NATURALISTIC DRIVING OBSERVATIONS TO INVESTIGATE DISTRACTION EXPOSURE AND IVIS PATTERNS OF USE: INTERESTS AND CONSTRAINTS OF THE APPROACH

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ABSTRACT: With the development of communication and information technologies, driver's distraction linked to In-Vehicle Information Systems has become a key issue for road safety. Despite ten years of investigation on IVIS impacts on driving behaviour, several research issues remain to be addressed. By observing in an unobtrusive way the behaviour of drivers, at the wheel of their own vehicle, during their daily journeys, naturalistic driving observations seem an interesting approach to investigate the link between driver distraction and critical situations occurrence, driver exposure to distraction related or not to IVIS and IVIS patterns of use. Despite the current technological offer permits their implementation, these studies raise some constraints, in terms of ethical issues, participants' selection, servicing processes, data coding and statistical analysis. Nevertheless, even if the issues to address are various, the outcomes of naturalistic driving observations in term of knowledge about IVIS integration in everyday life driving deserve the challenge.

1 Introduction

With the development of communication and information technologies and their deployment in the field of road transport, In-Vehicle Information Systems (IVIS) is becoming a common feature of the car environment. IVIS provide various functions and services to the driver. They may deliver information related to the trip management (e.g. navigation, traffic or weather information) but also completely unrelated to the driving activity (e.g. phone calls, e-mails…).

However, driver's distraction linked to the use of these electronic devices has become a key issue for road safety. Indeed, even if it is expected that IVIS can increase driving comfort when supporting the driver adequately in his or her driving task, it has been demonstrated that IVIS handling or checking can have negative side effects, such as distraction, mental workload increase, lapses of attention, reaction delays and inadequate situation awareness.

Since the nineties, numerous researches have been carried out, using various experimental contexts (driving simulators, test tracks or real traffic conditions) to estimate driver's demand while performing this kind of secondary task and to evaluate how this workload increase interferes on the driving performances [1-3]. In parallel, some authors showed that drivers engaged in secondary tasks have an increase risk of being involved in a crash or near-crash, whatever the solicitation modality (auditory, visual or manual) [4-6]. Accident analysis databases have also been analyzed to identify the part of distraction on crashes [7-8]. Aware of this issue, the European Commission, through the edition of European Statement of Principles on the design of Human Machine Interaction, decided to disseminate widely the best practices for the design of IVIS and their in-vehicle installation [9-10]. Their objective was to limit the risk that poorly designed interfaces introduce unnecessary driver's distraction. From a few years, driver's distraction due to IVIS use has become a major topic of interest for researchers, authorities and designers. Despite this interest and the efforts achieved, some issues remain unresolved.

We assume that naturalistic driving observations offer the opportunity to fill in these research gaps. Indeed, it will be a challenging approach to investigate drivers' distraction exposure and patterns of use of IVIS in everyday driving. In this paper, we present the main characteristics of naturalistic driving observations. Then, we highlight the research issues they can address and we describe the observations that can be carried out with this approach according to the current technological supply. However, the interests of these new possibilities of investigation must be balanced with their constraints. Thus, the different methodological questions raised by this approach are presented and discussed.

2 Naturalistic driving observations

2.1 Definition

Naturalistic driving studies consist in observing, in an unobtrusive way, drivers behaviour in naturalistic settings - that is, during their everyday life driving - out of experimental context [11-13]. Indeed, participants just drive where and when they want to, at the wheel of their own car. Participant cars are equipped with an instrumentation package, in order to record different information. Thus, it is possible to collect data related to the driver' state, to his or her driving behaviour, to the vehicle dynamics, to the infrastructure or to the environment surrounding the car. These data are recorded non-stop during all the observation period. After the observation, they permit an in-depth analysis of drivers' behaviour by researchers. Recorded and analyzed drivers' behaviours can concerns standard driving situations but also critical or accidental situations.

