SWOV Fact sheet

Naturalistic Driving: observing everyday driving behaviour

Summary
Naturalistic Driving is a relatively new research method for the observation of everyday driving behaviour of road users. For this purpose, systems are installed in subjects' own vehicles that unobtrusively register vehicle manoeuvres, driver behaviour (such as eye, head and hand manoeuvres) and external conditions. In a Naturalistic Driving study, the subjects drive the way they would normally do, in their own car and without specific instructions or interventions. This provides very interesting information about the relationship between driver, road, vehicle, weather and traffic conditions, not only under normal driving conditions, but also in the case of (near) crashes. Compared to conventional research methods, this new method is expected to provide greater insight into how and when hazardous situations occur and the possibilities it offers to make the traffic system safer.

Background and contents
The methods and techniques for road safety research are continuously being developed. Making use of advanced technology, the methods and techniques used so far cannot only be fine-tuned and adjusted, but sometimes completely new methods may be developed as well. This latter is the case with the relatively new observation method 'Naturalistic Driving', or, in other words, the 'observation method for naturalistic driving behaviour'. The purpose of this method is to observe (individual) road user behaviour in the driver's everyday (driving) context, instead of in a scientific experiment. The first experiments with Naturalistic Driving were conducted in the United States. This method was rapidly found to have great potential in obtaining information that cannot be gained by conventional research methods.
This fact sheet will describe the Naturalistic Driving method and put it in the perspective of conventional research methods. The way in which Naturalistic Driving studies can contribute to road safety will be discussed, and a number of these kinds of study will be presented.

What is Naturalistic Driving?
Naturalistic Driving is a recently developed research method, observing road users' everyday driving behaviour. The observations takes place during ordinary everyday drives in – preferably – drivers' own cars. In order to collect the required data, the car is fitted with various instruments that unobtrusively register vehicle manoeuvres (such as speed, acceleration/deceleration, direction), driver behaviour (such as eye, head and hand manoeuvres) and external conditions like characteristics of the road, traffic, weather et cetera (see for example *Figure 1*).

Naturalistic Driving has been developed as a result of advancing technique enabling the collection, storing and analysis of increasing amounts of data with increasingly smaller instrumentation. Studies in the United States and Europe have shown that Naturalistic Driving provides very interesting information about the relationship between drivers, road, vehicle, and weather and traffic conditions. This does not only apply to normal driving conditions, but also to (near) crashes. It is possible, for instance, to check how often drivers are distracted, tired, use their navigation system and suchlike, and whether this occurs more often in (near) crashes (for an overview of the research options, see for instance Backer-Grøndahl et al., 2009).

So far, the Naturalistic Driving method has mainly been used in passenger cars, but is equally well suited for use in other vehicles such as vans, trucks and motorcycles. It is also possible to use this type of advanced observation equipment alongside the road rather than inside the vehicle for so-called site-based observations. This way, (natural) road user behaviour of a great many road users (among whom cyclists and pedestrians in particular) can be studied at specific locations.

