EXPLORING APPLICATION AREAS FOR NATURALISTIC DRIVING OBSERVATION STUDIES: POTENTIAL FOR RESEARCH ON ITS

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ABSTRACT: Naturalistic Driving is a research method that is identified as promising for obtaining new insights in various road safety issues and is increasingly proposed and applied to investigate in-vehicle systems. This paper reports an exploration of the potential of Naturalistic Driving observation for research on ITS. The paper is based upon results from an ongoing European naturalistic driving project, PROLOGUE. A literature review was conducted on topics and applications of previous and current naturalistic studies, followed by an internet survey amongst road transport professionals in Europe to identify their interests and priorities for future naturalistic driving studies. The results show that European road safety professionals recognise the potential of using naturalistic driving studies to study in-vehicle systems and related driving behaviour and crash risk.

1 NATURALISTIC DRIVING OBSERVATION, A PROMISING RESEARCH METHOD

Naturalistic driving observation is a method to unobtrusively observe various driver behaviours. More specifically, naturalistic driving observation includes objective and unobtrusive observation of drivers in their normal driving context while driving. Typically, participants get their own vehicles equipped with devices that, for a considerable length of time, continuously monitor various aspects of driving behaviour, including vehicle movements, behaviour of the driver, and characteristics of the environment. The data logging device can record various driving behaviours such as speed, braking, lane keeping/variations, acceleration, deceleration, and it often includes the data from one or more video cameras as well. Optimally, this allows for the observation of the driver, vehicle, road and traffic environments and possible interaction between these factors.

1.1 Naturalistic driving observation compared to other methods

Naturalistic driving observation is a relatively new method for studying road safety issues, which has gained field within the last decade. What are the strengths and weaknesses of this method compared to other more traditional methods?

The golden standard for studying driving behaviour is highly controlled experiments, most often simulator experiments. The main advantage of controlled experiments is that one observes behaviour directly and has strict control over potential confounding variables, which in turn allows for causal

explanations. On the other hand, controlled experiments are most often conducted in artificial study settings and generalisation of the results is questioned. Driving behaviour is also often studied using self-report questionnaires and validated question batteries. As with all self-report measures, these measures can be subject to various biases and errors.

Epidemiological research on crashes is most often based on crash data bases from police data. Information gained from such databases is based on real crashes, and the sample sizes in such studies are large as such studies aim at giving information about crashes on a population level. However, the information about the crash reflects the information that is available for the police or the insurance company or other party that records or gathers the data. Therefore, the information available may be insufficient for understanding the factors contributing to the crash. Moreover, observation of variables of interest is indirect (i.e., accidents and related behavioural and characteristic variables are not directly observed), and one cannot rule out errors and biases in the recording of the data. Finally, not all crashes are reported or investigated, precluding a large amount of potential interesting crash data.

Naturalistic observation of driving behaviour allows for observing behaviour directly in a realistic context as drivers are observed during their everyday driving. Thus, the problem of the artificial study setting associated with experiments is alleviated. Also, observation of behaviours and factors leading to an incident or crash is observed, allowing for some interpretation of causality. However, as one does not have control over confounding variables as in experiments, conclusions about causality are limited at best. As for studying crashes, the main advantage with analysing crashes/near-crashes by means of naturalistic driving observation is of course the direct observation of driver behaviours, and depending on the technical equipment, environmental factors as well as road and traffic variables, preceding the event in question. Assuming one has a large sample, naturalistic driving observation studies allow for investigating crashes both quantitatively and qualitatively.

1.2 PROLOGUE

The main objective of the European project PROLOGUE (PROmoting real Life Observation for Gaining Understanding of road user behaviour in Europe) is to explore the usefulness, value, and feasibility of a large-scale naturalistic driving observation studies in a European context in order to investigate traffic safety of road users, as well as other traffic related issues such as eco-driving and traffic flow/traffic management. Naturalistic driving observation as a method is recognised to be able to substantially improve our knowledge and understanding of a wide range of road safety issues as well as eco-driving and traffic management. Though, it must be recognised that naturalistic driving observation as a method requires heavy resources in terms of samples, duration, data gathering, data storage, data reduction, and analysis. Therefore, it is of crucial importance to ensure that such a study is broadly supported and that the results can serve many purposes. The objective of the first Work Package of PROLOGUE is to identify interesting applications and research topics for future naturalistic driving studies.

