Understanding Behavioral Relapse in Driving: A Trip-Based Survival Analysis of Risk Indicators Post Feedback

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TRANSPORT RESEARCH ARENA BUDAPEST 18-21/05/26

Introduction

In recent years, **monitoring driver behavior** has gained increasing recognition within the transportation sector. Yet, researchers continue to face challenges in collecting accurate, real-time driving data through cost-effective means. The widespread use of smartphones presents new opportunities in this respect, as smartphone applications offer affordable and accessible solutions for data collection.

Feedback-based interventions have therefore been widely explored as a tool to improve driver behavior and enhance road safety. However, evidence of their long-term effectiveness remains mixed. Some studies report that improvements in driver behavior persist beyond the feedback period, while other studies observed that although improvements diminished somewhat, behavior remained better than baseline.

Taken together, these findings **reveal a clear research gap**: while feedback can influence driving behavior, its long-term effects remain uncertain and appear to vary depending on contextual factors such as driver characteristics, vehicle type, and the nature of the intervention.

Objectives

Addressing this gap, the **present study aims** to:

1. leverage **large-scale naturalistic driving** data collected via smartphone sensors
2. evaluate the **post-feedback effects on key risk indicators**, including speeding, harsh braking, harsh acceleration and mobile phone use.
3. Apply **survival models to analyze** whether, and to what extent, feedback contributes to lasting improvements in driver behavior

Experiment design

As part of a research project, a **21-month naturalistic driving experiment** was involving 230 participants across 106,776 trips. The primary objectives were to identify critical risk factors through continuous driver monitoring and to test feedback features aimed at improving skills, reducing errors, and lowering crash risk.

The **experiment was structured into three phases**.

- **Phase 1** served as the baseline, where drivers were monitored through the smartphone application but received no behavioral feedback.
- **Phase 2** progressively introduced different feedback features.
- **Phase 3** returned to a no-feedback condition to allow for analysis of post-feedback effects.

For this study, **a subset of 31 car drivers who participated in all phases**, baseline, feedback, and post-feedback, was analyzed. Over the 21-month period, this group completed **24,904 trips**, with each driver contributing at least 20 trips during the post-feedback phase, ensuring sufficient data for evaluating the long-term impacts of feedback interventions.

Smartphone application

Driver monitoring and feedback were facilitated through a smartphone application developed by **OSeven** (www.oseven.io), designed to assess and enhance driving behavior.

The app utilizes the **smartphone's sensors and APIs to capture detailed trip data**, which is stored locally and then uploaded to a secure cloud database for processing. Using advanced signal processing, machine learning algorithms, data fusion, and big data techniques. Figure 1 depicts and summarizes the OSeven data flow system.

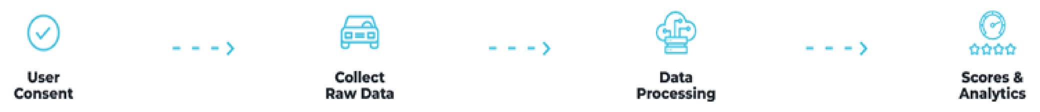

Figure 1. OSeven data flow

These **indicators cover both exposure variables** (e.g., trip distance, driving duration, road type, rush hour conditions) **and behavioral variables** (e.g., speeding episodes, severity of harsh braking or acceleration, and mobile phone distraction). Figure 2 illustrates examples of the app's feedback features across the different experimental phases.

