), which are very effective particularly if taken together.
Keywords:	Sleepiness, vehicle accidents, circadian rhythm
Comments:	Horne and Reyner concluded that more education of employers and employees is needed about planning journeys, the dangers of driving while sleepy, and driving at vulnerable times of the day.

Title:	**Fatigue, mindset and ecology in the hazard dominant environment**
Published:	Nelson, T.M. (1997). Fatigue, mindset and ecology in the hazard dominant environment. Accident Analysis & Prevention. Fatigue and Transport. Volume 29, Issue 4, Pages 407-553 (July 1997)
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457597000201 $41.95
Objectives:	Identifying specific experiences of driving fatigue and their relationship to the driver environment.
Methodology:	Ratings made by 47 experienced drivers to 18 items of a Fatigue Advisory.
Key Findings:	• Inattention and drowsiness are frequent threats. • Straight flat roadways with little variations in landscape content may be seen as deficiency hazards, where chronic deficiency of sensory stimulation can reduce arousal to dangerously low levels, causing inattention and drowsiness.
Keywords:	Fatigue, environment, ecology, hazards
Comments:	This study identifies the challenge to improve understanding of the manner in which the experience of fatigue emerges during driving. The study also shows that specific cognitive symptoms of fatigue such as boredom, tiredness, inattention, emerging with driving fatigue, are circumscribed within the activity of driving itself and reflect the particular conditions in which driving fatigue occurs.

Title:	**The validity of psychomotor vigilance tasks of less than 10-minute duration**
Published:	Loh, S., Lamond, N., Dorrian, J., Roach, G., Dawson, D. (2004). The validity of psychomotor vigilance tasks of less than 10-minute duration. Behavior Research Methods, Instruments, & Computers. 2004, 36 (2), 339-346
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pubmed/15354700 Free
Objectives:	To examine the suitability of PVT tests shorter than 10 min.
Methodology:	Fifteen young healthy subjects (7 males and 8 females) volunteered for the present study in response to advertisements displayed at local universities. The subjects were between the ages of 18 and 27 years (M 21.9, SD 2.7) years, with an average body mass index of 22.3 2.3.kg/m2. The subjects were non-smokers, did not regularly consume excessive quantities of caffeine (350 mg/day) or alcohol (6 drinks/week), and exercised regularly. In addition, they reported no history of health or sleep problems, did not habitually nap, and had not undertaken shift work or transmeridian travel in the past month. All of the subjects gave their written, informed consent. Ethics approval for the study was granted by the University of South Australia's Human Research Ethics Committee and the Ethics of Human Research Committee of Queen Elizabeth Hospital.
Key Findings:	• Separate repeated measures ANOVAs indicated that time of day had a significant effect on mean RT for the whole 10 min [F(7,98) 26.1, p .05], the first 5 min [F(7,98) 17.4, p .05], and the first 2 min [F(7,98) 9.32, p .05] of the task (Table 1, Figure 2). • For the comparison of the first 5 min with the whole 10 min of the PVT, repeated measures ANOVAs indicated that mean RT was significantly affected by time on task [F(1,14) 48.84, p .05] and time of day [F(7,98) 22.86, p .05]. A significant interaction [F(7,98) 3.79, p .05] indicated that the effect of time of day was greater for the 10-min task than it was for the first 5 min of the task; thus, the difference in RT between the two tasks was greater at the end of the night of wakefulness than it was at the start. • For the comparison of the first 2 min with the whole 10 min of the PVT, repeated measures ANOVAs indicated that mean RT was significantly affected by time on task [F(1,14) 39.19, p .05] and time of day [F(7,98) 19.88, p .05]. A significant interaction [F(7,98) 3.49, p .05] indicated that the effect of time of day was greater for the 10-min task than it was for the first 2 min of the task; thus, the difference in RT between the two tasks was greater at the end of the night of wakefulness than it was at the start.

Keywords:	Psychomotor vigilance, wakefulness, reaction time
Comments:	Overall, the study reinforced previous research that found that psychomotor vigilance performance during the 10-min PVT deteriorated with increasing wakefulness. The results of this study show that a significant decline in performance was detected during the first 2 min and the first 5 min of the 10-min PVT. Specifically, performance deterioration was observed for mean reaction times, optimum responses, and responses in the lapse domain. These results support the hypothesis that reaction times during the first half of a 10-min PVT are sensitive to the effects of sleep loss.

Title:	**Sleep related vehicle accidents**
Published:	Horne, J. A. and Reyner, L.A. (1995). "SLEEP RELATED VEHICLE ACCIDENTS." BMJ 310(6979): p. 565-567.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2548939/pdf/bmj00582-0029.pdf Free
Objectives:	Assess the incidence, time of day, and driver morbidity associated with vehicle accidents where the most likely cause was the driver falling asleep at the wheel.
Methodology:	Two surveys were undertaken, in southwest England and the midlands, by using police databases or on-the-spot interviews.
Key Findings:	• All vehicle accidents to which the police were summoned, sleep related vehicle accidents comprised 16% on major roads in southwest England, and over 20% on midland motorways. • About half of these drivers were men under 30 years; few such accidents involved women. • It was concluded that sleep-related vehicle accidents are largely dependent on the time of day and account for a considerable proportion of vehicle accidents, especially those on motorways and other monotonous roads.
Keywords:	Sleep, sleep related, vehicle accidents, driver morbidity, time of day
Comments:	This study concluded that sleep related vehicle accidents are largely dependent on the time of day and account for a considerable proportion of vehicle accidents, especially those on motorways and other monotonous roads. The study determined a criteria, still relevant today, for establishing a sleep-related vehicle accident. The findings of this study are similar to those undertaken internationally.

Title:	**Sleep-Related Crashes on Sections of Different Road Types in the UK (1995 - 2001)**
Published:	Flatley, D., Reyner, L.A. and Horne, J.A. (2004). Sleep-Related Crashes on Sections of Different Road Types in the UK (1995– 2001). Road Safety Research Report No.52. London: Department for Transport.
Link: **Free/priced:**	http://www.dft.gov.uk/rmd/search.asp?intStartMonthMin=1&intStartYearMin=2003&intStartMonthMax=1&intStartYearMax=2013&intFormStage=0&intProgrammeID=73&btnDate=Search&intForm=10&intPage=2&intPageSize=10 Free
Objectives:	To highlight areas of a motorway that have a higher than average incidences of sleep related vehicle accidents.
Methodology:	An analysis of police accident report forms, identifying those road traffic accidents that can be attributed to fatigue.
Key Findings:	• Overall, 17% of road traffic crashes (RTCs) resulting in injury or death were sleep related. • Sleep-related vehicle accidents are more evident during the early hours of the morning. • The proportion of sleep-related vehicle accidents increases as traffic volume increases on non-motorways, but for motorways the opposite is true. • Most (85%) of the drivers causing sleep-related vehicle accidents were men. 38% of all drivers causing sleep-related vehicle accidents were aged 30 or under. 67% of sleep-related vehicle accidents were caused by car drivers. • A quarter of all crashes causing death or serious injury were sleep-related vehicle accidents. • Given that 17% of road traffic crashes are sleep-related vehicle accidents; this indicates that sleep-related vehicle accidents are about 50% more likely than the average road traffic crash to result in death or serious injury.
Keywords:	Sleep, sleep related, vehicle accidents, road type, gender, age
Comments:	This is a follow on research project from Horne & Reyner 1995, where the research methodology was refined. A larger data set was used in this research, providing greater confidence of the results.

