



Vehicle-based studies of driving in the real world: The hard truth?



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ARTICLE INFO

Article history:

Received 7 May 2012

Received in revised form 30 May 2013

Accepted 5 June 2013

Keywords:

On-road studies

Field operational tests

Naturalistic driving studies

Field studies

ABSTRACT

Real-world studies of driving behaviour and safety have face validity and have the distinct advantage of focussing on driving in its natural habitat. But their very naturalism can lead to problems with confounds and with noise in the data. This paper reviews the three major categories of on-road studies – controlled observation, field operational tests and naturalistic driving studies – and discusses the major applications of each study type. It also assesses some of the methodological issues that arise in one or more category of study.

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1. Introduction

Real-world studies of driving behaviour do not form a homogeneous group. They vary in scale from short-term observations using a single vehicle to investigations of driving behaviour over many months with dozens and even hundreds of vehicles. They may use simple equipment and sometimes just human observers or they may record data via elaborate instrumentation and data storage systems. In terms of study design they can range from naturalistic investigations of driver behaviour and the quality of their performance to experimental studies focussed on one or more interventions. In recent years these experimental studies have been targeted particularly at the impact of driver assistance systems on behaviour and safety.

Small-scale studies with highly instrumented vehicles go back to at least the 1960s: [Michon and Koutstaal \(1969\)](#) describe a general-purpose instrumented vehicle with the facility to record lane position, longitudinal and lateral acceleration, steering wheel movement, brake, accelerator and clutch activation and psychophysiological data such as heart rate. The vehicle also used video to record driver eye movements and the external scene. Earlier studies using instrumentation in vehicles include those of [Hulbert \(1957\)](#) on drivers' physiological response to traffic events and of [Brown \(1967\)](#) on the effect of time on task on driving quality. Studies of near accidents using both in-vehicle observers and instrumentation go back at least as far as the early 1950s ([McFarland and Moseley, 1954](#)). The reduced cost and

growing capabilities of systems for data capture on board vehicles have stimulated field operational tests (FOTs) to evaluate how drivers behave with new driver assistance systems and to indicate whether the use of such systems improves behaviour. The same data acquisition systems have enabled large-scale naturalistic driving (ND) studies to reveal the patterns of behaviour in everyday driving and the antecedents to safety-related events and incidents.

But the fact that studies are conducted in the real world and thus have face validity does not guarantee their usefulness or scientific rigour. Real-world studies can be difficult to manage and costly to conduct. The very feature that hallmarks real-world studies entails that they are subject to a large number of uncontrolled confounding factors so that detecting a signal, let alone the right signal, through the noise can be difficult. It is important to use studies to enhance the power of the data collection and anticipate confounds that could undermine validity.

This paper examines the broad categories of real-world studies of driver behaviour and safety. The number of such studies is huge, and there is no intention here to review them all. Rather, exemplars are used as illustrations for the purpose of a discussion of the rationale for carrying out various kinds of studies and of some of the methodological pitfalls that can lead to inconclusive results and even undermine study validity. The paper attempts to identify the major ways in which on-road studies can make a scientific contribution while acknowledging that a consensus on methodology does not generally exist and that the findings from such studies need the same scrutiny that is applied to more fully controlled laboratory and simulator studies. On-road studies fall into three major categories, which are described in more detail in the following sections.

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2. Categories of on-road studies

The first category consists of relatively small, targeted and controlled studies conducted to study how driving behaviour and performance are affected by, for example, fatigue, alcohol or distraction or to look at an intervention in the very short term. Such studies typically collect data on minutes or hours of observed driving. The second grouping is a large-scale and more long-term evaluation of a treatment, often called a field operational test. This method has been applied particularly to the evaluation of driver assistance systems such as Adaptive Cruise Control and Intelligent Speed Adaptation, but it is arguably just as appropriate for the evaluation of other types of intervention such as driver education and training programmes. Studies of this type tend to collect data on days, weeks and even months of driving. The final grouping is that of Naturalistic Driving Studies which focus not on treatment but on diagnosis – on enhancing the understanding of how safety problems arise and unfold. As with FOTs, weeks and months of data are normally collected.

Very recently a new hybrid of FOT and NDS has emerged, in which the data collection itself becomes the intervention. Here the data may be used in a fleet context for monitoring driver behaviour for use in providing positive or negative feedback to drivers (e.g. Hickman and Hanowski, 2010). It may also be used to provide post-qualification training to newly qualified drivers as in the U.S. programmes targeted at teenage drivers where video information on incidents is captured to provide feedback to the drivers and in some cases to alert parents to the behaviour of their offspring (Carney et al., 2010).

In the description of each of the approaches below, examples are provided along with the advantages and disadvantages of using the approach, supplemented by suggestions of appropriate research questions.