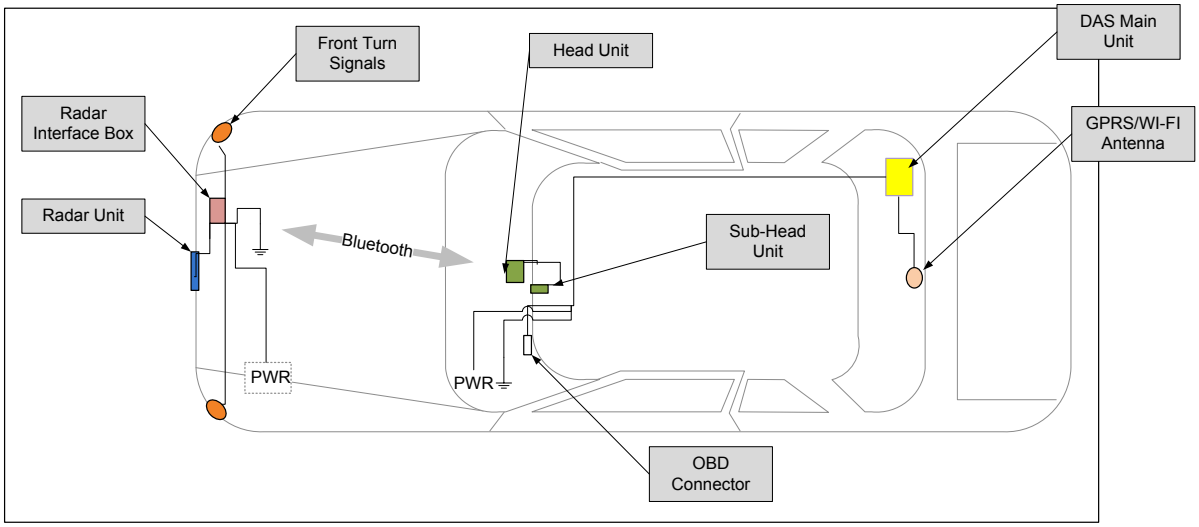

Figure 1. *Parts of the Data Acquisition System (DAS) of the Naturalistic Driving study in the United States (Dingus, 2008).*

What is the difference between Naturalistic Driving and a Field Operational Test?
The slightly longer used Field Operational Test (FOT) is closely related to Naturalistic Driving. A FOT is mainly conducted to evaluate new (vehicle) technologies and (market-ready) products. In this case, similar observation equipment and techniques are used as in a Naturalistic Driving study. However, in a Naturalistic Driving study the subject will drive as he or she is accustomed to, without specific instructions or interventions, once the equipment has been installed. On the other hand, a FOT often comes with an intervention. This usually implies that subjects drive with the system to be studied turned on (compulsorily) for a certain period, as well as turned off (compulsorily) for a certain period. An extensive manual has been written in the EU project FESTA (Field opErational teSt supporT Action) with information about the stages that generally have to be taken when a FOT is carried out (FESTA Consortium, 2011).

An example of a Dutch FOT is the recently finished project Anti-crash systems for trucks (AOS; Ministry of Transport, Public Works and Water Management et al., 2009). Commissioned by the Ministry, TNO and Buck Consultants International conducted a large-scale practical study with driver assistance systems in trucks in 2008 en 2009. During eight months, five different systems plus one registration system were tested in 2,400 trucks of 123 transport companies. The study focussed on the reduction of the number of crashes involving trucks and on improving the traffic flow on the motorways in the Netherlands.
Another example of a FOT is the EU-project EuroFot. EuroFot tested eight advanced driver assistance systems that should enhance safety, efficiency and driving comfort. In total, more than 1,000 cars and trucks in various European countries will be driving with observation equipment for one year.

What is the added value of Naturalistic Driving?
This section will discuss the strengths and weaknesses of the relatively new Naturalistic Driving method in comparison with other, conventional methods.

For a long time, controlled experiments, often in a driving simulator, were the standard method of studying driving behaviour. The major advantage of this kind of experiment is the large degree of control over the variables that (may) affect driving behaviour. For instance, the width of the road can be adjusted quite systematically, while other factors remain the same. On the other hand, however, controlled experiments are most often conducted in a created environment, such as in a driving simulator or on a test circuit. This makes the transfer of the results to actual traffic more difficult.

Secondly, driving behaviour if often studied by means of questionnaires (self-reporting). It remains a subject of discussion to what extent self-reported behaviour corresponds to actual behaviour.

A third traditional research method is epidemiological research into crashes. This method is generally based on police data about crashes in real traffic. The sample size in epidemiological studies is often

large and the results provide valuable information about crashes at the level of groups within populations. However, the available information is only the information also available to the police. Information about what preceded the crash, for instance, is solely derived from indirect sources, such as track investigation or witness statements. Moreover, the police mainly collect information with a view to the legal settlement of the crash. This type of information is therefore not sufficient for gaining insight into the factors that contributed to the cause or outcome of the crash.

