Evaluating the Long-Term Effects of Telematics Driver Feedback on Speeding Behavior: A Survival Analysis Approach

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Statement of Significance: We strongly believe that this paper makes a good scientific contribution, because to the best of our knowledge this is the first time that high-resolution smartphone data are exploited for the investigation of long-term effects of telematics feedback on driver behaviour through a multiphase driving naturalistic experiment via a survival analysis approach.

Author contribution statement
The authors confirm contribution to the paper as follows: study conception and design: A. Kontaxi, G. Yannis; data collection: A. Kontaxi; analysis and interpretation of results: A. Kontaxi; draft manuscript preparation: A. Kontaxi, G. Yannis. All authors reviewed the results and approved the final version of the manuscript

INTRODUCTION

Despite considerable progress in road safety over the past decade, road traffic crashes remain a pervasive public health issue globally, resulting in around 1.19 million road traffic deaths in 2021 (*1*), corresponding to a rate of 15 road traffic deaths per 100 000 population. The identification of critical risk factors leading to road traffic crashes has been researched by numerous studies over the years. Among these factors, human elements are consistently recognized as the most significant, accounting for the vast majority of road crashes. In fact, human error is cited as the cause of 95% of all road crashes (*2*). This underscores the importance of understanding and addressing driver behavior as a key component of road safety initiatives. By analyzing driver behavior, targeted interventions can be developed, aiming to mitigate risky actions such as distracted driving, speeding, and impaired driving. Despite the growing interest from both manufacturing companies and transportation researchers in driver behavior, there is a notable gap in research quantifying the long-term effect of driver feedback on road safety, particularly in terms of comparing data before, during, and after feedback provision.

In this regard, the present study aims to leverage large-scale trip data from smartphone sensors to assess the post feedback effects on key performance indicators, such as speeding, harsh braking, and harsh acceleration events. For this purpose, a naturalistic driving experiment has been conducted, thousands of trips have been used first to examine the trend of the risk driving indicators and then, survival models are applied to identify feedback effects to speeding behavior.

METHODOLOGY

As part of a research project, a 21-month naturalistic driving experiment involving 230 participants was conducted from July 2019 to March 2021, counting for 106,776 trips. This study included different types of drivers, namely car drivers, professional van drivers, and motorcycle riders. This paper focuses on car drivers, who correspondent the majority of the study's participants.

The main objectives of this experiment were to identify critical risk factors through driver monitoring using an innovative smartphone application and to develop feedback features that inform, notify, and motivate drivers to improve their skills, reduce driving errors, and lower crash risk. The experiment was divided into six phases, each providing different types of feedback to drivers. Phase 1 served as the baseline phase where drivers were recorded through the smartphone app and only a trip list was available with no other information about the driver behavior. In phases 2,3,4 and 5 different feedback features were added, as shown below, while drivers returned to no feedback in phase 6 for researchers to examine the post feedback effect.

For that purpose, an innovative smartphone application, developed by OSeven (www.oseven.io), was utilized to assess and improve driver behavior and safety. This application records driver behavior using the smartphone's hardware sensors and various APIs to collect sensor data, which is temporarily stored on the device before being transmitted to a central database. The collected data is highly detailed in terms of time and location. Once uploaded to the backend cloud server, the data is processed into meaningful driving behavior and safety indicators using advanced signal processing, Machine Learning (ML) algorithms, data fusion, and Big Data techniques, all in compliance with Greek and European GDPR regulations. Reader can refer to previous published papers to further read about the application (*3–5*).

A variety of different metadata are eventually calculated, including both exposure indicators, namely trip distance, driving duration, road type, rush hours etc., and driving behavior indicators, namely speeding (duration of speeding, speed limit exceedance etc.), number and severity of harsh events, harsh braking, harsh acceleration, and distraction from mobile phone use (mobile phone use is considered any type of phone use by the driver e.g. talking, texting etc.).