Title:	**Driver sleepiness—Comparisons between young and older men during a monotonous afternoon simulated drive**
Published:	Filtness, A.J., Reyner, L.A., & Horne, J.A. (2011). Driver sleepiness—Comparisons between young and older men during a monotonous afternoon simulated drive. Biol. Psychol. (2012), doi:10.1016/j.biopsycho.2012.01.002
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0301051112000038 $39.95
Objectives:	To compare the driving ability of young and older male drivers during the bi-circadian 'dip'.
Methodology:	The study assessed the effect of a normal night's sleep vs. prior sleep restricted to 5 hours, in a counterbalanced design, on prolonged (2 hour) afternoon simulated driving in 20 younger (av. 23 y) and 19 older (av. 67 y) healthy men. Driving was monitored for sleepiness related lane deviations, EEGs were recorded continuously and subjective ratings of sleepiness taken every 200 seconds.
Key Findings:	• After sleep restriction younger drivers showed significantly more sleepiness-related deviations and greater 4–11 Hz EEG power, indicative of sleepiness. • There was a near significant increase in subjective sleepiness. • Correlations between the EEG and subjective measures were highly significant for both groups, indicating good self-insight into increasing sleepiness. • The study confirmed the greater vulnerability of younger drivers to sleep loss under prolonged afternoon driving.
Keywords:	Sleepiness, driving ability, age effects, road safety, driving simulator
Comments:	This is a joint study by Monash University in Australia and the Sleep Research Centre at Loughborough University in the UK starting off with a review of previous studies in this area. The methodology, using a simulator to obtain data, is designed based on the findings of previous research undertaken by Horne & Reyner 1995 and Flatley, Reyner & Horne 2004.

Title:	**Reported Road Casualties Great Britain 2012**
Published:	Department for Transport, 2013
Link: **Free/priced:**	https://www.gov.uk/government/publications/reported-road-casualties-great-britain-annual-report-2012 Free
Objectives:	To report on the number of accidents and casualties in the UK during 2012 and to provide insight into why and how road accidents occur.
Methodology:	Analysis of road accident and casualty data reported by the police.
Key Findings:	• In 2012 a total of 1,754 people were killed and 23,039 were seriously injured on Britain's. • Of the accidents that were attended and reported by the police, fatigue was a contributory factor in 4% of fatal accidents and 2% of serious injury accidents. • Based on accident figures reported by the police, in 2012 fatigue was a contributory factor in 64 fatalities, 420 serious injuries and 2,310 slight injuries. • In the UK during 2012, fatigue was a contributory factor in 6% of all motorway accidents, 2% of accidents occurring on A roads, 1% of all accidents on B roads and 2% on other roads.
Keywords:	Reported road casualties, fatigue, contributory factors, accidents, casualties
Comments:	An annual government report providing statistical analysis of all road accidents and casualties in the UK during 2012.

Title:	**Reported Road Casualties Great Britain 2013**
Published:	Department for Transport, 2014
Link: **Free/priced:**	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/359311/rrcgb-2013.pdf Free
Objectives:	To report on the number of accidents and casualties in the UK during 2013 and to provide insight into why and how road accidents occur.
Methodology:	Analysis of road accident and casualty data reported by the police.
Key Findings:	• In 2013, a total of 1,713 people were killed and 21,657 were seriously injured on Britain's. • Of the accidents that were attended and reported by the police, fatigue was a contributory factor in 68 (5%) fatal accidents and 342 (2%) serious injury accidents. • Based on accident figures reported by the police, in 2013 fatigue was a contributory factor in 64 fatalities, 420 serious injuries and 2,310 slight injuries. • In GB during 2013, fatigue was a contributory factor in 6% of all motorway accidents, 2% of accidents occurring on A roads, 1% of all accidents on B roads and 1% on other roads.
Keywords:	Reported road casualties, fatigue, contributory factors, accidents, casualties
Comments:	An annual government report providing statistical analysis of all road accidents and casualties in the UK during 2013.

Title:	**Reported Road Casualties Great Britain 2014**
Published:	Department for Transport, 2015
Link: **Free/priced:**	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463797/rrcgb-2014.pdf Free
Objectives:	To report on the number of accidents and casualties in the UK during 2014 and to provide insight into why and how road accidents occur.
Methodology:	Analysis of road accident and casualty data reported by the police.
Key Findings:	• In 2014, a total of 1,775 people were killed and 22,807 were seriously injured on Britain's roads. • Of the accidents that were attended and reported by the police, fatigue was a contributory factor in 48 (3%) fatal accidents and 400 (2%) serious injury accidents. • Based on accident figures reported by the police, in 2014 fatigue was a contributory factor in 56 fatalities, 508 serious injuries and 2,650 slight injuries. • In GB during 2014, fatigue was a contributory factor in 7% of all motorway accidents, 2% of accidents occurring on A roads, 2% of all accidents on B roads and 1% on other roads.
Keywords:	Reported road casualties, fatigue, contributory factors, accidents, casualties
Comments:	An annual government report providing statistical analysis of all road accidents and casualties in the UK during 2014.

Title:	**The Facts About Fatigued Driving in Ontario: A guidebook for police**
Published:	Robertson, R., Holmes, E., Vanlaar, W. (2009) The Facts About Fatigued Driving in Ontario: A guidebook for police. Traffic Injury Research Foundation. Ottawa, Canada.
Link: **Free/priced:**	http://www.tirf.ca/publications/PDF_publications/2009_Facts_Fatigue_Driving_Ontario_Police_Guidebook.pdf Free
Objectives:	To provide guidance to police officers in Canada on how to identify fatigue-related crashes and improve enforcement strategies to reduce the problem.
Methodology:	Surveys of more than 800 police officers and 750 drivers.
Key Findings:	• In a recent survey of some 800 police officers in Ontario, conducted by the Traffic Injury Research Foundation (TIRF), more than half of those surveyed (56.6%) felt that they had not received adequate information about ways to identify drivers who are drowsy or fatigued or to determine the role of fatigue in crashes. • Officers are not always able to determine whether fatigue played a role in a crash if adequate evidence or eyewitness accounts are not available.
Keywords:	Fatigue-related crashes, enforcement, strategies
Comments:	This guidebook contains the facts about fatigued drivers, fatigued driving crashes, current enforcement strategies, and ways that they can be strengthened to reduce fatigued-driving. It summarises peer-reviewed research and the findings from two Ontario polls conducted by TIRF of more than 800 police officers in Ontario, and some 750 Ontario drivers.