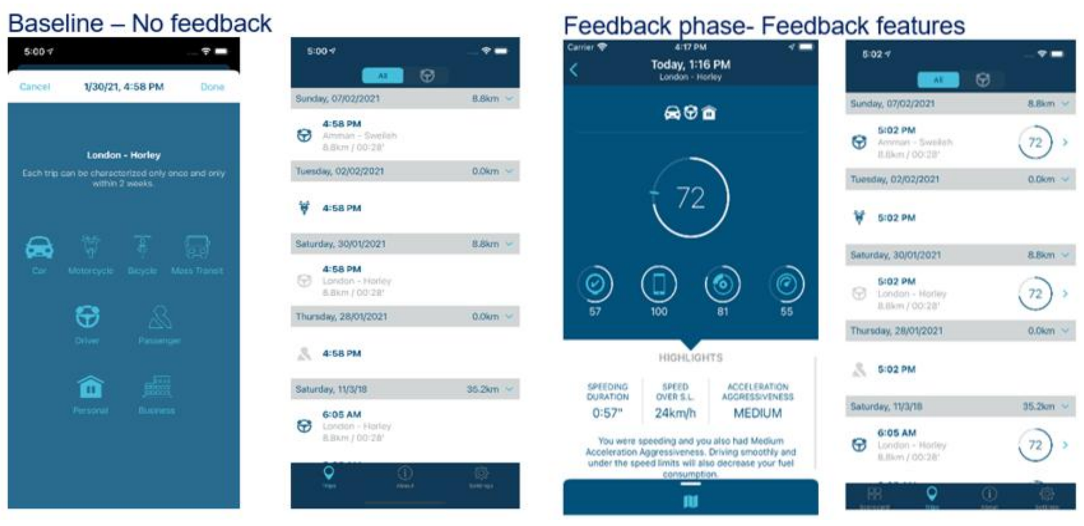

Figure 2. Example screenshots from the application features in Phase A – Baseline (left) and Phase B – Feedback phase (right)

Theoretical background

The **survival rate S(t) gives the probability that a driver will maintain improved driving behavior** below the threshold for a given number of trips, denoted by t. This can be interpreted as the probability of no relapse occurring within that period. Mathematically:

$$F(t) = P(T < t) = \int_0^t f(t)dt \qquad (1)$$

where F(t) is the cumulative probability of a relapse occurring by trip t.

The Kaplan-Meier survival function S(t) is defined as the probability that the event of interest has not occurred by a certain time t:

$$S(t) = P(T \geqslant t) \qquad (2)$$

where T represents the time to event.

The Kaplan-Meier estimator calculates the survival probability at each time point where an event occurs, updating the cumulative survival probability accordingly. The survival probability at each event time tj is calculated by:

$$\hat{S}(t) = \prod_{t_j \le t} \left(1 - \frac{d_j}{n_j}\right) \qquad (3)$$

Where:

•d_j is the number of events (e.g., relapses, failures) occurring at time t_j

•n_j is the number of subjects at risk just prior to time t_j

Descriptive statistics

Before modelling the survival probabilities of the indicators, descriptive statistics are first presented to provide an **overview of the experiment across its different phases** (Table 1). The sample of the remaining 31 drivers is 55% female and 45% male, with the largest age group being 18–34 years (45%).

Table 1. Summary statistics for critical driving indicators during the different phases

Indicators	Baseline	Feedback	Post-Feedback
Mean of the percentage of mobile phone use while driving (sd)	3.34% (0.11)	2.17% (0.09)	2.33% (0.09)
Mean of the percentage of speeding while driving (sd)	5.42% (0.09)	2.81% (0.06)	3.74% (0.07)
Mean of harsh accelerations per 100 km (sd)	6.68 (17.27)	6.88 (18.72)	7.96 (19.67)
Mean of harsh braking per 100km (sd)	16.86 (27.15)	14.47 (26.50)	16.734 (29.55)

Results show **improvements during the feedback period**, particularly in reducing mobile phone use and speeding, though **partial relapse is observed in the post-feedback phase**, while harsh events (accelerations and brakings) fluctuate with smaller changes.

Survival Analysis

The **Kaplan-Meier survival curve** shows the proportion of drivers who continue to maintain improved driving behavior without relapse across successive trips. The survival probability is recalculated at each relapse event, giving a stepwise depiction of the declining survival rate as drivers accumulate trips post-feedback.