2.1. Controlled on-road studies

A controlled on-road study can provide researchers with a limited range of data that can be highly tailored to the research questions under investigation. The defining feature of a controlled on-road study is in its reliance on using a pre-set route to reveal differences in behaviour and performance, when driving under different conditions. In this respect, the onus is on the researcher to identify a route that affords them the best opportunity of being able to evaluate their hypotheses. Unlike a naturalistic driving study, there is no question as to whether the road user does or does not encounter a particular traffic situation – this is predetermined by the characteristics of the route and the instructions provided by the experimenter.

Such studies also retain many features of a traditional experimental study, whereby extraneous (confounding) factors such as weather, time of day, and traffic conditions can be controlled for, to some extent. It is not possible, of course, to absolutely control such natural phenomena but rather to control when and where the study might take place. One of the advantages of using a predetermined route is that traffic data (counts and flows) can be used a priori to establish appropriate scheduling, for example if one wishes to study behaviour in peak versus off-peak traffic conditions, or time of day. Weather, on the other hand, is less predictable but can be inferred via meteorological data or via CAN data (e.g. activation of fog lights or windscreen wipers). Researchers may typically limit their controlled studies to weather conditions that are of relevance to their research hypotheses, and where that is not possible, use them as covariates in the data analysis.

Taking the definition of a “controlled study” to its very extreme, use of facilities such as the Virginia Smart Road (<http://www.vtti.vt.edu/virginiasmartroad.php>), a closed test-bed

research facility which features weather-making capabilities (rain, snow, fog), can provide some insight into behavioural adaptation in such conditions. However, whilst weather can be added in at this type of facility, it is significantly more challenging to remove it; so, to a certain extent, the problem remains.

It can be the case that the use of a predetermined route cannot be avoided. This is particularly so where the study aims to evaluate infrastructure interventions such as new road design (De Waard et al., 1995) or infrastructure based ITS applications. For example, Brewer et al. (2011) conducted an evaluation of an intersection violation warning prototype with 87 drivers navigating a predetermined route on public roads. The route included 13 intersections with roadside communications equipment: three intersections controlled by traffic signals and 10 controlled by stop signs.

Controlled trials, due to their relatively short duration, have the added bonus of being able to accommodate an observer. This can be invaluable in providing context to drivers' behaviours, where even the most sophisticated camera system may fail (such as observing driver-to-driver non-verbal behaviour). Using observers as data collection tools predates the present sophistication of black-box monitoring. For example, McGlade (1963) evaluated almost 30 aspects of driver behaviour including parking skill, gear use, lane observance, attention and the use of the accelerator. Quenault (1966, 1967) focussed less on aspects of basic driving skills and more on style, by obtaining measures of speed, use of signals, overtaking and mirror usage.

Furthermore, the presence of observer(s) in the test vehicle can supplement the objective data collection by using techniques such as the Wiener Fahrprobe which is essentially a method akin to a driving test. Total counts of the number of negative interactions are made including unsafe merging/gap acceptance at junctions, incorrect lane changes, poor interaction with other road users, unsafe overtaking and headway choice. The Wiener Fahrprobe has been used in evaluation studies of a number of driver support systems (e.g. Chaloupka and Risser, 1995). Researchers have adapted the original tool, which was designed to be used overtly, to study driver behaviour covertly. For example, Brühning et al. (1989) used the technique to observe car drivers from a vehicle following behind. The Wiener Fahrprobe has also been adapted by reducing the number of observers (Almqvist and Nygård, 1997).

Controlled studies also permit the compression of exposure to the elements under investigation, creating the opportunity to study learning or adaptation effects (e.g. Jamson, 2006). Due to their relatively short duration, controlled drives may not be able to study long-term adaptation. Even if participants return for numerous drives, it is unclear if the period between the controlled drives affects the subsequent drives, or indeed if we can truly consider experience as being cumulative in this case.

A further criticism of using controlled studies where there is an observer present is the unknown effect that the presence of that observer may have on driver behaviour. For example, whilst Höfner (1967) reported that the behaviour of moped riders did not change when they were aware of being observed and Hjalmdahl and Várhelyi (2004) report similar findings for car drivers, Rathmayer et al. (1999) found that participants' mean speed was approximately 2 km/h lower when an experimenter was present. Additionally, the authors report reduced lateral and longitudinal accelerations. So there is limited and conflicting evidence with regard to this type of bias, perhaps partly due to the ethical implications of this type of study: informed consent is an inherent part of participant handling. There is some comfort in the results obtained in on-road studies (whether data are collected subjectively or otherwise) whereby participants are captured violating traffic laws, even when they are aware (or have forgotten) they are being monitored (Dingus et al., 2006).

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