Title:	**Vermoeidheid achter het stuur; Een inventarisatie van oorzaken, gevolgen en maatregelen**
Published:	Schagen, I.N.L.G. van (2003). Vermoeidheid achter het stuur; Een inventarisatie van oorzaken, gevolgen en maatregelen. R-2003-16. SWOV, Leidschendam.
Link: **Free/priced:**	http://cardweb.swov.nl/swov/website_uk_detail.html?Zoek=Zoek&display=1&pg=q&q=r200316&start=0 Free
Objectives:	Provide an overview of the knowledge and insights about the relationship between fatigue and road safety
Methodology:	Literature study
Key Findings:	• The study showed that fatigue has many more causes than the time somebody has been driving. • Too little sleep or a poor quality sleep, the time of day, and stress situations all contribute to the occurrence of fatigue. • Determining the extent to which fatigue plays a part in accidents occurring is extremely awkward. It is almost impossible to objectively diagnose fatigue. • When the various foreign data sources are combined, it must be concluded that fatigue is a (partial) cause in 10-15% of all severe accidents.
Keywords:	Accident, fatigue (human), cause, driver, skill (road user), driving (vehicles), steering (process), reaction (human), accident prevention, publicity, legislation, safety culture
Comments:	This study concluded that the only effective intervention at that time was to provide further information and raise awareness of driver fatigue. It does acknowledge that in the future there is the possibility of starting fatigue management programmes and the development and implementation of intelligent systems that automatically detect and, if necessary, intervene.

Title:	**Road accidents caused by drivers falling asleep**
Published:	Sagberg, F. (1999). Road accidents caused by drivers falling asleep. Accid Anal Prev. 1999 Nov;31(6):639-49.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457599000238 Priced
Objectives:	Understand the causes of sleep-related vehicle accidents
Methodology:	About 29600 Norwegian accident-involved drivers received a questionnaire about the last accident reported to their insurance company. About 9200 drivers (31%) returned the questionnaire. It contained questions about sleep or fatigue as contributing factors to the accident. In addition, the drivers reported whether or not they had fallen asleep some time whilst driving and what the consequences had been.
Key Findings:	• Sleep or drowsiness was a contributing factor in 3.9% of all accidents, as reported by drivers who were at fault for the accident. • This factor was strongly over-represented in night-time accidents (18.6%), in running-off-the-road accidents (8.3%), accidents after driving more than 150 km on one trip (8.1%), and personal injury accidents (7.3%). • A logistic regression analysis showed that the following additional factors made significant and independent contributions to increasing the odds of sleep involvement in an accident: dry road, high speed limit, driving one's own car, not driving the car daily, high education, and few years of driving experience. • More male than female drivers were involved in sleep-related accidents, but this seems largely to be explained by males driving relatively more than females on roads with high speed limits. • A total of 10% of male drivers & 4% of females reported to have fallen asleep while driving during the last 12 months. • A total of 4% of these events resulted in an accident. • The most frequent consequence of falling asleep-amounting to more than 40% of the reported incidents-was crossing of the right edge-line before awaking, whereas crossing of the centreline was reported by 16%.
Keywords:	Sleep involvement, drowsiness, contributing factors, boredom, awareness, warning systems
Comments:	The study suggests that drivers lack awareness of important precursors of falling asleep, such as highway hypnosis, driving without awareness, and similar phenomena. It also points out that there is reluctance among drivers to discontinue driving despite feeling tired. The study concluded that knowledge about the drivers' experiences immediately preceding such accidents may give a better background for implementing effective driver warning systems and other countermeasures.

Title:	**Monotony of road environment and driver fatigue: a simulator study**
Published:	Thiffault, P. and Bergeron, J. (2003). Monotony of road environment and driver fatigue: a simulator study. Accident Analysis and Prevention 35 (2003) 381–391
Link: **Free/priced:**	http://web.ics.purdue.edu/~duffy/IE486_Spr07/IE486_p14_Accid%20Anal%20Prv.pdf Free
Objectives:	This paper focuses on the task induced factors that are involved in the development of drowsiness and hypovigilance frequently occur during highway driving and the associated implications in terms of accident causation.
Methodology:	A driving simulator study was conducted in order to evaluate the impact of the monotony of roadside visual stimulation using a steering wheel movement (SWM) analysis procedure. Fifty-six male subjects each drove during two different 40-min periods. In one case, roadside visual stimuli were essentially repetitive and monotonous, while in the other one, the environment contained disparate visual elements aiming to disrupt monotony without changing road geometry. Subject's driving performance was compared across these conditions in order to determine whether disruptions of monotony can have a positive effect and help alleviate driver fatigue.
Key Findings:	• Results reveal an early time-on-task effect on driving performance for both driving periods and more frequent large SWM when driving in the more monotonous road environment, which implies greater fatigue and vigilance decrements. • Implications in terms of environmental countermeasures for driver fatigue are discussed.
Keywords:	Visual stimulation, monotony, road geometry, time on task, countermeasures
Comments:	While Thiffault and Bergeron acknowledge the importance of measures like rumble strips and in-vehicle monitoring systems that are designed to wake a fatigued driver, they also believe that countermeasures should also be developed that assist the driver in staying awake in the first instance.

Title:	**Scientific Study "ETAC" European Truck Accident Causation**
Published:	The International Road Transport Union (2007). Scientific Study "ETAC" European Truck Accident Causation.
Link: **Free/priced:**	http://ec.europa.eu/transport/roadsafety_library/publications/etac_exec_summary.pdf Free
Objectives:	To develop a scientific, widely accepted and internationally benchmarked methodology; develop a European homogeneous database; investigate over 600 truck accidents in seven European countries; identify the main cause and the causal sequence of accidents involving trucks; recommend actions to various stakeholders which contribute to the improvement of road safety; make the results available to the research community.
Methodology:	Each accident studied involves at least one truck (commercial vehicle of Gross Weight >3.5t); All accidents involve at least one injured person; On-spot investigation of the accident, where: a) the vehicles are still in their final position, and b) the collection of information on infrastructure, vehicles and people involved in the accident (covering around 3000 parameters) can be fulfilled; The sample areas are statistically representative with reference to the national accident statistics and the distribution of national infrastructure.
Key Findings:	• Headline findings show that the main accident cause involving trucks is linked to human error in 85.2% of one of the road participants (truck driver, car driver, pedestrians etc). • However, out of the accidents linked to human error, only 25% are caused by the truck driver. Other factors such as weather conditions 4.4%, infrastructure conditions 5.1% or technical failures of the vehicle 5.3% played only a minor role.
Keywords:	Visual stimulation, monotony, road geometry, time on task, countermeasures
Comments:	The report provides a comprehensive breakdown of all results identified through the research within the relevant topics (. The report encourages all stakeholders within the road transport industry to take responsibility for improving road safety for truck drivers across Europe. The issue of human error in 86% of all accidents analysed is also reinforced, providing yet further justification for education, awareness and training countermeasures.

Title:	**The relationship between driver fatigue and rules limiting hours of driving and work**
Published:	Parkes, A.M., Gillan, W., Cynk, S. (2009). The relationship between driver fatigue and rules limiting hours of driving and work. PPR413. Transport Research Laboratory.
Link: **Free/priced:**	https://trl.co.uk/reports/PPR413-A Free
Objectives:	To review existing UK and international research and other published material in order to determine any links that exist between long driving or working hours and driver fatigue, and the extent to which limits on hours of driving or work help to prevent fatigue related accidents for drivers.
Methodology:	A review of drivers' hours rules in the UK, an analysis of relevant GB accident databases, a detailed review of domestic legislation around Europe and an examination of practice in the USA, Canada and Australia.
Key Findings:	• Any changes to current drivers' hours rules, both EU and UK domestic would need very careful consideration. The question of potential relaxation in exceptional circumstances, must first consider the evidence for a direct link between driving duration and accident rate. • Neither the research literature nor the GB accident databases considered in this review, have revealed a strong link between hours driven and accidents.
Keywords:	Drivers hours, driving duration, accident rate
Comments:	A comprehensive review of literature and data to support the on-going development of legislative and regulatory requirements to reduce the impact of driver fatigue on road accidents.

