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Is naturalistic driving research possible with highly instrumented cars? Lessons learnt in three research centres

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ABSTRACT

This paper provides an overview of the experiences using Highly Instrumented Cars (HICs) in three research Centres across Europe; Spain, the UK and Greece. The data collection capability of each car is described and an overview presented relating to the relationship between the level of instrumentation and the research possible. A discussion then follows which considers the advantages and disadvantages of using HICs for ND research. This includes the obtrusive nature of the data collection equipment, the cost of equipping the vehicles with sophisticated Data Acquisition Systems (DAS) and the challenges for data storage and analysis particularly with respect to video data. It is concluded that the use of HICs substantially increases the depth of knowledge relating to the driver's behaviour and their interaction with the vehicle and surroundings. With careful study design and integration into larger studies with Low(ly) instrumented Cars (LICs), HICs can contribute significantly and in a relatively naturalistic manner to the driver behaviour research.

1. Introduction

This paper describes the experience gained in three research centres using highly instrumented cars (HICs) for carrying out naturalistic driving studies. This method represents a step forward from traditional driving simulator studies where the environment is somewhat artificial. HICs are specialized research vehicles that record a large number of data continuously from the driver, the car, and the surroundings. HICs provide different sources of data including numerical driving parameters, video data from the driver and the surroundings, eye movements from the driver and geographical data. In summary, HICs record as much information as possible about what happens inside and outside the car when it is driven by participants of a study. In contrast, low instrumented cars (LICs) typically record a much smaller number of measures and the equipment used can be easily installed in the cars of participants.

The two types of vehicle should not however be considered mutually exclusive in a study. For example the EU TeleFOT project, www.telefot.eu demonstrates that in order to answer research questions that relate not just to travel patterns but also include questions relating to topics such as distraction and emissions, a large fleet of LICs needs to be complimented with further trials undertaken in a HIC.

The aim of naturalistic driving studies is to observe unobtrusively the behaviour of drivers (Backer-Grøndahl et al., 2009). However, notice that "observation" and "unobtrusive" are two words with somewhat conflicting meanings. Once a driver is being observed, this potentially interferes with normal behaviour since he/she is aware of being observed. Observation always involves some sort of intrusion. Thus, although the equipment used for recording or the observers themselves may be set as inconspicuously as possible in a study, simply the knowledge of being observed will act as an intrusion for subjects. In this way, naturalistic driving studies have the difficult task of balancing the need to observe for the sake of the experiment with the need to seem as unobtrusive as possible for the quality of the data. The extent of such interference is, however, a matter of debate as it has been claimed that drivers seem to forget very quickly that their actions are being recorded and often exhibit behaviours that seem to be "natural". Nevertheless, it still seems intuitive that drivers will exhibit at least some level of behavioural modification when they know they are under observation and that this may result in an absence of extreme behaviour such as risky or aggressive driving that might otherwise have been present.

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Fig. 1. Pictures of the three cars discussed in this paper, from left to right: Ford Mondeo – Transport Safety Research Centre, Loughborough University, UK; Lancia Thesis Emblema Centre for Research and Technology Hellas (CERTH), Hellenic Institute of Transport (HIT), Greece; SEAT Alhambra, INTRAS. University Research Institute on Traffic & Road Safety, Spain.

Using a HIC as a research instrument for a ND study imposes a number of specific restrictions that may jeopardize even more dramatically the spirit of such studies. The instrumentation in this type of car is often heavier than in an LIC and the aim of getting as much information as possible imposes very sophisticated data collection procedures. Therefore, some may argue that any study carried out with a HIC can hardly be considered naturalistic. However, as stated in the previous paragraph, any observational study may face similar criticisms and therefore should be analysed carefully in order to understand which elements of it are actually natural and which are not. This is necessary in order to form the right generalizations from the data relating to real life,[1] the level of instrumentation being only one of the aspects to be considered in such analyses.

The goal of this paper is firstly to provide a description of the HICs currently available in three research centres located respectively in the UK (Loughborough University), Spain (University of Valencia), and Greece (Hellenic Institute of Transport) with the purpose of providing an overview of the different capabilities, solutions, and technology used in each case. Secondly the paper describes some of the lessons that have been learnt from field-studies. Throughout, the paper aims to demonstrate the added benefit of HICs over and above LICs. Readers interested in carrying out studies using HICs will find this paper useful in order to understand the different options available and the consequences they have on the two main aspects that are needed to balance in these types of studies—naturalism and obtrusiveness of observation.

2. What is a highly instrumented car (HIC)?

HICs are vehicles equipped to record a large amount of data from a car, the driver of this car and the environment surrounding the car while it is being driven around. Combined, the data collected aim to provide a complete picture of the 'system' composed by the three sources aforementioned so that the majority of the specific questions that a researcher might be interested in can be answered. This is an ambitious goal and later we discuss a number of practical issues that hinder us from reaching it completely.

2.1. The cars

Pictures of the three vehicles described in this paper are provided in Fig. 1. They represent models of cars sold in the European market and as can be seen in the figure, they are not remarkable when viewed externally in any way except perhaps for being more spacious than average cars in Europe. Larger cars were chosen in all three cases since installing equipment within them was considered to be easier than in smaller cars.

[1] There is a similarity between this argument and the one used for driving simulators, where it is assumed that only partial aspects of reality are displayed in a simulation and consequently generalizations are only appropriate for those specific aspects.

2.2. Measures

Each of the three cars use different Data Acquisition Systems (DAS) in order to collect the data required for their current use, and in some cases also provide the capability to collect data for future studies. The DAS that have been used for each vehicle are listed below. These descriptions illustrate the use of both commercially available DAS and DAS that have been designed for a specific research purpose:

UK: The DAS in UK is a combination of three different systems providing the following capabilities:
- Aftermarket data-logger; this is a combination of GPS based data logger with tri-axial accelerometer and ability to configure additional auxiliary sensors, e.g. controller area network (CAN) and a video overlay system capable of synchronizing up to 4 high quality video cameras.
- Eye-tracking equipment; this operates by processing the images recorded by two cameras mounted on the dashboard in front of the driver in conjunction with the reflection from an infra-red emitter.
- Aftermarket warning device; this measures lane departure and time headway and provides forward collision warning.

SPAIN: The DAS in Spain is the output of an in-house project supported by the Spanish administration (López and García, 2008). This system has a modular design with a number of subsystems, namely; control and acquisition of information, storage of information (except video) and user interface, storage and management of video, detecting the lateral position and measuring distances to other cars to the left, right and front (Ibeo Automotive Systems GmbH). This system is notable as only a few commercial solutions were used. Most of the development was based on non-commercial systems (for example, Linux for the video analysis software).

GREECE: The car in Greece has an electronic unit (gateway) that receives information from the vehicle (CAN bus) and is then stored to the data logger. CAN bus data include gas/brake pedal position, longitudinal speed/acceleration, yaw rate, steering angle, lights/wiper status and external temperature. The same logger stores GPS data. A frontal Adaptive Cruise Control (ACC) radar enables distance and relative speed of the leading vehicle to be recorded and made available on the CAN bus network. Both Lane Departure and Collision Avoidance systems data are available on CAN bus. Finally, three synchronized cameras are mounted on the vehicle and positioned depending on the study requirements (e.g. frontal, face of driver and rear view). Video recordings are stored in a different acquisition unit.

Fig. 2 illustrates the different types of data collected across the three cars. As categorized previously, these are driver, vehicle or environment specific. The table also illustrates the type of data available depending upon the vehicle categorisation as either a LIC, a MIC (medium level of instrumentation) or a HIC. The