Fatigue

SWOV Fact sheet, September 2019

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Summary

Driver fatigue is estimated to be a (contributing) factor in 15 to 20% of crashes, but estimates in individual studies vary widely. Drivers who are tired are less attentive and react less quickly and less adequately than drivers who are not tired. They also get irritated and frustrated more easily.

Fatigue especially occurs in cases of (a combination of) insufficient or poor sleep, too many uninterrupted hours behind the wheel and having too much or too little to do for extended periods of time. Fatigue caused by too few driving tasks is bound to occur more often as more and more driving tasks are automated. Fatigue-related crashes relatively often involve commercial drivers, drivers working in (night) shifts, drivers with sleep problems/disorders and young men.

Rest and driving time legislation probably has a positive effect on the prevention of fatigue-related crashes of professional drivers, but this effect is hard to assess. For non-professional drivers, measures to counter fatigue are limited. It is for instance hard to set a legal limit to the degree of fatigue admissible for traffic participation. Automatic fatigue detection systems may help detect fatigue and alert the driver or may actively intervene. Other advanced driver assistance systems – such as Lane Keeping Systems – and infrastructural measures may prevent drivers from running off the road and may limit the associated crash implications.

1 What causes fatigue?

Fatigue has different causes. A distinction is often made between sleep-related fatigue and task-related fatigue [1]. Sleep-related fatigue for instance involves

- structural or once-only sleep deprivation;
- poor sleep quality, for example because of numerous interruptions, too much noise, being too hot;
- sleep disorders such as sleep apnoea and narcolepsy;
- being up and active at times when the body wants to sleep (biological clock).

Task-related fatigue for instance involves

- being physically or mentally active over long stretches of time (time-on-task);
- having performed/having to perform too many or too complicated tasks over long stretches of time (excessive workload);
- having performed/having to perform too few or too simple tasks over long stretches of time (too low workload).

To what degree these circumstances lead to fatigue, or to what degree fatigue manifests itself, depends on several other factors, such as physical condition, age and ambient temperature [2] [3].

The diversity of fatigue causes means that almost all people, and therefore almost all road users, are sometimes tired. Spending prolonged stretches of time behind the wheel is just one of the causes. The often voiced assumption that in countries such as the Netherlands, where distances are relatively short, fatigue in traffic will be a minor factor compared to countries where distances are longer, does therefore not hold water.

2 What is the effect of fatigue on road user behaviour?

People who are tired are less attentive and will therefore react less quickly and less adequately than people who are not tired [2] [3] [4]. Fatigue also affects mood and thus behaviour: tired people get irritated and frustrated more easily [4] [5].

A lot of research has been done into the effect of fatigue on driver behaviour. Most of these studies have been done by means of computer tasks or driving simulators in laboratories (for example [6] [7]); some of them, however, in actual traffic (for example [8]). For these studies, people are kept awake for a long time to attain sleep deprivation, or they have to continue driving for a long time. The effects may thus be summarised [2] [3] [4]:

- reacting more slowly;
- steering less accurately;
- wider variations in headway distance and speed.

There are some indications that drivers try to compensate for fatigue effects by complicating the driving task (higher speed, shorter headway distances) or, contrarily, by applying wider safety margins (low speed, longer headway distances) [3].

3 How often are road users (too) tired?

Almost everyone is tired sometimes, due to a short or poor night's sleep for instance. A questionnaire study among Dutch drivers [9] showed that, in the previous year, 55% of the drivers had sometimes driven while being tired. For that same period, a quarter of them admitted having driven while being so tired that they had trouble keeping their eyes open and 4% admitted having actually fallen asleep behind the wheel. Compared to car drivers, truck drivers more often appear to be very tired while driving or to (almost) fall asleep [3].

These data are generally based on questionnaires and therefore on self-reported data. Objective and large-scale measuring of fatigue while driving is very hard.

4 How many crashes are caused by fatigue?

It is estimated that in 15 to 20% of crashes driver fatigue is a contributing factor. However, estimates in individual studies vary widely (from 5 to 50%) [2] [3] [6] [7] [9] [10] [11] [12] [13] [14] [15]. The wide range is mostly caused by the definitions and research methodology used to determine whether a crash involved driver fatigue [15]. The lowest percentages originate from analyses of police-registered crash circumstances; the highest from studies that examine whether a crash was related to fatigued driving on the basis of specific crash characteristics (for example no skid marks). Percentages based on questionnaires (self-reported behaviour) are somewhere in between [2]. In general, studies focusing on professional transport/truck drivers find higher percentages than studies focusing on car drivers [9] [14] [16]. For fatal crashes and motorway crashes, the percentages are also higher [13].