Title:	**Characteristics of crashes attributed to the driver having fallen asleep**
Published:	Pack AI, Pack AM, Rodgman E, Cucchiara A, Dinges DF, Schwab CW., 1995. Characteristics of crashes attributed to the driver having fallen asleep. Accident Analysis and Prevention 27(6):769–775.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/0001457595000348 $41.95
Objectives:	To investigate the characteristics of crashes attributed to the driver being asleep.
Methodology:	The study utilised the database at the Highway Safety Research Center at the University of North Carolina that is based on the uniform crash reporting system in that state.
Key Findings:	• Over the years 1990-1992, inclusive, there were 4333 crashes in which the driver was judged to be asleep but not intoxicated. • The crashes were primarily of the drive-off-the-road type (78% of the total) and took place at higher speeds (62% in excess of 50 mph). • The fatality rate was of similar magnitude to that in alcohol-related crashes with fatalities in 1.4% of such crashes (alcohol crashes had fatalities in 2.1%). • The crashes occurred primarily at two times of day--during the night time period of increased sleepiness (midnight to 7.00 a.m.) and during the mid-afternoon "siesta" time of increased sleepiness (3.00 p.m.). • These crashes occurred predominately in young people. Fifty-five percent of these were in individuals 25 years of age or younger, with a peak age of occurrence at age 20 years.
Keywords:	Sleep, alcohol, vehicular crashes, circadian rhythm
Comments:	Pack et al. found that sleepiness may play a role in crashes other than those attributed by the police to the driver being asleep. However, the study was unable to establish the magnitude of the problem and acknowledged that this was a challenge to the road safety community.

Title:	**Advanced Driver Fatigue Research**
Published:	Eskandarian, A., Sayed, R., Delaigue, P., Blum, J., Mortazavi, A. (2007) Advanced Driver Fatigue Research (Report: FMCSA-RRR-07-001). Federal Motor Carrier Safety Administration, Washington, DC.
Link: **Free/priced:**	https://library.villanova.edu/Find/Record/1325888/Description Free
Objectives:	To develop an unobtrusive drowsy driver detection system for commercial motor vehicles.
Methodology:	A literature review organised by the type of technology and methods used for detecting fatigue/drowsiness. Experiments were performed in a simulated environment.
Key Findings:	• The data generated from the study experiments was analysed thoroughly to evaluate inputs for a drowsy driver detection system and performance metrics for the system. • This analysis showed a correlation between high amplitude steering corrections and drowsiness. Due to this correlation and the primary purpose of the drowsy driver warning systems, collision avoidance, the ability of the drowsiness detection system to detect drowsiness in a timely fashion prior to a collision was established as the most important evaluation criterion. • Artificial Neural Networks (ANNs) were seen as a natural approach to develop an effective system. The drowsy driver detection system developed in this project uses a unique data pre-processing step that discretizes the steering activity in fifteen-second intervals. • This discretisation enables the ANN to distinguish between low amplitude steering corrections in non-drowsy driving and the larger amplitude steering corrections that characterise drowsy driving.
Keywords:	Collision Avoidance, Commercial Motor Vehicle, Driver, Driving, Drowsy, Fatigue, PERCLOS, Sleep, Steering, Truck
Comments:	One of the core research projects on driver fatigue to have been undertaken in recent times in the USA. The first objective was to arrive at an experimentally validated system for fatigue detection in commercial motor carriers. By monitoring the driver’s steering activity and eye closure behaviour, the aim for this system is to be able to detect a state of driver drowsiness or fatigue sufficiently early to take preventive measures against potential crashes. The emphasis was on development of an algorithm for an unobtrusive monitoring system which mitigates the need for eye tracking as much as possible. A second objective was to research viable countermeasures, for example, warning systems that minimise the severity of crashes and reduce injuries and fatalities in highway crashes involving trucks.

Title:	**Sleep-related vehicle accidents: some guides for road safety policies**
Published:	Horne, J. and Reyner, L. (2001) Sleep-related vehicle accidents: some guides for road safety policies. Transportation Research Part F, 4, pp. 63-73
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S1369847801000146 Priced
Objectives:	To provide guidance for policies aimed at addressing the issue of driver fatigue.
Methodology:	Literature review
Key Findings:	• The best countermeasure is sleep, or even a short nap. Even more effective is the combination of a nap with caffeine.
Keywords:	Sleepiness, time of day, shiftwork, vehicle accidents, safety policies, countermeasures, sleep disorders
Comments:	Horne and Reyner provide guidance on the key requirements for policies aimed at addressing the researched risks associated with driver fatigue.

Title:	**The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment**
Published:	Dingus, T. A., Klauer, S.G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R.R. (1985) Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R. R.(2006) The 100-Car Naturalistic Driving Study, Phase II - Results of the 100-Car Field Experiment DOT HS 810 593
Link: **Free/priced:**	http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/Driver%20Distraction/100CarMain.pdf: Free
Objectives:	The "100-Car Naturalistic Driving Study" is a three-phased effort designed to accomplish three objectives: Phase I, Conduct Test Planning Activities; Phase II, Conduct a Field Test; and Phase III, Prepare for Large-Scale Field Data Collection Effort.
Methodology:	Instrumented vehicle study. The primary purpose of the study was to collect large-scale, naturalistic driving data The 100-Car Study instrumentation package was engineered by VTTI to be rugged, durable, expandable, and unobtrusive. The system was the seventh generation of hardware and software that has been developed over the previous 15 years. The system consisted of a Pentium-based computer that received and stored data from a network of sensors distributed around the vehicle. Data were stored on the system's hard drive, which could store several weeks of driving data before it needed to be downloaded. One-hundred drivers who commuted into or out of the Northern Virginia/Washington, DC metropolitan area were recruited as primary drivers for this study. They could either have their private vehicles instrumented or receive an instrumented leased vehicle to drive for the duration of the study.
Key Findings:	• Crash/collision-involvement was much higher than expected in that 82 total crashes/collisions were reported in this study, while only 15 of these crashes were reported to the police. • Almost 80 percent of all crashes and 65 percent of all near-crashes involved the driver looking away from the forward roadway just prior to the onset of the conflict. • Inattention was a contributing factor for 93 percent of the

	conflict with lead-vehicle crashes and minor collisions. • The rate of inattention-related crash and near-crash events decreases dramatically with age, with the rate being as much as four times higher for the 18-to-20 age group. • Drowsiness also appears to affect crashes and collisions at much higher rates than is reported using existing crash databases. Drowsiness was a contributing factor in 12 percent of all crashes and 10 percent of near-crashes.
Keywords:	100-Car, Naturalistic, Rear-End Collision, Lane Change, Collision Avoidance, Intelligent Vehicle Initiative, Driver Behaviour, Human Factors, Inattention, Distraction, Lead-Vehicle Conflict
Comments:	This research effort was initiated to provide an unprecedented level of detail concerning driver performance, behaviour, environment, driving context and other factors that were associated with critical incidents, near crashes and crashes for 100 drivers across a period of one year. A primary goal was to provide vital exposure and pre-crash data necessary for understanding causes of crashes, supporting the development and refinement of crash avoidance countermeasures, and estimating the potential of these countermeasures to reduce crashes and their consequences. This report documents the efforts of Phase II.