A fourth type of study into crashes is in-depth research (also called multi-disciplinary crash research). In contrast with epidemiological studies, in-depth research uses a relatively small sample size, but yields a large amount of information about a crash. This way, in-depth research provides important information about factors that have an effect on the causes of road crashes. On the other hand, in-depth research does not teach us anything about 'normal' road user behaviour of road users and does therefore not provide any information about situations in which a crash was prevented.

In Naturalistic Driving, driving behaviour is (directly) observed in the everyday driving context. Furthermore, the behaviour and factors that result in an incident or crash can also be observed directly. However, since the degree of control over the influencing variables is smaller than in experiments, it is difficult to use Naturalistic Driving to establish causal relations.

How can Naturalistic Driving contribute to road safety?
The traffic system traditionally consists of three relatively independent elements: driver, vehicle and road. This view has resulted in a number of very effective measures. However, further improvement of road safety requires a new generation of measures. This new generation should derive from the realization that the three elements are indeed connected and form the traffic system, together with other road users and external influences. The Naturalistic Driving method enables the systematic observation of road user behaviour in the everyday traffic context. In combination with knowledge of the abilities and limitations of human information processing, this type of observations provides a much wider perspective on the traffic system as a whole. This enables better understanding of road safety problems and provides a better description of driver behaviour in normal situations, in critical situations and even during crashes. It is to be expected that the method can therefore provide greater insight in how and when hazardous situations occur and the type of possibilities it provides for making the traffic system safer.

Can Naturalistic Driving contribute to other aspects of traffic and transport?
Not only can Naturalistic Driving be used in road safety research, it can also be applied to other areas. First of all, the method can be used to validate older, more conventional road safety research methods. Validation research can establish how accurate and reliable a method measures what it is supposed to measure. In addition, Naturalistic Driving provides opportunities for studying human behaviour, in relation with, for instance, environmentally friendly driving or in relation with traffic flow as human behaviour is also very important with respect to these aspects of traffic and transport (Sagberg & Backer-Grøndahl, 2010). Naturalistic Driving provides the opportunity to assess to what extent model-based calculations actually correspond to the daily practice of traffic participation. A survey among potential users of Naturalistic Driving research (Van Schagen et al., 2010) indicates that they are also interested in these types of application (human behaviour in relation to environmentally-friendly driving and traffic flows).

Which studies make use of Naturalistic Driving?
One of the first studies making use of Naturalistic Driving was the '100-Car Study' in the United States which was conducted by Virginia Tech Transportation Institute and partly financed by the National Highway Traffic Safety Administration. In this study, 100 passenger cars were fitted with observation instruments, consisting of five video cameras, radar sensors, acceleration meters and a GPS receiver, for the period of one year. The 100-Car Study was intended to generate detailed information about the factors that may play a role in the occurrence of crashes or near-crashes (Dingus et al., 2006). In total, data has become available about a distance of two million kilometres driven, on which seventy crashes occurred (of various degrees of severity; Neale et al., 2005). The most important outcome of this study was that in almost 80 percent of all the crashes (observed in this study), distraction or inattention (three seconds prior to the crash) played a role (see also SWOV Fact sheet *Attention problems behind the wheel*).

Presently, the 100-Car Study has been followed by the 'Strategic Highway Research Program 2' (SHRP2). One part of SHRP2 is a large-scale Naturalistic Driving study that started a few years ago. Almost 2,000 vehicles are being equipped with observation instruments for a period of two years. Emphasis in the SHRP2 Naturalistic Driving study will be put on junction and roadside crashes, although many other aspects will also be dealt with.

A number of European projects have been using Naturalistic Driving: INTERACTION, PROLOGUE, DaCoTA and 2-BE-SAFE. These projects were finished in 2011 or 2012. The main output and results can be found on each of the projects' websites.