In this study, a cohort of 31 car drivers who participated across all experimental phases, baseline, feedback, and post-feedback, was analyzed. Over the course of the 21-month experiment, these drivers completed a total of 24,904 trips, with each driver contributing a minimum of 20 trips in the post-feedback phase. This subset of 31 drivers was selected to closely examine the long-term effects of feedback interventions on driving behavior.

FINDINGS

Initially, summary statistics and Wilcoxon signed-rank tests revealed significant behavioral improvements during the feedback phase, particularly in reduced speeding, mobile phone use, and harsh braking. However, partial relapse was observed in the post-feedback phase, highlighting challenges in sustaining safer driving habits once interventions are withdrawn. To further explore the persistence of behavior change, we employed survival analysis, modeling relapse in speeding behavior using Kaplan-Meier curves, Cox proportional hazards models with frailty, Weibull Accelerated Failure Time (AFT) models with random effects, and Random Survival Forests (RSF). The Kaplan-Meier curve for speeding percentage reflects how quickly drivers relapse to pre-feedback levels of speeding.

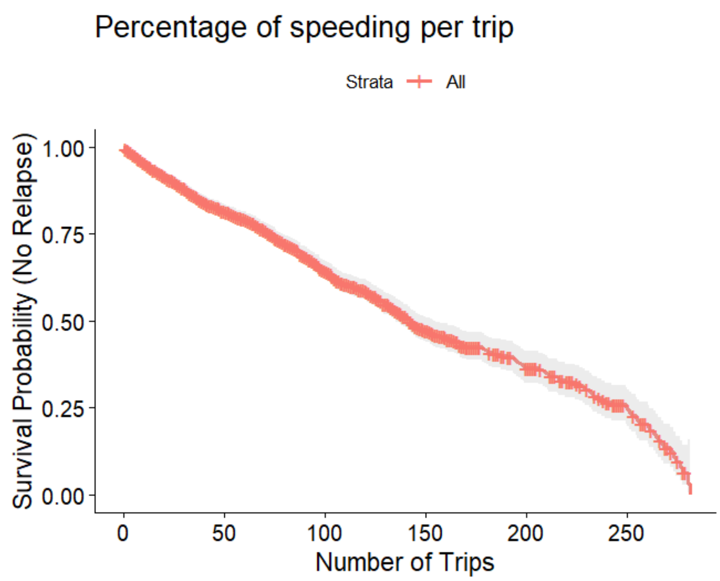

Figure 1 Kaplan-Meier survival curve for speeding percentage

Across models, trip duration emerged as a key predictor of relapse risk. The Weibull AFT model offered a strong balance between interpretability and accuracy, while the RSF model demonstrated superior predictive performance but lower transparency. Older age and afternoon peak hours were associated with safer driving, whereas self-reported aggressiveness and longer trips increased relapse likelihood.

DISCUSSION

Rapid technological advances, especially in telematics and Big Data analytics, as well as the increasing penetration and use of information technology by drivers (e.g. smartphones), provide new capabilities for monitoring and analyzing driving behavior. In this paper, we aimed to examine the long-term effect of driver feedback via a smartphone application on driving behavior risk indicators within a multiphase naturalistic driving experiment.

The results of this research underscore the critical need for sustained feedback mechanisms to reinforce safe driving behaviors over the long term, as relapse patterns were consistently observed across all examined indicators once feedback interventions were withdrawn. For speeding, the relapse trends were equally pronounced, with survival probabilities showing a gradual decline. At the 50-trip mark, 82.3% of drivers adhered to improved behavior, but by 100 trips, this proportion fell to 65.2%, and by

150 trips, only 46.8% of drivers maintained reduced speeding levels. This highlights that more than half of the participants relapsed into speeding behaviors in the absence of ongoing feedback.

The ultimate goal of providing feedback to drivers is to activate the process of learning and self-assessment, enabling them to gradually improve their performance and monitor their progress. This process involves establishing detailed cause-and-effect relationships between aggressive driving and associated risks, offering valuable insights for improving road safety (*6*). Additionally, feedback can serve as a tool for objectively proving driving behavior, allowing users to gain benefits from their insurance companies or to regain their driver's license after revocation.

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