Thus, conducting naturalistic driving observations seems a relevant method to collect information on the way drivers use IVIS in everyday driving, in addition to traditional crash investigation or experimental studies.

2.2 Research issues that can be addressed

Despite ten years of investigation on drivers' distraction and IVIS impacts on driving behaviour, several major issues of research remain to be addressed. However, this missing knowledge can be largely investigated by naturalistic driving observations under the three following aspects at least: the link between driver distraction and critical situations occurrence, the drivers' exposure to distraction related or not to IVIS and the patterns of use of IVIS.

Researchers that attempt to investigate the part of distraction on road accidents are confronted with the weakness of police reports and crash investigations regarding information on driver's distraction or inattention at the moment of the crash [7-8]. Indeed, this distraction or inattention information is only issued from self-report of drivers involved in crash, or eyewitness accounts. But drivers generally try to hide some details of what really occurred for fear of prosecution. Furthermore, it is difficult for the crash eyewitness to establish if the driver was running a secondary task just before the accident. At last, the recording of distraction or inattention information is not currently generalized in all accident databases. For example, in spite of the high media coverage of the risk linked to mobile phone use while driving, this information is not systemically available. And the solution retained by Redelmeier [4] to match the crash information given by the police reports to the phone activity of the drivers few minutes before the crash given by their telecommunication company is also spoilt by mistakes due to the inaccuracy of the collision time. For these reasons, naturalistic driving observations offer an efficient way to evaluate objectively the part of distraction on accidents with a possible in-depth analysis of crash and near-crash events recorded during the observation period [6].

Moreover, there is a lack of knowledge concerning the driver exposure to distraction. Authorities focus on the distraction risk due to electronic devices handling or checking, but the relative part of this specific kind of distraction amongst all the other potential distraction sources needs to be investigated. For example, what are the driver's exposures to adjusting ordinary vehicle controls as climate control or radio, to locating or reaching objects inside the vehicle, to being distracted by car passengers, to being distracted by billboards along roads or to being lost in thoughts? And what is the actual exposure to handling or checking IVIS? If questionnaire-based surveys permit to distinguish clearly drivers that decide to use IVIS or not while driving, they are less relevant to evaluate accurately the frequency of IVIS use and the characteristic of the drivers that are more likely to use them. This information is necessary for an accurate exposure analysis and can be provided by naturalistic driving observations [11].

Beyond frequency of IVIS use, it is important to identify the patterns of use of IVIS in everyday driving. Under experimental conditions, subjects are instructed to pay maximum attention to the driving task, but they are still in a position to run a secondary task at the experimenter' request. We assume that in the everyday driving, some drivers decide to minimize the risk due to electronic devices handling or checking by choosing carefully the driving context for their use. For example, they can decide to perform some interactions only when their vehicle is stopped. They can also decide to limit IVIS use according to the type of road or the traffic condition. They can also defer some interactions waiting for a more suitable driving context. Finally, they can slow down in order to keep safety margin thresholds at an acceptable level. Thus, it is interesting to highlight the detailed modalities of driver interactions with IVIS. Furthermore, IVIS are designed for a reference use that is defined by the objectives of the systems and the conditions in which it should be operated. We assume that some drivers might misuse their systems, using them for objectives or in conditions that were not anticipated by their designers. For example, a driver could activate the cruise control system in order to be more available to read the SMS message he has just received on his cell phone. This unexpected uses of systems, called misuses, have to be evaluated and quantified. Finally, when providing drivers with driving-related information, IVIS can modify driving behaviour at strategic, tactical or operational levels. The way drivers really use all the available IVIS information, the related modifications of their travel pattern and the long term effects on their driving behaviour are still unknown. These three different aspects of patterns of IVIS use could be evaluated thanks to naturalistic driving observations.

Some North-American researches attempted to answer these questions [11-13]. Nevertheless, their outcomes can not be applied straight away to the European drivers because of major differences on vehicle models, on road network characteristics and on available technologies on the market. European countries also present cultural, institutional and economic differences that can explain various levels of IVIS availability or different drivers' willingness to use IVIS. All this argues to launch naturalistic driving observations in Europe in order to address all these unresolved research issues, all the more so since the technological offer permits nowadays their setting-up on a large scale.