Title:	**Driver fatigue**
Published:	Brown, I.D. (1994) Brown, I. D. (1994). Driver fatigue. Human Factors, 36(2), 298–314.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pubmed/8070794 (Abstract)
Objectives:	Consider the implications of driver fatigue on professional drivers.
Methodology:	Empirical evidence for the separate and combined effects of these factors on fatigue, performance decrement, and accident risk are briefly reviewed, and the implications of these findings for driving and road safety are considered, with particular reference to the professional driver.
Key Findings:	• This study shows that fatigue is insufficiently recognised and reported as a cause of road accidents and that its effects stem largely from prolonged and irregular working hours, rather than simply from time spent at the wheel.
Keywords:	Duty periods, rest, sleep periods, fatigue, performance decrement, accident risk
Comments:	Brown's research identified the impact on driver performance of long, monotonous road environments.

Title:	**Sleep disorders in the elderly.**
Published:	Roepke, S.K., Ancoli-Israel, S. (2010) Sleep disorders in the elderly. Indian J Med Res. 2010 Feb;131:302-10.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pubmed/20308755 (Abstract)
Objectives:	Discuss age-related changes in sleep architecture, aetiology, presentation, and treatment of sleep disorders prevalent among the elderly and other factors relevant to ageing that are likely to affect sleep quality and quantity.
Methodology:	Literature review
Key Findings:	• Nearly half of older adults report difficulty initiating and maintaining sleep. • With age, several changes occur that can place one at risk for sleep disturbance including increased prevalence of medical conditions, increased medication use, age-related changes in various circadian rhythms, and environmental and lifestyle changes. • Although sleep complaints are common among all age groups, older adults have increased prevalence of many primary sleep disorders including sleep-disordered breathing, periodic limb movements in sleep, restless legs syndrome, rapid eye movement (REM) sleep behaviour disorder, insomnia, and circadian rhythm disturbances.
Keywords:	Sleep disturbance, rapid eye movement, circadian rhythm, insomnia, medication, age-related
Comments:	Important research into the effects of sleep-disturbance on the older population and its potential application to fatigue in older drivers.

Title:	**Sleepy at the wheel: Knowledge, symptoms and behaviour among car drivers**
Published:	Nordbakke, S., Sagberg, F. (2006) Sleepy at the wheel: Knowledge, symptoms and behaviour among car drivers. Transportation Research Part F 10 (2007) 1–10
Link: **Free/priced:**	http://trafiksikkerhedsforskning.dk/images/Sleepy%20at%20the%20wheel_artikel_1.pdf Free
Objectives:	To increase the understanding of drivers' actions when feeling sleepy.
Methodology:	A national Internet panel survey was conducted among private drivers in the autumn of 2003.
Key Findings:	• The results indicate that drivers in general have a good knowledge of the various factors influencing the risk of falling asleep while driving. • Furthermore, most of them are well aware of the most effective measures to prevent falling asleep at the wheel, such as stopping the car and take a nap. • In spite of all their knowledge, most of the drivers continue driving when recognising sleepiness while driving. • A short trip, appointments, and the wish to arrive at a reasonable hour are the most frequently reported reasons for continuing driving while fatigued or sleepy.
Keywords:	Sleepiness, behaviour, road safety
Comments:	This research, along with that of Oran-Gilad & Shinar, (2000) and Maycock (1995) are key to understanding the attitudes of drivers towards managing fatigue whilst driving.

Title:	**Review of on-road driver fatigue monitoring devices**
Published:	Williamson, A. & Chamberlain, T. (2005) NSW Injury Risk Management Research Centre, University of New South Wales.
Link: **Free/priced:**	https://www.researchgate.net/publication/242103490_Review_of_on-road_driver_fatigue_monitoring_devices Free
Objectives:	To assess the current status of research into fatigue performance and detection technology and to identify any pertinent issues.
Methodology:	The initial search for information on fatigue detection technology in the scientific literature including Medline, Embase, Transport, IEEE Xplore, and PsycINFO using the search terms, "driver monitoring and fatigue". As it was expected that a reasonable amount of the literature would be in the commercial or 'grey' area of the literature searches of the web were also conducted using Google. In addition, a number of articles concerning known fatigue detection systems (e.g., ALVINN, MANIAC, DAISY, DriveCam, faceLAB) were sought in the IEEE Xplore database.
Key Findings:	• There is evidence that warnings to the driver that their alertness is below a level compatible with safe operation of a vehicle are useful to drivers who may be aware that drowsiness is increasing, but not aware of the impact of the drowsiness on their driving capacity. • Devices that provide this warning may have additional benefits for drivers. • Some of the problems with the fatigue detection devices currently under development include the stage of drowsiness that is being detected, the focus of the measure on driver state or the effects on driver performance (which may not be sensitive to only driver fatigue), and the timing and nature of the warnings used.
Keywords:	Driver monitoring, fatigue
Comments:	This review recognises that the characteristics of fatigue measurement present a real problem for road safety and that the industry and drivers need to be able to detect when fatigue is occurring as a first step in managing the problem. Importantly, the review acknowledges that there are shortcomings in current research into the effectiveness of fatigue detection devices and that further research and development is needed before fatigue monitoring devices are standard features in on-road vehicles.

Title:	**A review of in-vehicle sleepiness detection devices**
Published:	Wright, N.A., Stone, B.M., Horberry, T.J. & Reed, N. (2007) Published Project report PPR157. Transport Research Laboratory. Wokingham.
Link: **Free/priced:**	https://trl.co.uk/reports/PPR157 Free
Objectives:	Analyse the current status of sleepiness detection devices that are commercially available or in the latter stages of development. Assess the sensitivity of the devices, validation issues and likely driver acceptance, as well as the current market status of the device and known operational problems.
Methodology:	The databases and internet search engines used for the information search were 'PubMed', 'PsychInfo', 'Scopus', 'Google' and 'Google Scholar'. An analysis of the scientific evidence for the usefulness of the measures currently used in sleepiness detection devices
Key Findings:	Although many devices for detecting sleepiness are available, most proved unsuitable for detecting sleepiness in drivers, due to a variety of factors, such as insensitivity, intrusiveness and assumed driver acceptance issues. • No single method exists that is commonly accepted to detect driver fatigue in an operational context • Devices based on physiological measures were too intrusive • Devices based on physical measures are not sufficiently sensitive • Devices measuring eye activity were most suitable for detecting sleepiness, although effectiveness is dependent on how the measurements are taken • Devices using a model-based approach offer some promising results, although further research is required
Keywords:	Alertness detector, alertness detection device, alertness device, alertness monitor, sleepiness, sleep, drowsiness, alertness, eye blinking, sleepiness
Comments:	This review is a deliverable under the Department for Transport funded 'Evaluation of Sleepiness Detection Devices' contract. Each device's relationship with sleepiness and performance is described, and general problems and pitfalls associated with their practical use in road transportation are identified.