Crash circumstances according to police

Up until 2015, Dutch police registered crash circumstances. Fatigue/falling asleep was one of the categories, but was hardly ever used, probably because it was hard to ascertain objectively. Should a driver have been tired, then this fatigue will mostly have disappeared after a crash – which usually leads to stress and elevated adrenalin levels. Neither is it likely that the driver involved will voluntarily admit having been very tired or having fallen asleep. In a police report, causes which are easier to prove will usually be registered, such as *not giving right of way/not granting passage* or *red light negation,* yet, in those cases fatigue may also have been a contributing factor. Up until 2015, fatigue/falling asleep was categorised under 'circumstances' in an average 1% of the registered fatal crashes. In light of the above, this is almost sure to be a substantial underestimate.

Self-reported behaviour

The involvement of fatigue in crashes is also studied by means of questionnaires in which drivers have to report whether fatigue contributed to the crash. These questionnaires are usually anonymous, meaning that socially acceptable answers are not expected to crucially affect the result. Questionnaire studies usually come up with percentages of 10 to 15% [2].

Crash circumstances

A fatigue-related crash has a number of specific characteristics (no skid marks for instance); also see the question *What is typical for a fatigue-related crash?*. If some of the specific characteristics apply to a crash, it will be qualified as (probably) being caused by fatigue. Studies that analysed crashes in this way, estimated that fatigue was related to 20 to 30% of the crashes [2]. Countries often use different criteria for determining if a crash is related to fatigue [15].

Crash risk

In general, the chances of a crash considerably increase when the road user is tired. Methodologies to determine the chances, and thus the individual study results, widely vary [17]. A 2018 meta-analysis of 14 studies [13] showed a 29% risk increase (OR: 1.29; 95% CI: 1.24-1.34) for tired drivers compared to those who were not tired. A 2014 meta-analysis of 11 studies [18], which specifically focused on professional drivers, arrived at a 72% risk increase (OR 1.72; 95% CI: 1.36-2.18) for drivers who are extremely tired during the day (Excessive Daytime Sleepiness - EDS). EDS is a form of chronic fatigue caused by sleep disorders such as sleep apnoea or narcolepsy which has nothing to do with the amount of sleep (also see the question *Which groups are most at risk?*).

5 What is typical for a fatigue-related crash?

In general, a fatigue-related crash has some of the following characteristics [12] [15]:

- The vehicle ran off the road or bumped into a (stationary) car in front/object.
- The crash occurred on a road with a high speed limit.
- The crash occurred between midnight and dawn.
- There were no skid marks.
- The driver had a clear view of the road.
- There were no passengers in the vehicle.
- There are no other plausible explanations (such as alcohol use or indisposition).

In general, the outcome of a fatigue-related crash is serious, in particular because the impact speed is high as brakes are not used.

6 Which groups are most at risk?

Fatigue-related crash risk groups

Some people have a higher chance of being involved in a fatigue-related crash than others. This relates to the circumstances of their traffic participation, to physical aspects, lifestyle and combinations of these factors. Groups that are relatively often involved in a fatigue-related crash are [3]:

- (international) truck drivers;
- taxi drivers;
- people working in (night) shifts;
- people with sleep problems/disorders;
- young men.

Proof of over-representation of taxi drivers is circumstantial. An Australian study [19] shows that this group has a higher crash risk. The researchers suspect that fatigue is an important factor on account of the nature of their work (long shifts, also after midnight). A Chinese study reaches similar conclusions on the basis of questionnaire outcomes [20].

Sleep disorders notably include obstructive sleep apnoea (temporary respiratory arrest while sleeping) and narcolepsy (tendency to suddenly fall asleep, also by day). If these disorders are not treated, they will lead to extreme daytime fatigue even after sufficient nighttime sleep. So, this will lead to an increased risk of a fatigue-related crash [18] [21] [22]. The prevalence of sleep apnoea in the Netherlands is not well-established, but is estimated to be between 0.45 en 4% for men (for women prevalence is lower). Sleep apnoea often goes hand in hand with overweight

[23]). Overweight, and thus sleep apnoea, is relatively common among truck drivers [22] [24] and taxi drivers [11].