1.3 Exploration of areas of interest and potential for research on ITS

As indicated before, naturalistic driving observation as a method is recognised to be able to substantially improve our understanding of a wide range of road safety issues. Based on this increased understanding, new measures could be identified to improve road safety. These measures could concern a wide range of road safety issues, such as road design, distraction, fatigue, (pre)crash information, risk taking behaviours. The strength of Naturalistic Driving Observation lies in the understanding of the issue and the identification of potential measures.

For research on ITS, the value of a large scale naturalistic driving observation study lies in the identification of new areas for ITS applications. An analysis of the natural driving behaviour is expected to lead to new insights into current difficulties or problems in driving performance. Following these difficulties, possible ITS solutions could be identified to support the driver. Also very interesting for the identification of areas of new ITS applications is that such a Naturalistic Driving Observation study could provide knowledge about the behaviour of different user groups, such as young drivers, older drivers or other special groups. ITS solutions could be tailored to the needs of the different groups. Special devices could be developed for groups with special needs, or one device could be tailored to the needs of different drivers.

This paper discusses the potential of Naturalistic Driving Observation for research on ITS and the views of European Road transport professionals about this. To explore the potential research area's for Naturalistic Driving Observation studies, a literature review was performed within the PROLOGUE project to identify topics and applications within the field of naturalistic driving in previous and current research. Moreover, an internet survey was performed among European road transport professionals to identify which areas they find most interesting and to ask for additional thoughts on interesting application areas.

2 TOPICS AND APPLICATIONS OF PREVIOUS AND CURRENT NATURALISTIC DRIVING STUDIES

In order to identify previous and current research topics and applications within the field of naturalistic driving observation, a literature review was conducted (Backer-Grøndahl et al., 2010). The present section builds upon the report by Backer-Grøndahl et al. (2010). In the first section, scientific literature on naturalistic driving is discussed in relation to various topics and applications. The second section focuses on the use of naturalistic driving for studying ITS in particular. Included literature covers peer reviewed articles/papers, published reports and unpublished material.

2.1 Topics studied by using naturalistic driving observation

Although relatively new as a method, research using naturalistic driving observation has been conducted in various fields the last decade. Backer-Grøndahl et al. (2010) found that in particular driver distraction and inattention

have been studied quite extensively by use of naturalistic driving observation (Stutts et al., 2005; Klauer et al., 2006; Olson et al., 2009),. Also new and invaluable knowledge has been gained regarding relative risks and population attributable risks. Other topics that have been investigated by use of naturalistic driving observation are 'driver drowsiness' (Hanowski et al., 2007), 'lane-change behaviour' (Toledo and Zohar, 2007), 'interaction between heavy and light vehicles' (Hanowski et al., 2006) and 'driver characteristics and states' such as age, gender, diseases, etc.(Prato et al., 2010; McGehee et al., 2007; Silverstein et al., 2009). All these areas would gain from further research using this method.

Taking another perspective, naturalistic driving observation also allows for investigation of and validation of other more traditional research methods for studying road user behaviour, such as self-report measures or driving simulator research (Klauer et al. 2006).

2.2 Application for in-vehicle systems

A significant objective within safety research is to develop and evaluate in-vehicle systems that may support drivers in their daily driving by making some specific tasks easier or safer, e.g., finding one's way. One important step in the development and evaluation of such in-vehicle support and safety systems is to test the system in question in a real driving context. By testing the systems in real driving conditions one can study how drivers use the system in question, how often it is used, whether the system works as intended (i.e., that a forward collision warning system actually warns the driver at the appropriate time), whether there are any unintended side effects, how it affects the drivers' behaviour, and possible effects on crash risk.

The type of study that is often used for testing in-vehicle devices is field operational tests (FOT), which is "a test run under normal operating conditions in the environment typically encountered by the subjects and the equipment being tested" (Karlsson et al. 2009). In a FOT the main objective is to test a specific system, be it in-vehicle or nomadic, by use of more or less naturalistic observations. A number of FOTs have been and are being performed in Europe at the present, including TeleFOT, SemiFOT, Test Site Sweden, EuroFOT, AOS, SIMTD and FESTA. Naturalistic driving studies may also address the question of in-vehicle support systems and nomadic devices, but then the main objective is often not to test the system per se. Rather, the main objective in such naturalistic driving studies is to investigate the behaviour of the driver. An increased understanding of the driver behaviour when using in-vehicle systems could provide insight in effects and possible side effects of these systems. But also observation of drivers not using in-vehicle systems is highly relevant, as this could provide more fundamental understanding of driver behaviour and the existing difficulties. From this potential area for development of new in-vehicle systems could be identified. In literature there is no clear cut difference between naturalistic FOTs and 'pure' naturalistic driving studies and there seems to be an overlapping area when naturalistic driving observations are used to test an in-vehicle system. In the literature review, a thorough review of all FOTs was precluded, and studies with a more naturalistic observation perspective were prioritised.