Title:	**Driver fatigue and driving hours: Reducing collision risk through the effective management of fatigue**
Published:	Charman, S. (2009) Driver fatigue and driving hours: Reducing collision risk through the effective management of fatigue. Project Report CPR554. Transport Research Laboratory. Wokingham
Link: **Free/priced:**	https://trl.co.uk/reports/PPR413-A Free
Objectives:	Review current literature on fatigue, sleepiness and collision risk; review relevant collision data; describe potential countermeasures that may be effective for minimising the impact of fatigue on collision risk.
Methodology:	The study included a literature review, an analysis of the European Truck Accident Causation (ETAC) database and national Stats 19 data, and a review of self-management, in-cab technologies and potential innovative measures to managing driver fatigue.
Key Findings:	The report makes a series of recommendations as summarised below: • Focus on reducing sleepiness and fatigue, rather than solely the number of hours driven • Increased enforcement, training and education programmes • Focus interventions on young, inexperienced and long-haul drivers • Focus enforcement during 10pm-6am for HGV drivers • Undertake independent evaluations of in-cab technologies • Introduce fatigue management schemes similar to those in Australia • Improve existing collision databases • Changes in enforcement activity targets or patterns should be reviewed • Better understand the risk of driving beyond 4.5 hours without a break and the risk when the daily allowance of 9-10 hours is exceeded
Keywords:	Sleepiness, fatigue, collision risk, task monotony, time on task, countermeasures
Comments:	This study was undertaken on behalf of VOSA to assist in developing their strategy to tackle fatigue in a proportionate and appropriate manner in order to effectively enforce drivers' hours regulations.

Title:	**Fatigue and Road Safety: A Critical Analysis of Recent Evidence**
Published:	Jackson, P., Hilditch, C., Holmes, A., Reed, N., Merat, N. & Smith, L. (2011) Fatigue and Road Safety: A Critical Analysis of Recent Evidence. Road Safety Web Publication No. 21. Department for Transport. London.
Link: **Free/priced:**	http://assets.dft.gov.uk/publications/fatigue-and-road-safety-a-critical-analysis-of-recent-evidence/rswp21report.pdf Free
Objectives:	To provide a comprehensive and critical review of the literature that synthesises the evidence relating to fatigue and road safety.
Methodology:	The Department for Transport research specification identified a list of research questions that were to be addressed by this project. These questions were distributed between the three teams collaborating on the project: Clockwork Research, the University of Leeds and the Transport Research Laboratory (TRL). Each team worked independently to identify and critically evaluate the key sources relevant to their research questions, according to criteria agreed with the client at the inception meeting.
Key Findings:	• There had been little research up to the date of the study conducted in the UK to explore this issue. Current understanding of the prevalence of driver fatigue, its impacts on casualty rates, and on drivers' actual behaviour is based on partial information, historic data or international research. • There is now considerable evidence that the effects of fatigue impact upon performance prior to the onset of micro-sleeps and/or lapses. • Fatigue is associated with a progressive escalation of performance variability and the deregulation of neurocognitive performance, of which micro-sleeps are an extreme symptom. • Young, male drivers are over-represented in driver fatigue crashes. However, it is also the case that this group may be more at risk due to higher exposure rates and lifestyle factors. • Obstructive sleep apnoea is very much under diagnosed and compliance with treatment is poor. Commercial vehicle drivers are known to be at higher risk of having obstructive sleep apnoea.

	• Drivers of large goods vehicle are involved in a disproportionately high number of fatigue-related accidents. • Understanding of the link between fatigue and work-related road safety in the UK suffers from a lack of information. • Many drivers continue to drive tired despite being aware of their tiredness placing themselves and others at risk.
Keywords:	Sleep, driving, performance, simulator, psychological factors, physiological factors, obstructive sleep apnoea, attitudes, countermeasures,
Comments:	A comprehensive review of evidence surrounding the issue of driver fatigue undertaken on behalf of the Department for Transport. This study is one of six used as a core guide to the development of this synthesis.

Title:	**Think! Annual Survey Report 2013**
Published:	TNS BRMB (2013) Think! Annual Survey Report 2013. Department for Transport. London.
Link: **Free/priced:**	https://www.gov.uk/government/publications/think-research Free
Objectives:	Gaining annual measures of road safety attitudes and behaviour among the British population.
Methodology:	The July 2013 Annual Survey covered the following elements: • Awareness of, attitudes towards, and perceptions of the THINK! road safety brand as a whole; • General attitudes towards road safety, and its perceived importance in relation to other social issues; • Attitudes towards driving, and influences on driving behaviour; • Driving and road safety behaviour among different users, including the prevalence of dangerous driving behaviour. Fieldwork for the Annual Survey ran from 24th to 28th July 2013 among adults aged 16+ in England and Wales (in previous annual surveys, Scotland was also included). Interviews were conducted using the TNS Omnibus survey.
Key Findings:	• Relevant to this synthesis, the results showed that around two thirds of respondents (68%) agreed completely that it is dangerous to carry on driving when too tired, a level that has remained stable since tracking began. • Around half (46%) claim to know someone who carries on driving when too tired, a similar level to the previous wave. • The level of those claiming to carry on driving when too tired remained the same as the previous wave, at 37% and is still lower than the peaks recorded in February 2011.
Keywords:	
Comments:	This is a regular survey undertaken on behalf of the Department for Transport to measure attitudes to road safety. It does not measure the impact of campaigns on impact on driving behaviour and/or on driver-fatigue incidents.

Title:	**Behavioural Adaptation to Fatigue Warning Systems**
Published:	Vincent, A., Noy, I. & Laing, A. (1998) Behavioural Adaptation to Fatigue Warning Systems. Transport Canada. Page number 98-S2-P-21
Link: **Free/priced:**	http://www-nrd.nhtsa.dot.gov/pdf/esv/esv16/98S2P21.PDF Free
Objectives:	Evaluate the impact of driver fatigue detection devices.
Methodology:	Behavioural adaptation of drivers to a FWS was evaluated in a closed track study. Thirty-two drivers completed two lengthy overnight drives, separated by one week, with half the drivers completing the second drive with an active FWS. During the drives, drivers voluntarily took breaks for as long as they liked.
Key Findings:	• Behavioural results demonstrate that the FWS had no impact on objective and subjective driver fatigue, on driving time, on the number of breaks or on break duration. • Results also demonstrate that 30 minute breaks are an ineffective drowsiness countermeasure. • These findings suggest that a FWS as currently conceived may not contribute to reduce fatigue induced collisions.
Keywords:	FWS, breaks, behaviour, subjective fatigue, driving time, countermeasure
Comments:	This research complements that previously undertaken by Sagberg (1999) and supporting the notion that drivers do not use the systems as intended, but to assist them in staying awake, believing that they will be able to driver for longer periods.