7 Do summer/winter time changeovers effect fatigue and/or crash risk?

When changing over to winter time, we can sleep for another hour; when changing over to summer time for one hour less. For some people, the latter may lead to usually temporary sleep deprivation and fatigue. Since the time difference only amounts to one hour, most people's biological clock gets used to this quickly. The changeover to winter time is usually easier and leads to fewer complaints about fatigue; the reason being that our biological clock encompasses a period slightly longer than 24 hours [25] [26]. The changeovers from and to winter and summer time do therefore not noticeably effect road user fatigue.

Yet, the changeover to winter time *is* related to a higher crash risk. This is not caused by fatigue however, but rather by the sudden change of an evening rush hour in daylight to one in darkness. During evening rush hours in darkness the number of crashes is higher than that in daylight. Above all, pedestrians and cyclists run higher risks in darkness, but car drivers run higher risks as well [27]. The increased risk remains apparent for a few months after the winter time changeover and does, therefore, not relate to the changeover as such but to the rush hour *in darkness*. In terms of traffic safety, a permanent changeover to summer time would, therefore, be preferable.

8 Do road users get tired sooner when workload is low?

If people have few things or only simple things to do – so when the workload is low – fatigue symptoms may occur. This is also called passive task-related fatigue [1]. A drive on a motorway with little traffic is an example of a task with a low workload. There are also intelligent driver assistance systems (ADAS) that reduce the driver's task load, Advanced Cruise Control (ACC) for example and the successor to Cooperative Advanced Cruise Control (CACC) (also see SWOV fact sheet *Intelligent transport and driver assistance systems (ITS and ADAS)*).

Passive fatigue does not occur on account of a lack of visual stimuli, but rather because drivers have too little to do [28]. It is expected that the increasing in-vehicle automation will also increase this type of fatigue [29]. After all, drivers will then be less actively involved in driving tasks and will increasingly acquire the role of supervisor who is only occasionally obliged to intervene. Passive fatigue may cause drivers to be less alert when obliged to take over driving tasks, with a crash as possible outcome.

9 Do regulations on driving time and rest period help prevent fatigue-related crashes?

Driving time and rest period regulations apply to truck, public transport bus and coach drivers. The regulations are meant to increase road safety without inhibiting fair competition. To what extent these regulations do indeed increase road safety is hard to ascertain. This would imply comparing road safety before and after the introduction of the regulations. Since all western countries have some form of driving time and rest period legislation, this is virtually impossible in practice. Research into the effect of *changes* in existent regulations, in particular in the United States, leads to the conclusion that the effect is probably positive [30].

The European regulation on driving time and rest period (regulation 561/2006) applies to carriage by road within the European Union. In the Netherlands, the same driving times and rest periods have been laid down in the Arbeidstijdenbesluit vervoer (Road Carriage Working Hours Decree). This decree determines the maximum daily, weekly and bi-weekly driving times, and the minimum daily and weekly rest periods for truck and coach drivers. The Human Environment and Transport Inspectorate monitors enforcement.

Some elaborations [31] [32]:

A truck or coach driver is allowed to

- drive up to 10 hours a day twice a week, and up to 9 hours on the other days in that same week;
- drive up to 56 hours a week;
- drive up to 90 hours in two consecutive weeks.

Furthermore, the uninterrupted driving time may not exceed 4.5 hours. After a driving period of 4.5 hours, the driver must take a 45-minute break, except in cases of double-manned vehicles. Not only driving, but also other tasks, such as loading and unloading, count as work. If a driver works for a 6-hour (uninterrupted) period, a break is required. A 30-minute break is required for uninterrupted 6- to 9-hour working periods, a 45-minute break for working periods exceeding 9 hours. These breaks may also be divided into 15-minute periods.

The daily rest period, meaning the period no work or availability is allowed, must be made up of 11 consecutive hours. In between two sufficient weekly rest periods, the daily rest period may be reduced to 9 hours. The daily rest period may also be split into two parts, of which the first part must at least comprise 3 hours and the second part at least 9 hours. For working hours between 0h00 and 6h00 there are rules as well: up to 43 times in 16 weeks or up to 20 hours in 2 weeks.