2.3 Available technology

Nowadays, actual technological equipments enable us to easily and efficiently equip the participants' personal car and to collect several hours of data and video. Basically, a simple video recording system would be a good basis to study naturalistic driving behaviours, by filming what happens inside and around the vehicle [11]. However, a broad range of sensors can come in addition to this system [13]. Various vehicle parameters, like speed, steering wheel angle or indicator use can be collected via the E-OBD interface, by scanning the CAN bus of the vehicle or via specific additional sensors. The instrumentation package could also include a GPS to collect information on the vehicle whereabouts or several accelerometers to collect the lateral and longitudinal acceleration of the vehicle. We can even imagine the integration of advanced perception sensors like lane tracking systems or radars to know the position of the car on the road, and the surrounding traffic. However, these sensors are still expensive and their relevance is yet to be determined, as some of this information can be computed a posteriori from the video with image processing algorithms. Furthermore, given the constantly increasing size of the hard disk drives in computers, such a hardware data collection system could collect hours and hours of continuous driving data.

Obviously, it is easily possible to use many different sensors for the data collection with the only constraints of cost and of available space. However, to perform an in-depth investigation of driving behaviours, the recorded parameters will have to be carefully analysed.

To ease this analysis, the large amount of collected data can be automatically processed with the objective to find models that may deliver interesting behavioural information. For example, triggers can be set in order to select the near-accident sequences [13] or other potentially interesting sequences. To do so, the recorded parameters must include data that might act as triggers to indicate interesting sequences (e.g. beginning of a phone call, entering of a destination…). Even if the relevance of these sequences still has to be validated by an expert, it will facilitate and optimize the analysis work. However, some behavioural information can only be found manually by experts. This implies that they will have to check cautiously most of the collected data and videos, in order to code relevant behavioural information, which is very time-consuming.

Finally, technological choices must be a compromise. A simple data collection system offers a higher reliability and will be simpler and faster to equip in the participants' cars. However, due to the complexity and the cost of naturalistic driving observations, the instrumentation should still be rich and open enough to allow future exploitations.

Even if naturalistic driving observations are promising in terms of research issues to address and in terms of instrumentation development, the implementation of this kind of studies raises a set of additional constraints.

3 Constraints of Naturalistic driving observations

3.1 Ethical issues

First of all, from the ethical point of view, it is important to respect the privacy of the drivers and of the potential passengers. Indeed, data protection is a fundamental human right that must be guaranteed by experimenters, even if data protection laws may differ from a country to another.

Thus, experimenters must ask participants to sign an informed consent form. This consent form explains the purpose and the constraints of the study. It also explains that the confidentiality of the personal data is guaranteed and that their personal data will be anonymous. Finally, it offers them the possibility to withdraw from the study at anytime. When signing the consent form, participants fully agree to be involved in this study and that their personal data will be analysed by experimenters for the research needs. The difficulty is that the instrumented vehicle can be driven by secondary drivers and drivers can also carry some passengers, adults but also children and teenagers. Experimenters could then have difficulties for collecting consent forms of these casual secondary drivers or passengers.

Moreover, the respect of personal data protection can have a major impact on the kind of data that can be recorded during naturalistic driving observations, and especially concerning the video and audio recording systems. Different technical solutions can address this issue. The inside camera could only capture the driver's face and not the entire vehicle cabin to guarantee the anonymity of potential passengers. Also, the audio information could not be recorded with the video to respect participants' private life [13]. This kind of restrictions was used during previous studies, even if it considerably decreases the quality of dual task situations analysis. Indeed, with such recording conditions, it is hard to distinguish if the driver is talking with a passenger or if he/she conversing on a hands-free phone. It would also be difficult to identify which IVIS is handled by the driver [13].