Title:	**Controlled breaks as a fatigue countermeasure on the flight deck**
Published:	Neri, D.F., Oyung, R.L., Colletti, L.M., Mallis, M.M., Tam, P.Y., Dinges, D.F. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. Aviation Space and Environmental Medicine, 73(7), pp. 654-664.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pubmed/12137101 (Abstract)
Objectives:	This study hypothesized that brief, regular breaks could improve alertness and performance during an overnight flight.
Methodology:	A 6-hour, uneventful, night time flight in a Boeing 747-400 flight simulator was flown by fourteen two-man crews. The 14 subjects in the treatment group received 5 short breaks spaced hourly during cruise; the 14 subjects in the control group received 1 break in the middle of cruise. Continuous EEG/EOG, subjective sleepiness, and psychomotor vigilance performance data were collected.
Key Findings:	• During the latter part of the night, the treatment group showed significant reductions for 15 min post-break in slow eye movements, theta-band activity, and unintended sleep episodes compared with the control group. • The treatment group reported significantly greater subjective alertness for up to 25 min post-break, with strongest effects near the time of the circadian trough. • There was no evidence of objective vigilance performance improvement at 15-25 min post-break, with expected performance deterioration occurring due to elevated sleep drive and circadian time.
Keywords:	Short-breaks, subjective sleepiness, psychomotor vigilance, performance deterioration, subjective alertness
Comments:	The physiological and subjective data indicate the breaks reduced night time sleepiness for at least 15 min post-break and may have masked sleepiness for up to 25 min, suggesting the potential usefulness of short-duration breaks as an in-flight fatigue countermeasure. The results of this research, along with that of Rosekind, Co & Gregory, (2000) can also be applied to reducing the effects of driver sleepiness.

Title:	**Effects of an afternoon nap on nighttime alertness and performance in long-haul drivers**
Published:	Macchia, M.M., Boulosa, Z., Ranneyb, T., Simmonsc, L. & Campbella, S.S. (2002) Effects of an afternoon nap on nighttime alertness and performance in long-haul drivers. Accident Analysis & Prevention. Volume 34, Issue 6, November 2002, Pages 825–834.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457501000896 $41.95
Objectives:	Measure the impact of naps on alertness and performance.
Methodology:	The effects of an afternoon nap on alertness and psychomotor performance were assessed during a simulated night shift. After a night of partial sleep restriction, eight professional long-haul drivers either slept (nap condition) or engaged in sedentary activities (no-nap condition) from 14:00 to 17:00 h. Alertness and performance testing sessions were conducted at 12:00 (pre-nap baseline), 24:00, 02:30, 05:00 and 07:30 h, and followed 2-h runs in a driving simulator.
Key Findings:	• In the nap condition, the subjects showed lower subjective sleepiness and fatigue, as measured by visual analog scales, and faster reaction times and less variability on psychomotor performance tasks. • Electrophysiological indices of arousal during the driving runs also reflected the beneficial effects of the afternoon nap, with lower spectral activity in the theta (4–7.75 Hz), alpha (8–11.75 Hz) and fast theta-slow alpha (6–9.75 Hz) frequency bands of the electroencephalogram, indicating higher arousal levels. • Thus, a 3-hour napping opportunity ending at 17:00 improved significantly several indices of alertness and performance measured 7–14 hours later.
Keywords:	Nap, night shift, sleepiness, quantitative EEG, driving, driving simulator, performance
Comments:	This research has far reaching positive impacts for night time truck drivers, showing that a 3 hour afternoon nap can improve their performance significantly when driving at night.

Title:	**Effects of caffeine on human behavior**
Published:	Smith, A. (2002) "Effects of caffeine on human behavior". Food and Chemical Toxicology 40 (9): 1243–55. doi:10.1016/S0278-6915(02)00096-0. PMID 12204388.
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0278691502000960 $35.95
Objectives:	Identify the effects of caffeine on behaviour.
Methodology:	Literature review.
Key Findings:	• The evidence clearly shows that levels of caffeine consumed by most people have largely positive effects on behaviour. Excessive consumption can lead to problems, especially in sensitive individuals.
Keywords:	Caffeine, behaviour, alertness, fatigue, arousal situation, vigilance
Comments:	This review concludes that research has demonstrated the benefits of caffeine consumption on driving performance. However there are also some negative effects and drivers need to be cautious about their levels of consumption.

Title:	**Effects of caffeine on mood and performance: a study of realistic consumption**
Published:	Brice, C.F. & Smith, A.P. (2002) Effects of caffeine on mood and performance: a study of realistic consumption. Psychopharmacology (2002) 164:188–192 DOI 10.1007/s00213-002-1175-2
Link: **Free/priced:**	http://www.nutraxin.com.tr/pdf/PaulliniaCupana/Paullinia_05.pdf Free
Objectives:	The present study aimed to determine whether a realistic drinking regime (multiple small doses – 4 65 mg over a 5-hour period) produced the same effects as a single large dose (200 mg).
Methodology:	A double-blind, placebo controlled, within-subjects experiment was, therefore, carried out. The participants (n=24) attended for four sessions. Each session started with a baseline measurement of mood and performance at 0930 hours. On two of the sessions, coffee was then consumed at 1000, 1100, 1200 and 1300 hours. In one of these sessions 65 mg caffeine was added to the de-caffeinated coffee. In the other two sessions, the participants consumed coffee at 1300 hours and 200 mg caffeine was added in one of the sessions. The volunteers completed the battery of tests again at 1500 hours.
Key Findings:	• The results showed that in both consumption regimes, caffeine led to increased alertness and anxiety and improved performance on simple and choice reactive tasks, a cognitive vigilance task, a task requiring sustained response and a dual task involving tracking and target detection.
Keywords:	Caffeine, mood, reaction time, sustained attention, dual tasks, performance
Comments:	This research further reinforces the positive impact of caffeine consumption to assist in counteracting the effects of driver fatigue. Again, there must be some caution allocated to the use of caffeine as there are also some negative effects. Caffeine has been shown (Smith, 2002) to increase anxiety and impair sleep. There is also some evidence that fine motor control may be impaired as a function of the increase in anxiety.

Title:	**An evaluation of energy drinks containing glucose and caffeine using the TRL driving simulator**
Published:	Parkes, A.M., York, I., Burton, S., Luke, T. (2005) An evaluation of energy drinks containing glucose and caffeine using the TRL driving simulator. PPR059. Transport Research Laboratory
Link: **Free/priced:**	https://trl.co.uk/reports/PPR059 Free
Objectives:	Examine the effect of different levels of caffeine and glucose on driver fatigue.
Methodology:	The experiment was conducted using the TRL advanced full-mission driving simulator and provided a range of realistic traffic scenarios. 48 experienced drivers aged between 25 and 50 participated in this study. The sample was split evenly by gender. The study employed a double-blind, placebo controlled, repeated measures design. The three experimental conditions were: (1) Control drink (330ml, taste matched to energy drinks), (2) Level 1 energy drink (330ml, 60g glucose and 25mg caffeine), (3) Level 2 energy drink (330ml, 60g glucose and 40mg caffeine). These drinks were formulated in order to taste and appear the same in all conditions, the only difference being the caffeine and glucose dose. All participants were tested during the post lunch dip where natural alertness is at a low.
Key Findings:	• Overall the results indicate an improvement in driving performance (lane keeping, reaction time and following performance) after drinking the level 2 drink (containing 40 mg caffeine and 60g glucose) compared to the control drink. • Some measures also showed a slight improvement with the level 1 drink (containing 25 mg caffeine and 60g glucose).
Keywords:	Driving simulator, glucose, caffeine, lane keeping, reaction time, following performance, alertness
Comments:	It is clear from this research that there is a benefit in stopping the vehicle, consuming an energy drink and resting to assist in combating the effects of driver fatigue. Other research, such as Brice & Smith (2002) and Reyner & Horne (2002) should be used in conjunction with this study to obtain a comprehensive picture of the effects of caffeine and glucose on driver performance.