At least once every two weeks, drivers are obliged to take a normal weekly rest of 45 hours. In 2017, the European Court decided that this rest could no longer be taken in the truck cabin, and since January 2018 this rule has been enforced in the Netherlands.

For taxi drivers different, generally less strict, driving times and rest periods apply (see table below for the statutory times and periods as of 1 January 2015 [33] [34]); the Human Environment and Transport Inspectorate monitors enforcement.

Table 1. Driving times and rest periods as of 1 January 2015 [33].

	Employees	Self-employed drivers
Break	› 30' for > 5,5 hours work (optionally 2x 15') › 45' for > 10 hours work (optionally 3x 15') In case of collective agreement, possible deviation up to: › **15' for > 5,5 hours work**	› **15' for > 5,5 hours work**
Daily rest period	› at least 10 uninterrupted hours, every 24 hours In case of collective agreement, possible deviation up to: › **10 uninterrupted hours, every 24 hours** › **reduced: 8 uninterrupted hours (max. 2x in every 14x24 hours)**	› **10 uninterrupted hours, every 24 hours** › **reduced: 8 uninterrupted hours (max. 2x in every 14x24 hours)**
Weekly rest period	› 36 uninterrupted hours for every 7x24-hour period In case of collective agreement, possible deviation up to: › **a 72-hour minimum in every 14x24 hours, to be divided into 24-hour uninterrupted periods**	› **a 72-hour minimum in every 14x24 hours, to be divided into 24-hour uninterrupted periods**
Working hours	› 60 hours a week › 12 hours a shift › a 48-hour average every 16 weeks In case of collective agreement, possible deviation up to: › **a 48-hour average every 26 weeks**	
Working on Sundays	› at least 13 free Sundays every 52 weeks In case of collective and personal agreement, deviation is possible	
Working between 0h00 and 0h06	› 52x every 16 weeks › 140x every 52 weeks or › 38 hours between 0h.00 – 0h06 every 2 weeks In case of collective and personal agreement, deviation is possible	

10 Do road users sufficiently recognise when they are tired and how do they remedy fatigue?

In general, car drivers think fatigued driving is dangerous and recognise their own signs of fatigue. They know which measures are effective, but do not take them or take ineffective measures (opening a window, turning up the music). This is shown by Australian simulator research [10] and also by comprehensive questionnaire studies in the Netherlands [9]. The Dutch study shows that car drivers take yawning, loss of concentration, and not being able to keep their eyes open as the most important indications of fatigue (mentioned by respectively 70%, 43% and 38% of the nearly 2,000 respondents). Yet, by no means all car drivers take adequate actions. Approximately 20% indicated having started or kept driving while being too tired in their own eyes. For truck drivers the percentage was 37% [9].

Once drivers get tired, they may decide to stop driving to 'take a nap' or to ask a passenger to take the wheel. These are the two most effective strategies to prevent driving while being tired, both according to drivers themselves [9] and according to research [35]. They are, however, not the most common strategies. Car drivers admit opting for fresh air in the car (opening a window or turning on the air conditioning), talking to a passenger, stopping to eat or move around, or turning up the music. However, these strategies do not work or work only briefly [35].

Truck drivers more often say that, when tired, they stop driving to take a rest or to sleep [9]. Obviously, driving time and rest period regulations also oblige them to do so (see the question *Do regulations on driving time and rest period help prevent fatigue-related crashes?*).

11 What measures are possible?

It is impossible to set a legal limit to the degree of fatigue permissible for traffic participation. Fatigue is hard to measure, which means legislation and enforcement in this field (contrary to alcohol use for instance) are hard to implement. Several other measures to reduce driver fatigue and its consequences are, however, possible (see for instance [2] [3] [36]). A distinction can be made between measures for professional drivers and non-professional drivers and between options by means of infrastructural measures, advanced driver assistance systems and fatigue detection systems.

Professional drivers

For professional drivers, regulations on driving time and rest period apply (see the question *Do regulations on driving times and rest period help prevent fatigue-related crashes?*). Although, obviously, these legal requirements cannot entirely prevent fatigue, they do, in principle, reduce chances of extreme fatigue caused by being behind the wheel for too long stretches of time and not taking enough breaks. It is of course essential that drivers abide by these driving times and

rest periods. At present, there are large differences between European countries in the extent to which this is the case and the extent to which the requirements are enforced [30].