One interesting question with regard to the effect of in-vehicle support systems is if such systems have any unintended effects on behaviour. This has been studied by Sayer et al. (2005). The proposed mechanism, although not explicitly discussed in the paper, is that of risk compensation. That is, the perceived (and intended) increase of safety that comes with an in-vehicle safety system is compensated for by driving more risky, for instance driving faster, more aggressively or engage in more secondary (distractive) behaviours. A traditional assumption is that the intervention or system in question has to be either intrusive or conspicuous in order to be compensated for. However, some researchers also claim that there is a distinction between injury reducing and crash reducing interventions, and that normally only the latter are compensated (Graham 1982; Lund and O'Neill 1986; OECD 1990; Bjørnskau 1995; Sagberg, Fosser et al. 1997). The main objective in the study by Sayer et al. (2005) was to investigate if there was an increase in secondary behaviour when driving with the crash reducing systems Forward Collision Warning (FCW) and Adaptive Cruise Control (ACC). The results indicated that there was no increase in distractive secondary behaviours, except from talking with a passenger, which was interpreted as drivers explaining the systems to the passenger in question. However, such systems may be compensated for by other risk indicative behaviours than engaging in distractive activities, such as for instance driving faster. Moreover, in the study by Sayer et al. (2005), FCW and ACC are tested simultaneously and it is not possible to distinguish between the two. Thus, further research should address the question of risk compensation of various injury and crash reducing systems in naturalistic driving studies.

In the European project 'INTERACTION', the main objective is to use various methods to study and understand driver interaction with mature in-vehicle technologies (IVT) in the market. Naturalistic driving observation is one of the methods that will be used in INTERACTION to identify drivers' patterns of use of IVT in everyday life, and the implication of such use for safety.

Naturalistic driving observation has also been used to develop a method for evaluating the performance of collision avoidance systems (CAS) based on speed and acceleration data for the subject vehicle and, separation between two vehicles (McLaughlin et al. 2008). In the study by McLaughlin et al. (2008), different algorithms were developed in order to define the latest point in time where a deceleration would be necessary in order to avoid a collision. The naturalistic driving data enabled identification of the 'observed response point', i.e., the point in time when the driver initiated an avoidance response. Various algorithms were tested, and the results indicated that the frequency of false alerts appeared to be unacceptably high, warranting further developing of CAS and research on the performance of this system. Moreover, this study demonstrates the potential and usefulness of naturalistic studies investigating in-vehicle systems.

3 THE SURVEY

The literature review shows that naturalistic driving observation allows for investigating a broad range of research questions. This wide variety of application areas makes the results of naturalistic driving studies potentially interesting to many different stakeholders, including road administrations and

other authorities, primarily with road safety responsibilities, but also other aspects of road transport, such as car industry, insurance companies, road transport operators, road user organisations, driver training and certification organisations, as well as knowledge and research organisations.

To identify the interests of potential users of knowledge provided by naturalistic driving observations, a survey was performed among European road transport professionals (Van Schagen et. al., 2010). The present section builds upon the report of Van Schagen et. al. (2010).

3.1 Method

Almost 140 mainly European professionals in the area of road transport and related areas were invited by e-mail to participate in the survey. A total of 72 people completed the questionnaire. Ten of the respondents represented a national or regional governmental organisation; 6 represented industry, 31 a research organisation and 25 represented another organization type, mainly other non-governmental organizations. The respondents originated from 18 European countries

The questionnaire was presented at the internet. Depending on the answers, a respondent was automatically linked to the next questions relevant for him/her, and irrelevant questions were skipped. The questionnaire started with some general information about naturalistic driving as a research method and a few examples of how knowledge gained from naturalistic driving studies could contribute to various areas. In the next section, respondents were asked to rate the importance of investigating 17 pre-selected topics in a large-scale European naturalistic driving study. This pre-selection was based on the literature survey of Backer-Grøndahl et al., 2010. If respondents rated a topic as important they got two follow-up questions: why they considered that topic as important and what issues within this topic had their particular interest.

3.2 Results

3.2.1 General areas of interest

The results showed that almost all respondents were interested in road safety topics (92%), many (61%) were also interested in eco-driving and environmental effects of road traffic and least, though still almost half of the respondents, were also interested in traffic management-related topics. Many respondents also had additional suggestions for interesting topics for a large-scale naturalistic driving study.