To guarantee an accurate analysis of dual task situations, it seems preferable not to restrict the collected parameters, but to allow the participants to stop the data recording when they want to, with the only constraint to inform the experimenters of the reason of their decision. Thus, when participants take part in long observation period, they are able to preserve their private life when exceptionally needed, with only little impact on the final analysis.

3.2 Definition & representativeness of the driver's sample

The correct definition of the sample of drivers involved in a naturalistic driving study and the capacity to generalize its results to the entire population are also major issues.

For experimental studies, the subjects are usually selected according to their gender and their age class. But in the case of a naturalistic driving study investigating the patterns of IVIS use, the participants' sample should not be only constituted according to these two criteria [11] and other parameters should be taken into account.

In order to avoid any biased results, it is necessary to check if the devices at the disposal of the participants are sufficiently representative of the market. Indeed, the commercial offer for IVIS is diversified between the OEM systems, the after market ones and the nomadic devices. The human machine interfaces of the systems are also varied. They can be based on a visual/manual or on a vocal interface; the navigation in the menus can be more or less complex and so on. As these interaction modalities can have a direct and strong effect on the impact of IVIS on drivers' behaviour, they have to be selected very carefully.

Of course, the fact that drivers are regular or irregular IVIS users must also be considered. In order to detect significant associations between IVIS use and driver's behaviours, and even more to detect associations between IVIS use and crash or pre-crash situations, it is necessary to collect various patterns of IVIS use in sufficient quantities. However, even if it is practically preferable to use a sample with intensive IVIS users in order to clearly highlight typical patterns of use and to limit the necessary observation period, the possibility to generalise the results should be balanced. Indeed, drivers' population is composed of individuals with very heterogeneous IVIS handling habits and irregular users also have to be taken into account.

Finally, the sample has also to take into account the various travel patterns of the population in order to highlight different patterns of use of IVIS and different conditions of distraction exposure. For example, concerning distraction, we assume that a commuter will probably be easily distracted by a phone call but maybe won't be aware of outside distractions like special road signs. On the opposite, a couple with children that mainly drive to the countryside on the week ends will be more likely distracted by a navigation system (or by their children!). It will be necessary to control the participants' sample in terms of numbers of driven kilometres, of road networks taken and of travels purposes.

As a conclusion, it is important to control the characteristics of the sample, not only in terms of gender and age. Even if we try to obtain a representative sample, a correction of the exposure data will still be necessary to extend accurately the results to the entire population.

3.3 Suitable servicing processes setup

Another major issue is to guarantee the quality and the consistency of the data collected during the whole observation period. First of all, this can be achieved by focusing on the simplicity and on the robustness of the data recording system [13], as it is a good solution to prevent potential hardware or software failures. However, it is also important to have additional processes to detect any possible breakdown. It is necessary to organise suitable servicing processes. This servicing will have to be reactive and mobile, given that the car can be anywhere. It is also important to plan repetitive partial data downloads to minimize the potential risks of data loss [13]. All these processes will permit to fix most of the problems. It will guarantee a maximum quality of the information collected during the whole experimentation. However, to limit the workload and the journeys of the servicing team, a periodic remote monitoring of functioning of the technical equipments installed in the participants' car can be assured. For example, the system could send automatic reports via a wireless connection about the functioning status of its different components, but also summary information about the last collected data [14]. Moreover, download could also be done remotely using a wireless connection. Communication strategies will be necessary to keep a connection with the car even when it goes out of network coverage.

3.4 Event selection and data coding issue

As it was briefly presented in part 2.3, the selection of the significant events for the statistical analysis and the additional coding of the selected sequences are crucial issues to obtain relevant results from the naturalistic driving observation.

