SWOV Fact sheet

Attention problems behind the wheel

Summary
Attention problems of drivers have a negative effect on driving behaviour. When drivers are absent-minded, it may for instance cause longer reaction times, less adequate observation of the environment, and later and more abrupt braking. This could endanger the driver's safety and that of other road users. The driver's attention is increasingly claimed by electronic devices. Based on American research, approximately 7% of all crashes are expected to be partly caused by drivers' attention problems. Other than rumble strips and public information, there are few concrete measures to tackle attention problems. Before long, however, detection equipment in the car may serve as a warning device.

Background and content

Every driver sooner or later discovers that he does not remember what happened in the immediately preceding time. This does not necessarily mean that he did not drive safely, but rather that many tasks were done automatically. Attention may wane from the driving task because:

– the driver has to divide his attention between different tasks, because he is also doing other things like making a phone call, tuning the radio, listening to the radio, talking with a passenger, or eating while driving (see SWOV Fact sheet *Use of the mobile phone while driving*);
– the attention is drawn by noticeable things and events inside or outside the car, like a crash on the other lane, a striking person on the pavement, a conspicuous billboard alongside the road, or a wasp in the car (see SWOV Fact sheet *Distraction caused by roadside advertising and information*).

However, the driver may also pay insufficient attention because:

– he is tired (see SWOV Fact sheet *Fatigue in traffic: causes and effects*);
– he is preoccupied with other things, or is daydreaming without being fatigued. This is called *loss of attention.*

When people focus their attention on what they are occupied with (in this case the driving task), and when the attention is both lasting and intense (‘focused attention’), they are said to be concentrated. According to Gaillard (2005) concentration is a dynamic mechanism which activates and coordinates our physical and mental capacities to develop and to maintain goal-oriented behaviour. Three aspects play a role here: *selectivity* (the things the attention is focussed on), *intensity* (the extent to which body and mind are mobilized to perform the set tasks) and *motivation* (the degree of intent to realize the planned target). In traffic concentration is also resisting the temptation to focus one's attention on things other than the driving task. The task difficulty is often low - driving is to a large extent automatic behaviour - which stimulates the desire to do other things. However, a traffic situation can change within a few seconds which makes it essential that the driver is always attentive and is not occupied with other matters.

The present factsheet will describe a study into the extent of the problem of reduced attention, the effects it has on the driving task and the risk of crashes due to reduced attention, and measures that could be taken.

What is the extent of the problem?

In the Netherlands, it is not systematically investigated whether distraction of whatever kind contributed to the origin of a crash. An important reason is that it is difficult to establish attention problems. Since 1995, the United States have been investigating whether loss of concentration did play a role. To that end police officials who investigate crashes were trained in detecting information (for example by interview training). In 2000 Stutts et al., (2001) analysed 5000 circumstantial descriptions made by these police officials.

For this purpose they asked the following questions:

- Was the driver alert and was his attention focused on the driving task?
- Was the driver alert, but was his attention distracted from the driving task because he was doing other things, or because he was lost in thought?
- Did the driver look, but did he not see the danger?
- Was the driver sleepy, or did he fall asleep?

In 36% of the crashes it was not possible to retrieve if anything had been wrong with the attention of the driver involved. In 5.4% of the crashes the driver had looked, but had failed to see without fatigue being involved and without the driver being occupied with matters that were not connected with the driving task. Looking but not seeing can be caused by loss of attention: the driver looks in the right direction, but because his mind is not on the driving task, visual information is not being processed. There can, however, also be other reasons for looking without actually seeing like the driver being bad at hazard perception (see SWOV Fact sheet *Hazard perception in traffic*). This may cause the driver who has looked to say he did not see anything. It may also be the case that a driver tells the police as an excuse that he looked, but did not see. Finally, a driver could fail to see, because his observation strategy is inadequate. Taking into account that matters other than concentration loss can play a part, and that in a large percentage of crashes it was not possible to determine attention deficiency, the 5.4 percentage of drivers who looked but failed to see is rather inconclusive about the number of crashes caused by loss of concentration.