The fact that respondents were most interested in road safety topics for a naturalistic driving study may be partly explained by a sampling bias. The respondents were selected on the basis of the project partners' network and the project partners are mainly road safety institutes. Whereas partners explicitly included business contacts with road transport in a wide sense, it is not surprising that respondents with a road safety interest were overrepresented.

The interest in road safety topics does, however, reflect the application of naturalistic driving studies so far. By far most studies have focused on road safety topics (see Backer-Grøndahl et al., 2010 for an overview). So it is likely

that respondents associate naturalistic driving studies most with road safety and that road safety professionals are most familiar with naturalistic driving observation as a method.

3.2.2 Specific topics of interest

Figure 1 shows the ranking of the 17 presented topics to investigate in a naturalistic driving study on a scale from 'very important' to 'not at all important'. The most important topics, ranked by at least half of the respondents as 'very important', were: risk taking behaviour, pre-crash behaviour, crash avoidance behaviour, and driver condition. These are closely followed by in-vehicle safety support systems and distractions inside the vehicle.

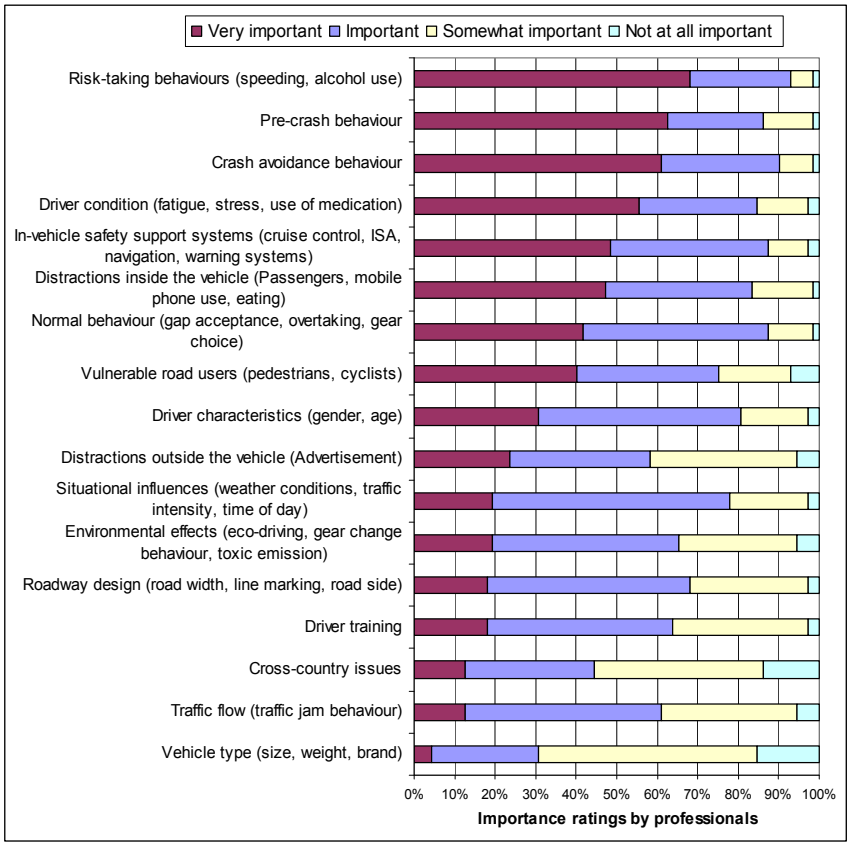

Fig.1. Areas of interest for naturalistic driving observation studies (ordered by importance as indicated by the respondents)

There were only minor differences between the interests of respondents from different organisation types. The results indicate that national and regional governments may be a little more interested than other respondents in the non-road safety topics such as vehicle type, traffic flow/congestion and environmental aspects. Industry was also somewhat more interested in environmental aspects compared to research institutes. However, the number of respondents in these categories was very small, so it is not possible to draw

firm conclusions.

The differences between countries were also minor. Since most countries only had a very few respondents, the countries were grouped according to their mortality rate, i.e. the number of road fatalities per million inhabitants. Three groups were distinguished: highest (n=26), medium (n=23) and lowest (n=23) mortality rate countries. Respondents from all three groups consider road safety to be the most interesting topic for naturalistic driving studies. Respondents from countries with the highest mortality were the only group that is more interested in traffic management than in environmental aspects. In the other two groups this was the other way round. Regarding the topics of interest; risk taking behaviour, crash avoidance and pre-crash behaviour are in the top five of all three groups of countries.

When asked whether the respondent's organisation was interested to contribute to a future large-scale European naturalistic driving study, over 80% of the respondents indicated that they were interested to participate in such a study; 4% was interested to fund such a project and 10% to fund such a project in kind.