Title:	**Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers**
Published:	Smit, H.J. & Rogers, P.J (2000) Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. Psychopharmacology. October 2000, Volume 152, Issue 2, pp 167-173
Link: **Free/priced:**	http://link.springer.com/article/10.1007/s002130000506# $39.95
Objectives:	This study measured the effects of 0, 12.5, 25, 50 and 100 mg caffeine on cognitive performance, mood and thirst in adults with low and moderate to high habitual caffeine intakes.
Methodology:	This was a double-blind, within-subjects study. Following overnight caffeine abstinence, participants (n=23) completed a test battery once before and three times after placebo or caffeine administration. The test battery consisted of two performance tests, a long duration simple reaction time task and a rapid visual information processing task, and a mood questionnaire (including also an item on thirst).
Key Findings:	• Effects on performance and mood confirmed a psychostimulant action of caffeine. • All doses of caffeine significantly affected cognitive performance, and the dose-response relationships for these effects were rather flat. • The effects on performance were more marked in individuals with a higher level of habitual caffeine intake, whereas caffeine increased thirst only in low caffeine consumers.
Keywords:	Caffeine, cognitive performance, mood, thirst, rapid visual information, psychostimulant
Comments:	This research demonstrates the effect of caffeine of cognitive performance and the mood of an individual who is used to different daily intakes.

Title:	**Obstructive Sleep Apnoea and Risk of Motor Vehicle Crash: Systematic Review and Meta-Analysis**
Published:	Tregear S, Reston J, Schoelles K, Phillips B. (2009) Obstructive Sleep Apnoea and Risk of Motor Vehicle Crash: Systematic Review and Meta-Analysis. J Clin Sleep Med. 2009 December 15; 5(6): 573–581.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2792976/ Free
Objectives:	Determining whether individuals with obstructive sleep apnoea (OSA) are at an increased risk for a motor vehicle accident when compared to comparable individuals who do not have the disorder. A secondary objective involved determining what factors are associated with an increased motor vehicle accident risk among individuals with OSA.
Methodology:	Literature review searching MEDLINE, PubMed (PreMEDLINE), EMBASE, PsycINFO, CINAHL, TRIS, and the Cochrane library. Evaluated the quality of each study and the interplay between the quality, quantity, robustness, and consistency of the body of evidence, and tested for publication bias. When appropriate, data from different studies were combined in a fixed- or random-effects meta-analysis.
Key Findings:	• Individuals with OSA are clearly at increased risk for accident. • The mean accident-rate ratio associated with OSA is likely to fall within the range of 1.21 to 4.89. • Characteristics that may predict accident in drivers with OSA include BMI, apnoea plus hypopnea index, oxygen saturation, and possibly daytime sleepiness.
Keywords:	Crash, driver, commercial motor vehicle, sleepiness, obesity
Comments:	This research not only shows that people suffering from OSA are at increased risk of being involved in an accident, but also that the increased risk can, in some ways, be predicted through an awareness of specific medical conditions.

Title:	**Continuous positive airway pressure reduces risk of motor vehicle crash among drivers with obstructive sleep apnoea: systematic review and meta-analysis.**
Published:	Tregear S, Reston J, Schoelles K, Phillips B. (2010) Continuous positive airway pressure reduces risk of motor vehicle accident among drivers with obstructive sleep apnoea: systematic review and meta-analysis. Sleep. 2010 October 1; 33(10): 1373–1380.
Link: **Free/priced:**	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2941424/ Free
Objectives:	Determine whether CPAP use could reduce the risk of motor vehicle accidents among drivers with OSA. A secondary objective involved determining the time on treatment required for CPAP to improve driver safety.
Methodology:	Literature review searching MEDLINE, PubMed (PreMEDLINE), EMBASE, PsycINFO, CINAHL, TRIS, and the Cochrane library.
Key Findings:	• A meta-analysis of 9 observational studies examining accident risk of drivers with OSA pre- vs. post-CPAP found a significant risk reduction following treatment (risk ratio = 0.278, 95% CI: 0.22 to 0.35; P < 0.001). • Although accident data are not available to assess the time course of change, daytime sleepiness improves significantly following a single night of treatment, and simulated driving performance improves significantly within 2 to 7 days of CPAP treatment. • Observational studies indicate that CPAP reduces motor vehicle accident risk among drivers with OSA.
Keywords:	Sleep apnoea, crash, motor vehicle, CPAP, public health
Comments:	This review demonstrates the benefits of CPAP in reducing daytime sleepiness and the increased risk associated with sleepiness when driving.

Title:	**Comparison of the effects of sleep deprivation, alcohol and obstructive sleep apnoea (OSA) on simulated steering performance**
Published:	Hack MA, Choi SJ, Vijayapalan P, Davies RJ, Stradling JR. (2001) Comparison of the effects of sleep deprivation, alcohol and obstructive sleep apnoea (OSA) on simulated steering performance. Respir Med 2001;95:594–601
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0954611101911096 Free
Objectives:	This study examines the nature of the impairment during simulated steering in patients with Obstructive Sleep Apnoea, compared to normal subjects following either sleep deprivation or alcohol ingestion
Methodology:	Twenty-six patients with OSA and 12 normal subjects, either deprived of one night's sleep or following alcohol ingestion [mean (SD) alcohol blood level 71.6 mg dl−1(19·6)], performed a simulated steering task for a total of 90 min. Performance was measured using the tendency to wander (SD), deterioration across the task, number of 'off-road' events and the reaction time to peripheral events. Control data for OSA, sleep deprivation and alcohol were obtained following treatment with nasal continuous positive airway pressure (nCPAP), after a normal night of sleep, and following no alcohol, respectively.
Key Findings:	• Patients with untreated OSA, and sleep-deprived or alcohol-intoxicated normal subjects performed significantly less well, compared to their respective controls ($P<0{\cdot}01$ for all tests), with untreated OSA lying between that of alcohol intoxication and sleep deprivation. • Alcohol impaired steering error equally throughout the whole drive, whilst sleep deprivation caused progressive deterioration through the drive, but not initially. • Untreated OSA was more like sleep deprivation than alcohol, although there was a wide spread of data. • This suggests that the driving impairment in patients with OSA is more compatible with sleep deprivation or fragmentation as the cause, rather than abnormal cognitive or motor skills.
Keywords:	Obstructive sleep apnoea, driving, automobile accidents, steering simulation, sleep deprivation, alcohol
Comments:	The seriousness of untreated OSA in relation to accident risk is demonstrated in this research. This has since been further supported by Gibson (2005) and Finkel et al. (2009) who estimate that at least 80% of people with OSA are untreated due to a lack of awareness or diagnosis.