Indeed, according to the events studied by researchers (phone calls, consulting traffic or navigation information, pre-crashes and incidents) and their occurring frequency while driving, it is necessary to observe drivers and to collect data continuously during more or less long periods (a few weeks, several months or even a year). Amongst this huge amount of collected data, only a small subset of sequences is significant for the statistical analysis. Different kinds of procedures can be used to select these sequences. First, events can consist of few-seconds or few-minutes period of time selected randomly. This procedure has been used to evaluate drivers' distractions exposure [11-12]. Events can also be selected from event triggers. For example, for the identification of pre-crashes or incidents, a set of variables measuring vehicle kinematics with a set of associated trigger criteria have been used to pre-select applicant events, selections are later strengthened by watching the corresponding video clip [13][15]. We can also dream up to conceive event triggers that identify the moments when drivers are using their electronic devices, with an analysis of video or audio data, or with specific sensors of devices running. This latter solution will be easier to set up when the instrumented vehicles are lent to subjects and then experimenters can control IVIS present in the vehicle.

All in all, this reduction process is necessary to reduce the effort for the following step, the data coding. Indeed, this part of the study is very time-consuming, but the accuracy of this work has a direct impact on the quality of the outcomes of the research. Video data plays a major part in the data coding process. Video clips permit first to evaluate if the driver is attentive or distracted and in the case of distraction to evaluate the distraction source. It permits also to code information about the driving environment like road characteristics, traffic, light conditions and so on. At last, the driving task under way can only be described in detail by watching video. Moreover, the coding of video data has a subjective nature and because of the amount of data, several people could be involved in this activity during several months. For that, they must be trained, and the quality of their must be controlled on a regular basis with the objective to increase inter and intra reliability [13].

3.5 Statistical analysis constraints

The last major issue raised by naturalistic driving observations concerns the statistical analyses and their constraints that differ according to the research objectives. For example, for researches that attempt to evaluate drivers' distraction exposure, the challenge is to extend the results obtained for the subjects' sample to the whole population. We have already tackled the constraints raised by such an analysis in section 3.2, so we don't broach this topic again and we prefer to focus on the case of researches attempting to evaluate the impact of IVIS on driver's behaviour.

Statistical approaches have already been tested to analyse data collected during naturalistic driving studies. However, they have to be applied carefully. For example, an approach consists in selecting random driving sequences in order to assess drivers' distraction status, according to the fact that the driver is distracted or not, and according to the nature of the distraction [12]. Then, these authors evaluate the impact of distraction on drivers' behaviour by aggregating all the sequences with the same distraction status and by looking for significant differences on driving performance among them. However, this aggregating process doesn't into account the heterogeneous driving context of the selected sequences, which can mask specific dual task effects.

Indeed, in the case of naturalistic observation, unlike experimental research, all the situations of dual task studied for each participant are unique, in terms of secondary task nature and also in terms of driving context. Here, it is not possible to isolate the effect of dual task by controlling all the interfering variables by the experimental design. A possible solution would be to realize matched-paired comparison. For that, each driver is considered as his/her own control and each situation of dual task must be matched with a baseline situation. The baseline situation must be as similar as possible to the dual task situation in terms of driving context. For example, a dual task situation can be matched with a sequence of the same duration, randomly selected just before, or just after, the studied sequence and during which the driver must be not distracted by any source of distraction. It is also possible to identify sequences with similar characteristics, like manoeuvre, traffic condition and road infrastructure, using advanced mathematical modelling like hidden Markov modelling [16]. This new approach would bring interesting information about the impact of IVIS use while driving.

Nevertheless, the effect of IVIS handling and checking on drivers' behaviours at operational level must be certainly hard to evaluate. Indeed, the experimental studies on mobile phone use while driving show with a clear consensus that performing secondary task increases reaction time [1][3]. Conversely, the results concerning impacts on vehicle control (e.g. speed, headway, lateral position) are divergent [1][3]. And even for the authors who found significant effects, these effects are low. Thus, for naturalistic driving observations in everyday driving, it could be difficult to show effects on vehicle controls specifically due to the dual task situation and not to some variations in the driving context. Furthermore, the setting-up of compensatory processes during dual task situations is linked to the driving context, but it is also linked to personal characteristics of drivers, like the awareness of the risks taken to handle or to check an IVIS, or the driving style.