The INTERACTION project studied why, how and when drivers use intelligent technologies in their vehicle and their effect on driving behaviour. The following four technologies were studied: cruise control, mobile phone, navigation systems and speed limiters (this latter system is not yet found often in Dutch passenger cars). See also the SWOV Fact sheets *Use of mobile phone while driving* and *Safety effects of navigation systems*.

PROLOGUE (PROmoting real Life Observations for Gaining Understanding of road user behaviour in Europe) studied the feasibility and benefits of a large-scale European Naturalistic Driving study for organizations with direct or indirect interest in road safety and other aspects of traffic and transport (such as road safety researchers, environmental organizations, insurance companies, car industry, road authorities and governments). The interest of these organizations in Naturalistic Driving was also mapped. Benefits and feasibility were partly determined by five field studies focusing on various aspects of road safety, such as the everyday driving behaviour of novice drivers and cyclists and pedestrians. In October 2012, such a large-scale European Naturalistic Driving study did indeed start: UDRIVE (www.UDRIVE.eu), UDRIVE will look at passenger cars, trucks and motorcycles, with a special focus on crash causation factors, distraction and inattention, vulnerable road users and eco-driving. Data will be collected in seven EU Member States.

DaCoTA intended to provide policy makers and other stakeholders in Europe with data and knowledge of road safety, and methods for data collection and processing. In doing so, the methods developed in previous projects were the main starting point. When collecting road safety data, the guidelines established by SafetyNet in particular were further developed. DaCoTA included, among others, the work package Naturalistic Driving Observations, which explored the possibilities for using the Naturalistic Driving approach for cross-national monitoring of developments in safety performance indicators and risk exposure .

In the 2-BE-SAFE project, new methods and techniques were developed to study riding behaviour of motorized two-wheelers in relation with road safety. Part of this project consisted of Naturalistic Driving observations (called 'Naturalistic Riding' in this project).

How is Naturalistic Driving data processed and analyzed?

The Naturalistic Driving method provides an enormous amount of data that can be used for a wide range of analyses. Naturalistic Driving data does not only result in a great many data points (two million kilometres driving in the 100-Car Study), but the video recordings in particular also result in the data set being large in size, that it to say, in terms of storage capacity. The 100-Car Study resulted in 6 terabytes of data, the estimated size of SHRP2 being 1,000 terabytes. An advanced infrastructure is required to process such large amounts of data. For instance, the network in which the data is stored must be of large capacity, as several researchers must be able to analyze the (video) data at the same time.

As a result of the large amount of video data, coding and analyzing it is also extremely time-consuming. It is often impossible to watch and analyze all video data (the 100-Car Study resulted in almost five years of continuous video images). For this reason, a strategy is required to determine which fragments of the video data will probably contain interesting information and how to identify them (Groenewoud et al., 2010; Welsh et al., 2010). In the 100-Car Study, for example, researchers intended to study what takes place in the car or on the road, immediately prior to a (near) crash. To identify the relevant video fragments, 10% of all data were first analyzed. This way, it could be determined which values of which variables characterize a (near) crash, such as braking hard or a sudden steering manoeuvre. Based on these criteria, the relevant video fragments in the remaining 90% of the data could be identified.

Conclusion

The expectations of the possibilities of the relatively new Naturalistic Driving research method are high. This method makes it possible to study the everyday (driving) behaviour of road users in both normal traffic conditions and in conflict situations. Compared to more conventional research methods, this method is expected to provide greater insight into how and when hazardous situations occur and which possibilities this offers for making the traffic system safer. With the Naturalistic Driving method, not only road safety aspects, but also environmental and traffic management aspects can be studied. In Europe, this research method is already being applied on a small and medium scale. In 2012, with the EU project UDRIVE, a large-scale application of Naturalistic Driving started in Europe.

Publications and sources

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