In 2006, also in the United States, a so-called Naturalistic Driving study was carried out to determine the extent of the problem of attention loss (Dingus et al, 2006; see also SWOV Fact sheet *Naturalistic Driving: observing everyday driving behaviour*). In this study, 100 cars were equipped with cameras. These cameras were aimed at both the driver and at the road environment. The cars were also equipped with all kinds of measuring equipment which continuously registered the driver's as well as the car's performance.

During one year all data of these 100 so-called 'instrumented vehicles' were recorded. This made it possible to determine precisely what had happened in the moments immediately preceding 69 actual crashes and 761 near-crashes. In almost 78% of all crashes and in 65% of all near-crashes, the driver did not look in the direction of the arising conflict. Next, it was investigated whether this was caused by:

- the driver being occupied with other things than the driving task, like making a mobile phone call (24% of all crashes);
- the driver being occupied with matters related to the driving task (e.g controlling the windscreen wipers), which at that moment were not immediately relevant for the arising of the conflict (19% of all crashes);
- the driver being tired, which was demonstrated by, for instance, the frequency of blinking the eyes (9% of all crashes);
- the driver for no specific reason staring in a different direction from where the conflict was arising (7% of all crashes).

In 20% of the crashes two or more of these causes coincided. Reduced attention is plausible when a driver stares in a different direction than the direction from which the danger comes. This is, therefore, the case in 7% of all crashes in this study of natural driving behaviour.

What are the effects of loss of attention on the driving task?

As was mentioned earlier, three aspects play a role in concentration: *selectivity*, *intensity* and *motivation.* There is a problem with selectivity when the driver thinks of other things than the driving task or is occupied with other things while driving. There is a problem with intensity when the brain activity decreases, without fatigue being involved. This may for instance be the case when the driving task is very monotonous. An example is what in the Netherlands is called polder-blindness: a reduced alertness on long, straight roads. The driver must also be motivated to apply the required attention to the driving task; 'fighting fatigue' is an example.

Study of selectivity

The influence of absent-mindedness on performing the driving task without the driver being occupied with other activities or without being tired, is investigated by experiments in which the driver is set a task which requires thought, but no action. Mental arithmetic can be such a task. Another possibility is to ask the driver to recall specific things. Next, the influence is investigated of for example mental arithmetic on observation, reaction time and vehicle control (increasing or decreasing speed, zigzagging, et cetera). Recarte & Nunes (2003) and Harbluk et al. (2007) performed these types of study. The SWOV report *Concentration problems behind the wheel* (Vlakveld, Aarts & Mesken, 2006) gives an elaborate description of these studies. Their study illustrates that when a driver is absent-minded:

- he looks straight ahead for longer time spans and less often in the periphery (e.g. pedestrians on the pavement;
- he looks at the dashboard and in the mirrors less frequently;
- reaction times increase;
- he displays late and abrupt braking.

Research into the role of selectivity in loss of attention while driving has also been carried out in the Netherlands (Martens & Brouwer, 2006). Three groups of subjects were asked to make a relatively easy journey on a motorway in a simulator. The first group was the control group and was not given any extra tasks beside the driving task. In the middle part of the drive, the second group was asked to consider the possible suspect of a crime, based on information in a police file which they had seen before the drive. Also in the middle part of the drive, the third group was given a 'listen-and-remember' task: they had to identify and remember certain sounds which were played during the drive. It was studied if the thinking task influenced the driving performance and if the extent of the influence was similar to that of the 'listen-and-remember' task which was not easily ignored. The effects on vehicle behaviour (speed, headway time, zigzagging, braking, et cetera), the effects on the driver's behaviour (e.g. looking behaviour) and his pulse were measured. The thinking task caused drivers to decrease speed, and also led to more abrupt braking. During the thinking task, drivers used the mirrors less often, and the variability of their pulse increased. The 'listen-and-remember' task was a stronger influence on the driving behaviour than the thinking task.