The statistical approach retained for the data analysis, and its specifics constraints, must be taken into account at an early stage of the design of the naturalistic driving observation in order to make sure to achieve the desired research outcomes.

4 Conclusion

As a conclusion, even if naturalistic driving observations raise issues of different natures, they are still an interesting challenge that promises many visionary outcomes and that will certainly bring us new knowledge and new methodological approaches. Very aware of this interest, European researchers have already tackled this challenge and make strong efforts to implement naturalistic driving observations, with the support of their government and of the European Commission. We can assume that in a near future, large scale naturalistic driving observations will be launched in Europe and will complete the knowledge brought by American studies.

5 References

[1] Caird, J. K., Scialfa, C. T., Ho, G., and Smiley, A.: 'Effects of cellular telephones on driving behaviour and crash risk: results of meta-analysis' (CAA Foundation for Traffic Safety, 2004)

[2] Road Safety Committee: 'Inquiry into Driver Distraction' (Parliament of Victoria, 2006)

[3] Brusque, C. (Ed): 'The Influence of In-Vehicle Information Systems on driver behaviour and road safety: Synthesis of existing knowledge', (Les collections de l’Inrets - Synthèse Inrets, 2007)

[4] Redelmeier, D. A., and Tibshirani, R. J.: 'Association between cellular-telephone calls and motor vehicle collisions', The New England journal of medicine, 1997, 336, (7), pp. 453-458

[5] McEvoy, S. P., Stevenson, M. R., McCartt, A. T., Woodward, M., Haworth, C., Palamara, P., and Cercarelli, R.: 'Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study', British Medical Journal, 2005, pp. bmj.38537.397512.55

[6] Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., and Ramsey, D. J.: 'The Impact of Driver Inattention On Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data' (Virginia Tech Transportation Institute, 2006)

[7] Stutts, J. C., Reinfurt, D. W., Staplin, L., and Rodgman, E. A.: 'The role of driver distraction in traffic crashes' (University of North Carolina at Chapel Hill - Highway Safety Research Center, 2001)

[8] Stevens, A., and Minton, R.: 'In-vehicle distraction and fatal accidents in England and Wales', Accident Analysis & Prevention, 2001, 33, (4), pp. 539-545

[9] European Commission: 'Commission Recommendation of 21 December 1999 on safe and efficient in-vehicle information and communication

systems: A European statement of principles on human machine interface (notified under document number C(1999) 4786)', Official Journal, 2000, L019, pp. 0064-0068

[10] European Commission: 'Commission Recommendation of 22 December 2006 on safe and efficient in-vehicle information and communication systems: Update of the European Statement of Principles on human machine interface (notified under document number C(2006) 7125 final)', Official Journal, 2007, L 32, pp. 200-241

[11] Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C., Gish, K., and Staplin, L.: 'Driver's exposure to distractions in their natural driving environment', Accident Analysis & Prevention, 2005, 37, (6), pp. 1093-1101

[12] Sayer, J. R., Devonshire, J. M., and Flannagan, C. A.: 'The effects of secondary tasks on naturalistic driving performance' (The University of Michigan - Transportation Research Institute, 2005)

[13] Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R. R.: 'The 100-Car Naturalistic Driving Study Phase II – Results of the 100-Car Field Experiment' (Virginia Tech Transportation Institute, 2006)

[14] 'Website of LAVIA project', http://heberge.lcpc.fr/lavia/index.html, accessed Jan. 2008

[15] Dingus, T. A., Neale, V. L., Klauer, S. G., Petersen, A. D., and Carroll, R. J.: 'The development of a naturalistic data collection system to perform critical incident analysis: An investigation of safety and fatigue issues in long-haul trucking', Accident Analysis & Prevention, 2006, 38, (6), pp. 1127-1136

[16] Dapzol, N.: 'Weight Semi Hidden Markov Model and driving situations classification for driver behavior diagnostic', 4th international Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Stevenson, Washington, USA, 9-12 July 2007, 84-90