3.2.3 In-vehicle safety support systems

The literature review indicated that naturalistic driving observation is considered a useful method for investigating drivers' behaviours associated with in-vehicle systems, like for instance risk compensation and behavioural adaptations. What are the views of European road transport professionals on this?

In the survey of Van Schagen et al. (2010), European road transport professionals identified 'in-vehicle safety support systems' and 'distractions inside the vehicle' as the fifth and sixth most important topics to investigate within future naturalistic driving observation studies. Both subjects are considered as most relevant to road safety and second most to human-machine interface design.

For in-vehicle safety support systems, not much difference was found between countries with different mortality rates, 87 to 89 % considered this issue as 'important' or 'very important'. For distraction inside the vehicle the difference between countries with different mortality rates was larger: distraction was considered to be more important in countries with higher mortality rates. It was considered (very) important by 96 % of the respondents in countries with the highest mortality rates, 83% of the respondents in the countries with medium mortality rates and 73% of the respondents in countries with the lowest mortality rates

Topics that are considered particularly interesting within the area of in-vehicle safety support systems are Lane departure warning (78%), Intelligent speed adaptation (ISA) (77%) and Forward collision warning (75%), followed by Navigation systems (63%), side blind zone alert (63%) and cruise control (48%). Other topics identified as interesting are: brake assist, lane keeping assist, seatbelt reminders, adaptive cruise control (ACC), Plus ACC, Collision Avoidance Systems, ADAS in general, IVDR - black box, the effect of real time information such as travel time, traffic jams, all systems, drowsiness warning,

lane keeping, ESP, collision mitigation systems.

Effects of the systems that are considered as most interesting are: intended effects of in-vehicle safety systems on behaviour and safety (86%) and risk compensation when using in-vehicle safety systems (84%). Also the unintended side effect was considered important: Unintended side effects of use of in-vehicle safety systems (69%) and the unintended side effects of other in-vehicle support systems (52%).

3.2.4 Limitations of the survey

As indicated by Van Schagen et. al. (2010), one must realise that the final sample of 72 respondents cannot be considered as representative of the European road transport professionals and the supposed stake-holders of an ND study. In particular, industry was underrepresented, and research organisations were overrepresented. This unbalanced distribution is likely to be attributed to the sampling procedure where the consortium partners, mainly non-profit research institutes, nominated people from their own network to be invited to participate in PROLOGUE's User Forum, and subsequently in the survey. Despite explicit attempts to involve car industry, insurance industry etc., they were underrepresented in the sample. The distribution over countries is not very representative either with the home country of the co-ordinator institute and one of the partners being substantially overrepresented. With 18 countries included, the sample does, however, cover a broad range of European countries. Since the sample is not representative for the population of parties that are potentially interested in ND studies, the results have to be considered as an indication only.

4 CONCLUSION

Naturalistic driving observation is identified as a promising method as it allows for observing behaviour directly in a realistic context. In order to gain knowledge about driving behaviour and potential crash risk associated with using various in-vehicle devices, naturalistic driving studies are promising and are expected to provide insights that are not easily obtained by other methods such as for instance controlled experiments and self-report measures. Further on, naturalistic driving studies may be complimentary to FOTs, as the latter first and foremost focus on testing the system per se, whereas naturalistic driving studies investigate the behaviour of the driver in relation to the system in a “broader” context. Also, given large samples, there is the potential for investigating accident risk and population attributable risks associated with ITS.

It can be concluded that the potential users of naturalistic driving studies have a broad interest. Almost all topics that were presented in the survey were considered important to study in a future naturalistic driving study by a majority of the respondents. Naturalistic Driving Observation is recognised by the European road transport professionals as a promising a method to study In-vehicle safety support systems with nearly 90% of the respondents indicating to find this topics important or very important.

Overall, naturalistic driving observation as a method is recognised to be able to substantially improve our understanding of a wide range of road safety issues.

Based on this increased understanding, new measures could be identified to improve road safety.

For research on in-vehicle systems in particular, an important added value of a large scale naturalistic driving observation study lies in the identification of new application areas for in-vehicle systems. Moreover, Naturalistic Driving Observation study could provide insight in the behaviour of different user groups. For the identification of new ITS solutions, this is relevant to develop systems tailored to the needs of the different groups.

In this application naturalistic driving observation has a completely different purpose as FOTs. FOTs are used to test ITS applications when they are ready to market – at the end of the product development process - whereas naturalistic driving observation offers the opportunity to identify new areas for ITS development and be the starting point for new product development.

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