A problem in studies in which subjects are asked to think about something else while they are carrying out a task is that it is impossible to find out if they are *really* thinking about the other matters, or whether they pay hardly any attention to them.

Measuring how often a driver looks in the rear view mirror is a different method for measuring whether the driver focuses his attention on the driving task. Drivers who often look in the rear view mirror are concentrated in carrying out their driving task.

Pastor et al. (2006) used electroencyphalography to measure alertness behind the wheel. The study indicated that the extent to which the rear view mirror was used had a direct relation with alertness. For motorway driving this was a positive relation, for driving on a single lane road the relation was negative. This seems logical as on a single lane road it is more important what happens in front of the car and attention should be focused on this. This is much less the case on motorways and also for overtaking one must look in the rear view mirror more frequently on motorways. How frequently mirrors are used is therefore an indication of the attention that is focused on the driving task, but this relation depends on the road type.

Study of intensity

Concentration loss through low intensity of attention, without fatigue being involved, especially occurs when the driving task is very monotonous. In the Netherlands this is called polder blindness and English speaking countries use the term 'highway hypnosis': reduced alertness on long, straight roads. In the case of reduced alertness, the attention is thought to shift from stimuli in the environment to inner processes like daydreaming. Karrer et al. (2005) talk about Driving Without Awareness (DWA). In DWA the eyes remain open (as opposed to microsleep in which the eyes are closed for a minimum of two seconds). Karrer et al. (2005) asked 83 subjects to take a boring drive on motorway in a simulator. This drive took approximately two hours. Trained researchers registered when DWA occurred in the subjects. During the entire drive an electroencephalogram (EEG) was made to examine if the subjects became sleepy. At the same time an electrooculogram (EOG) was used to register the eye movements. DWA was registered in 18% of the subjects. Proportionally, this was more so for young male subjects. The 83 subjects unintentionally exceeded the lane markings a total of 260 times. In 33.5% of the cases there was DWA at that particular moment. There was no strong relation between DWA and fatigue, but there was a relation with a lessening of fast eye movements (saccades) and with a reduction of the size of the saccades. When the frequency of the DWA moments increased, the time the driver had his eyes open without blinking, also increased. Based on the research of Karrer et al. (2005) we can conclude that the number of traffic errors increases as a result of low intensity of attention.

He et al. (2011) speak of ‘mind wandering’ or being absent minded when the intensity of attention is low. In a simulator, participants in their study were asked to follow a car and to indicate when their thoughts wandered. The results showed that the participants had a much more restricted picture of their environment when this was the case. This forms a risk factor in the occurrence of crashes.

What is the crash rate caused by loss of attention?

To determine the crash rate, we need to know how often drivers suffer from loss of attention and how often attention loss plays a part in the occurrence of a crash. To answer the first part of this question, McEvoy et al. (2006) in Australia carried out a telephone survey among 1,347 drivers. They were asked to think back of their last drive which lasted at least five minutes. They were then asked if they had been distracted during that last drive, and if their attention had slackened. Almost 72% of the subjects reported attention loss during that last drive. There is hardly any information about the second part of the question (either). The Naturalistic Driving study of which was mentioned earlier (Dingus et al., 2006), leads to the assumption that loss of attention plays a part in 7% of the crashes. Both percentages, however, are too inaccurate to make a fair estimate of the crash rate caused by attention loss.

