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Can feedback from in-vehicle data recorders improve driver behavior and reduce fuel consumption?

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A R T I C L E I N F O

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A B S T R A C T

This paper evaluates the effectiveness of feedback, based on In-Vehicle Data Recorders (IVDR), to improve driving behavior, increase driving safety, and reduce fuel consumption. We developed a framework for driving-behavior measurement, incorporating second-by-second data collected by IVDRs. IVDR units were installed in over 150 vehicles driven by more than 350 drivers for over a year. The experiment was divided into three stages. The first stage was a "blind", control stage, with no feedback. The second stage incorporated verbal feedback given only to riskiest drivers. In the third stage all drivers received a bi-weekly written report about their driving performance. Safety events, such as braking, lateral acceleration or speeding, were recorded. Supplementary data regarding safety related events and fuel consumption were also collected. Safety incidents and fuel consumption were modeled as a function of IVDR measurement-based events, in order to identify which events best reflect safety incidents and excessive fuel consumption. Our results show that braking events best explain safety incidents, and all events together best explain fuel consumption. In addition, we found that for the riskiest drivers, feedback significantly reduced the IVDR events. Our models show that feedback can lead to a reduction of 8% in safety incidents, and 3–10% in fuel consumption, with a larger reduction obtained for large vehicles.

1. Introduction

In-Vehicle Data Recorders (IVDRs) have gained popularity as means to monitor and improve driving behavior and contribute to eco-driving, which reduces fuel consumption and emissions. In a typical setting, the IVDR unit - a relatively small box hidden under the vehicle dashboard - monitors, records and transfers data to a computer server. Raw measurements normally include, among others, speed, lateral and vertical acceleration, and vehicle location, and enable observation of natural driving behavior.

IVDRs' measurements can be used to define a series of events that characterize driving behavior. These driving characteristics are then used in providing feedback to drivers regarding their driving, thus contributing to reducing the likelihood of car crashes, operating costs, and emissions. Feedback can be provided in real time, by means of a dashboard display or sounds. A commonly used dashboard display utilizes green, yellow, and red lights, to indicate good, intermediate, and bad driving behavior. Alternatively, a periodical report can be provided to drivers in hard copy or electronically. The accumulated information can be further used to design personal training programs for drivers.

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Although the literature describes a wide range of uses of IVDRs, there is limited evidence to support the association of IVDRs with improved driving behavior, safety, and fuel economy. Based on a detailed review of the key issues associated with crash-frequency data, Lord and Mannering (2010) claim that, for the most part, naturalistic driving data have not yet provided significant new insight with broad applicability. The few studies focusing on whether IVDRs can influence driving behavior were mostly before-after field experiments, presenting the overall statistics of events' occurrences and fuel consumption. These studies have not addressed different types of feedback, and how these influence driving behaviors in a controlled experiment. The main objective of this study was to evaluate the impact of IVDR feedback on safe driving and fuel consumption (i.e. eco-driving). A large field study, financed by the Israeli Ministry of Transport, was conducted over a period of one year. IVDRs were installed in over 150 vehicles utilized by more than 350 different drivers. The collected data were analyzed in an attempt to identify which measurements can guide reduced fuel consumption or best reflect the risk of being involved in a car crash.

2. Literature review

The first application of vehicle data recorders was in an experiment run by the U. S. National Highway Traffic Safety Administration (NHTSA) in the 1970s (Chidester et al., 2001). Since then, various studies suggested that the installation of Event Data Recorders (EDRs) reduces crash rates and improves the effectiveness and accuracy of accident investigation (German, 2001; Arai et al., 2001). Such early EDRs were useful to study the events themselves, but since the data they stored were limited to a few seconds prior to events, they were insufficient for broader studies of driver behavior.