Employers also have an important role to play: they should plan the work in such a way that their drivers can abide by the driving times and rest periods, and they should actively stimulate drivers to indeed comply with these requirements. In this, self-employed drivers also have their own responsibility. Moreover, haulage companies should inform their drivers about causes and consequences of fatigue. As far as the onset of fatigue is concerned, the impact of drivers' individual circumstances (life style) and their own responsibilities should not be forgotten. Finally, screening drivers for (untreated) sleep disorders, particularly sleep apnoea, may be considered a company task.

Fatigue Management programmes, especially in Australia and North America, are based on these starting points. Examples may be found in a special edition of the magazine Accident Analysis and Prevention. Ideas about a safety culture for haulage companies clearly tie in with this [37] [38].

Non-professional drivers

Measures targeting non-professional drivers primarily focus on education: education and information about causes, effects, fatigue symptoms and advice on how to limit fatigue effects at least for a while. An example of an education campaign is the Dutch national 2008-2011 campaign 'Don't be a Sleep Driver'. Education and information could at least raise awareness of causes and road safety effects of fatigue, which is an important, albeit insufficient, step towards behavioural change.

Infrastructural measures

An infrastructural measure aimed at reducing fatigued driving is the provision of sufficient locations and facilities allowing truck and car drivers to take a rest while not jeopardising traffic safety or social safety.

Most infrastructural measures, however, are aimed at mitigating crash consequences for vehicles running off the road or threatening to do so, for instance on account of fatigue. This mainly involves longitudinal rumble strips to warn drivers, both auditorily and kinetically, that their vehicle is about to run off the road. In addition, roadside barriers and obstacle-free zones are very important to limit the consequences of running off the road.

Advanced driver assistance systems (ADAS)

Advanced driver assistance systems (ADAS) may contribute to reducing the number of fatigue-related crashes, e.g., by warning the driver or by actually intervening. Examples of warning systems are Lane Departure Warning (LDW) and Forward Collision Warning (FCW) systems. Examples of intervening systems are (Cooperative) Advanced Cruise Control and Lane Keeping Systems (LKS). Although these systems do not prevent fatigue itself (in some cases they may even be conducive to fatigue (see the question *Do road users get tired sooner when task loads are low?*)), they do in principle limit the consequences, viz running off the road or driving into vehicles in front.

At present, the effectiveness of warning systems is unclear [39] and there are doubts about the support for intervening systems. For its new regulation concerning motor vehicle type approval [40], the European Committee has nevertheless proposed making an intervening LKS mandatory for cars and delivery vans and a warning LDW systems for trucks and buses/coaches (see SWOV fact sheet *Intelligent transport and driver assistance systems (ITS and ADAS)*.

Automatic fatigue detection systems

In recent years, a lot of research has been done into the possibilities offered by automatic fatigue detection systems, and several studies in this field are still in progress [41]. These systems should notice that the driver is getting so tired that he can no long drive safely, and should then warn the driver or intervene. Some of the systems take input from driving behaviour: does the car swerve more than usually, does speed fluctuate more, are brakes more often used abruptly? Other systems take input from physical driver characteristics, such as blinking, facial muscle spasms and yawning. For now, none of the systems appear to be rock-solid [39]. The major challenge is avoiding false positives (warning or intervening when there is no question of fatigue) and false negatives (failing to warn or intervene when fatigue is indeed at issue). The former will lead to irritation and possible system sabotage, the latter will erode confidence in the system. It is feared that fatigue detection systems tempt tired drivers to keep driving until the system responds. There is, however, no empirical evidence to support this fear [39].

At present, several car brands are equipped with fatigue detection systems. These systems generally take input from driving style changes, notably steering movements. The European Committee has proposed making an warning fatigue detection and attention detection system mandatory for all vehicle categories [40].

Publications and sources

Below you will find the list of references that are used in this fact sheet; all sources can be consulted or retrieved. Via Publications you can find more literature on the subject of road safety.

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Colophon

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SWOV (2021). *Fatigue*. SWOV Fact sheet, September 2019. SWOV, The Hague.

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