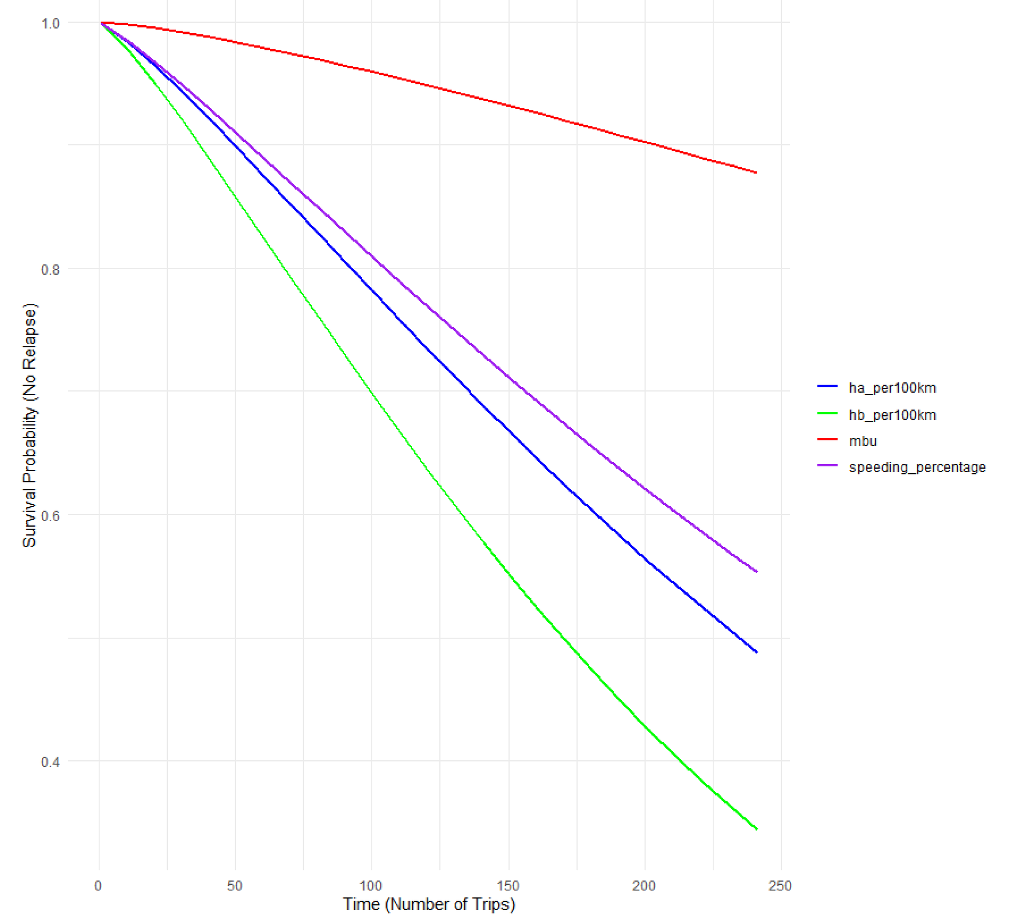

Figure 2. Kaplan-Meier survival curves for the four behavioural indicators

As the number of trips increases, the survival probability declines at different rates across indicators. More precisely:

- By around 50 trips, survival is ~0.98 for mobile phone use, ~0.91 for speeding, ~0.90 for harsh acceleration, and ~0.85 for harsh braking.
- At 100 trips, probabilities drop to ~0.96 (mobile phone use), ~0.81 (speeding), ~0.78 (harsh acceleration), and ~0.70 (harsh braking). At 150 trips, survival is ~0.94 (mobile phone use), ~0.71 (speeding), ~0.67 (harsh acceleration), and ~0.49 (harsh braking).
- Finally, by 200 trips, the probabilities fall further to ~0.90 for mobile phone use, ~0.62 for speeding, ~0.57 for harsh acceleration, and ~0.43 for harsh braking.

Conclusions

Survival analysis techniques were applied to a dataset of 24,904 trips from 31 car drivers, each contributing at least 20 trips in the post-feedback phase, to investigate the long-term effects of driver telematics feedback on driving behavior.

The findings demonstrate the effectiveness of feedback interventions in achieving significant short-term behavioral improvements during the feedback phase. However, **the post-feedback phase reveals varied relapse tendencies**, emphasizing the need for sustained interventions to maintain these improvements over time.

Future research could address integrating more granular datasets that **capture traffic flow, contextual dynamics, and moment-to-moment driver decisions**, thereby providing a richer behavioral perspective. Expanding the study to include larger and more diverse samples, as well as testing across different geographic and cultural contexts, would further improve the robustness and applicability of findings.

Acknowledgements

This project has received funding from the Horizon Europe programme under grant agreement No GAP-101146652.

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