However, it is possible to compare the crash rate of drivers *with* attention problems with that of drivers *without* such problems. Brouwer (2002), for example, investigated which groups of drivers suffer from attention deficiencies caused by neurological disorders. He distinguished three types of attention deficiency:

1. problems with *retaining* the attention;
2. problems with *focusing* the attention;
3. problems with the attention required for the *execution of tasks*

As an example for the first category Brouwer (2002) mentions people suffering from sleep apnoea, whose breathing during sleep is disturbed. This prevents them from falling into a deep sleep. As a result, they can only work briefly on a certain task with concentration during daytime. Vaa (2003) made a meta-analysis based on eight epidemiological studies of sleep apnoea, which showed the relative risk ratio to be 3.71. This means that for drivers suffering from sleep apnoea the crash rate per kilometre driven is 3.71 times the crash rate for drivers who do not have sleep apnoea. People suffering from sleep apnoea not only have problems retaining their concentration, they also have fatigue problems. Therefore, the increased crash rate for people with sleep apnoea is caused by concentration as well as fatigue problems. It is impossible to make a distinction between these two causes.

As an example for the second category, Brouwer (2002) mentions people who have problems with processing visual information. This is often indicated with the term 'Useful Field Of View (UFOV)'. A meta-analysis based on fifteen studies (Vlakveld et al., 2005) shows that drivers with a reduction in UFOV of 40% or more, have a 4.74 relative risk ratio as opposed to people whose UFOV- reduction is lower than 40%. For this group also, it holds that problems with visual information processing are related to more factors than just a attention deficiency. Particularly the elderly have a reduced UFOV.

As an example for the third category Brouwer (2002) mentions people who suffer from Attention Deficiency Hyperactivity Disorder (ADHD). People suffering from ADHD have a slightly increased crash rate. The earlier mentioned meta-analysis of Vaa (2003) shows, based on eleven studies, that the relative risk ratio for drivers with ADHD is 1.54. However, the increased crash rate due to ADHD says relatively little about the risk of attention loss in traffic, as people who suffer from ADHD not only have attention problems, but they also have problems with suppressing impulses.

Which measures can be taken?

There is no point in prohibiting drivers to think of other matters while driving. It is possible, however, to inform drivers about attention problems, and to advise them not to drive when their minds are on other things. Loss of attention due to a low intensity without fatigue being involved, can be prevented by livening up the driving task. This can for instance be done by bringing more variety to long straight road stretches. Longitudinal rumble strips may be useful to prevent going off the road due to attention loss as well as due to fatigue.

Much research is being done into equipment that warns the driver when he gets tired (see SWOV Fact sheet *Fatigue in traffic: causes and effects*). An example is a steering wheel that vibrates when the driver is found to be outside his lane (Kozak et al., 2006). Although this equipment continues to improve, it is still far from perfect at this moment. Too often it gives an unnecessary alarm signal, and fails to give one when it is due. Because the equipment does not measure the degree of fatigue itself, but its consequences (zigzagging, speed relative to other traffic, eye blinking and movement), it could in the somewhat more distant future be used to warn drivers for attention problems caused by lack of intensity. Many car manufacturers are working on such detection systems, like Volvo with Driver Alert Control which is based on the movements of the car(see: http://www.youtube.com/watch?v=Gb9G9vZ0Tyg). PERCLOS, a system that measures the percentage of time during which the driver has his eyes shut, has also proved to be very sensitive (Xia, Song & Zhu, 2008).

Conclusion
Attention problems can have a negative effect on driving skills. The driver does no longer look about properly, is slow to react, is late or entirely fails to notice things, and when he brakes, it is often late and abrupt. The extent of the problem is hard to estimate, but research in the United States which accurately recorded driver behaviour immediately before a crash (Dingus et al., 2006) suggests that 7% of the crashes is partly caused by the driver's attention problems, without the driver being occupied with other things and without fatigue being involved. However, much more epidemiological research is required to enable accurate estimates. Other than public information and applying longitudinal rumble strips to roads, no clear measures are known to fight concentration problems behind the wheel. In the somewhat more distant future detection equipment may make it possible to warn the driver inside the vehicle for loss of attention caused by too low attention intensity.