The naturalistic driving approach has substantial added value over more traditional methods, at it ensures continuous, automatic and standardized data collection (Wegman and Bos, 2013; Gordon et al., 2013). The 100-Car Naturalistic Driving Study (NHTSA, 2006) was the first instrumented-vehicle study undertaken with the purpose of collecting large-scale, naturalistic driving data. Klauer et al. (2009) used this database to compare drivers who had been involved in multiple versus few crashes or near-crashes. Two projects, PROLOGUE (PROmoting real Life Observation for Gaining Understanding of road user behavior in Europe, PROLOGUE, 2009, 2010, 2011) and DaCoTA (Driver Behavior Monitoring through Naturalistic Driving, 2010), were undertaken to demonstrate the value of studying naturalistic driving. These projects also helped to establish methodologies for continuous monitoring of normal driving behavior, mainly in order to support the development and evaluation of safety policies. The Argos project was developed to better understand drivers' behavior under realistic, albeit artificial, conditions, (Perez et al., 2010). However, these studies did not involve any feedback to drivers.

The use of IVDRs recently expanded to other functionalities, including monitoring and improving driving behavior. Some studies demonstrated a positive impact on safe driving when weekly safety-performance reports were provided to fleets' supervisors (Grindle et al., 2000; Sulzer-Azaroff and Austin, 2000). Musicant et al. (2014) demonstrated the benefits of feedback offered on longer trips, concluding that feedback affected magnitude, trend and frequencies of change over time, promoting safer driving behavior. Lotan and Toledo (2006) used IVDRs to characterize the driving behavior of young drivers during their accompanied driving period, and showed that initial exposure to IVDR, and access to its feedback, had a positive impact on the drivers' behavior and performance. Taubman Ben-Ari et al. (2015) used IVDR data from parents and their male teen drivers to show that parents' involvement in the intervention, either by feedback or by training, led to lower rates of risky driving. Shimshoni et al. (2015) showed that IVDRs' based feedback, combined with parental training in vigilant care, may help reduce adolescent driving risk. Tapp et al. (2013) used IVDR data to show improvement in driving skills amongst young drivers following a social marketing intervention trial in the UK.

Toledo et al. (2008) and Musicant et al. (2007) evaluated the validity of IVDR as a measurement tool, and concluded that IVDR data offered a reliable source for studying driving behavior. Rosenbloom and Eldror (2014) used IVDR data to test the impact of simulation-based driving training on actual driving behavior. Various other studies demonstrated that IVDR feedback can significantly increase safe-driving behavior (Musicant et al., 2007; Wouters and Bos, 1997; Lotan et al., 2010). However, Heinzmann and Schade (2003) showed that the installation of the unit alone had no significant effect on driving behavior or crash rates. Paefgen et al. (2014) used a commercial IVDR data set to explore the relationships between exposure and crash risk, and found non-linear relationships between mileage and crash risk.

Commercially, some insurance companies adopted IVDR as a mean to evaluate individuals' crash-involvement risk. In Minnesota, TripSense (2005) offered an in-vehicle monitoring device that evaluated driving history, and calculated insurance premiums in accordance with individuals' risks. Other companies offered "Pay as You Go" insurance programs, combining a fixed monthly fee with a variable fee based on the distance traveled, so drivers could save money by driving less (Bordoff and Noel, 2008; Moenig, 2009). Coroama (2006) developed the Smart Tachograph system, which sends IVDR data to a server in order to calculate insurance rates.

Driver feedback has also been used in the context of eco-driving applications. Modifying drivers' behavior can potentially lead to reduced fuel consumption (Haworth and Symmons, 2001; Young et al., 2011), as well as to reduced vehicle wear and tear (Berry, 2010; Gonder et al., 2012). The IEA workshop on eco-driving (2007) showed an average reduction of 10–15% in operating costs immediately after training. Over the medium term, fuel savings averaged 5% if there was no further involvement and 10% if feedback continued. Barkenbus (2010) and Berry (2010) suggested elevating public awareness to driving styles and the effects of eco-driving on fuel consumption and vehicle emissions through education and feedback. Barkenbus (2010) claims that promoting eco-driving through feedback can reduce fuel consumption by up to 10%. In a study