Publications and sources
(Dutch SWOV reports have a summary in English)

Brouwer, W.H. (2002). *Attention and driving; A cognitive neuropsychological approach*. In: Leclercq, M. & Zimmermann, P. (eds.), Applied neuropsychology of attention; Theory, diagnosis and rehabilitation. Psychology Press, Hove, United Kingdom.

Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., et al. (2006). *The 100-car naturalistic driving study, phase II; Results of the 100-car field experiment*. DOT HS 810593. National Highway Traffic Safety Administration NHTSA, Washington, D.C.

Gaillard, A.W.W. (2005). *Concentration; An instrument to augment cognition*. In: Proceedings of the 1st International Conference on augmented Cognition, Las Vegas, 22-27 July 2005. Augmented Cognition International Society, [s.l.].

Harbluk, J.L., et al. (2007). *An on-road assessment of cognitive distraction: Impacts on drivers' visual behaviour and braking performance*. In: Accident Analysis and Prevention, vol. 39, nr. 2, p. 372-379.

He, J., Bebic, E., Lee, Y.C. & McCarley, J.S. (2011). *Mind wandering behind the wheel: Performance and oculomotor correlates*. In: The Journal of the Human Factors and Ergonomics Society, vol. 53, nr. 1, p. 13-21.

Karrer, K., et al. (2005). *Driving without awareness*. In: Underwood, G. (eds.), Traffic & transport psychology; Theory and application. Elsevier, London, p. 455-469.

Kozak, K., Pohl, J., Birk, W., Greenberg, J., et al. (2006). *Evaluation of lane departure warnings for drowsy drivers*. In: Proceedings of the Human Factors and Ergonomics Society, 50th annual meeting.

Martens, M.H. & Brouwer, R.T.F. (2006). *Aandacht en interne afleiding in het verkeer: een rijsimulatorstudie*. TNO-DV 2006 C292. TNO Defensie en Veiligheid, Soesterberg.

May, J.F. & Baldwin, C.L. (2009). *Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies*. In: Transportation Research Part F: Traffic Psychology and Behaviour, vol. 12, nr. 3, p. 218-224.

McEvoy, S.P., Stevenson, M.R. & Woodward, M. (2006). *The impact of driver distraction on road safety; Results from a representative survey in two Australian states*. In: Injury Prevention, vol. 12, nr. 4, p. 242-247.

Pastor, G., Jejero, P., Chóliz, M. & Roca, J. (2006). *Rear-view mirror use, driver alertness and road type: An empirical study using EEG measures*. In: Transportation Research Part F, vol. 9, nr. 4, p. 286-297

Recarte, M.A. & Nunes, L.M. (2003). *Mental workload while driving; Effects on visual search, discrimination and decision making*. In: Journal of Experimental Psychology: Applied, vol. 9, nr. 2, p. 119-137.

Stutts, J.C., et al. (2001). *The role of driver distraction in traffic crashes.* American Automobile Association AAA Foundation for Traffic Safety, Washington D.C.

Vaa, T. (2003). *Impairment, diseases, age and their relative risks of accident involvement; Results from meta-analysis.* Deliverable R1.1 to project IMMORTAL (Impaired Motorists, Methods of Roadside Testing and Assessment for Licensing). University of Leeds, Leeds.

Vlakveld, W.P., Aarts, L.T. & Mesken, J. (2006). *Concentratieproblemen achter het stuur; Een beknopte literatuurstudie.* D-2005-5. SWOV, Leidschendam.

Vlakveld, W.P., et al. (2005). *Detailed cost-benefit analysis of potential impairment countermeasures. Research in the framework of the European research programme IMMORTAL*. R-2005-10. SWOV, Leidschendam.

Waard, D. de (1996). *The measurement of drivers' mental workload*. Proefschrift Verkeerskundig Studiecentrum, Rijksuniversiteit Groningen.

