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Examining the Impact of Feedback on Traffic and Safety Behavior of Car Drivers in a Naturalistic Driving Study

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Introduction

- Numerous studies have focused on driving behavior and naturalistic observations, primarily examining behavior recording and subsequently analyzing and modeling driver profiles

- Researchers have developed technologies and machine learning algorithms to detect these behaviors and technologies that provide feedback to drivers

- Feedback to drivers has been shown to be a highly effective method for enhancing road safety

- Many studies have examined the effect of feedback, however there is very little research that quantify the exact effect on driver behavior and safety

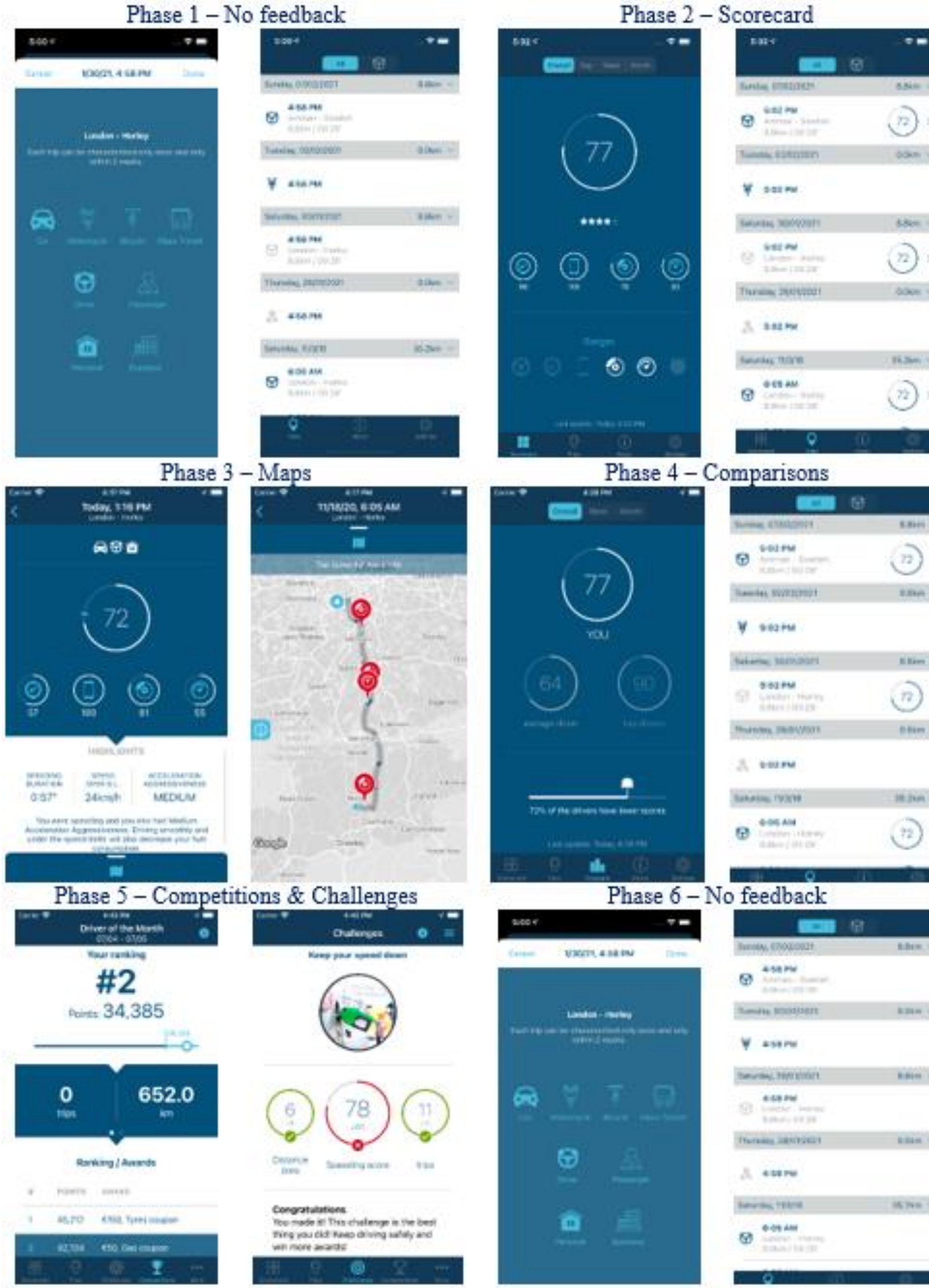
Research Scope

- The objective of the current research is to exploit large-scale trip data from smartphone sensors to identify the impacts of driver feedback on various key performance indicators, namely speeding, harsh braking and harsh acceleration events

Naturalistic Driving Experiment

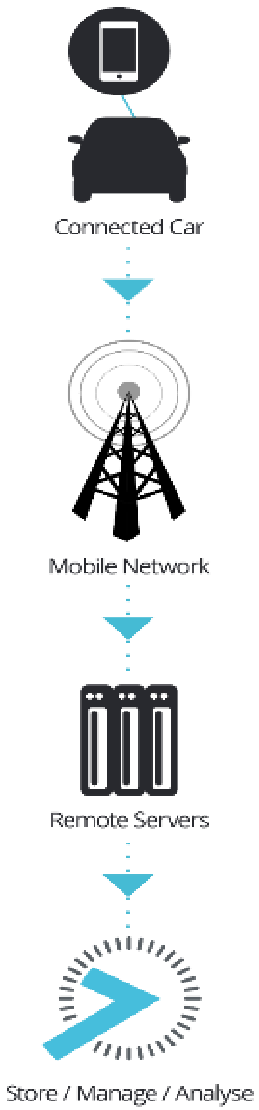
➤ The experiment consists of 6 different phases differing in the type of feedback provided to drivers:

- Phase 1 - trip list and characterization accessible to the application user
- Phase 2 - Scorecard enabling scoring per trip
- Phase 3 - Maps and Highlights providing further information per trip
- Phase 4 - Comparisons between drivers
- Phase 5 - Competitions with prizes for safe driving
- Phase 6 – back to Phase 1 - all additional feedback removed from the drivers



The Smartphone Application

- A mobile application to record user's driving behavior (automatic start / stop)
- A variety of APIs is used to read mobile phone sensor data
- Data is transmitted from the mobile App to the central database
- Driving behavior indicators are designed using:
  - machine learning algorithms
  - big data mining techniques
- State-of-the-art technologies and procedures in compliance with standing Greek and European personal data protection laws (GDPR)



Methodological Approach

- Structural Equation Models (SEM)
- The underlying mathematical structure of SEMs can be defined as follows:

$$\eta = \beta\eta + \gamma\xi + \varepsilon$$

- where:
  - η is a vector expressing the dependent variables
  - ξ is a vector expressing the independent variables
  - ε is a vector expressing the regression error term
  - β is a vector expressing the regression coefficients for the dependent variables
  - γ is a vector expressing the regression coefficients for the independent variables

- The proposed SEM structure retained two latent unobserved variables:
  - Feedback, expressing the influence of the different features of the smartphone app
  - Exposure, expressing the influence of the exposure metrics

Descriptive Statistics

➤ Overall, during the 21-months experiment 73,869 trips were recorded from a sample of 175 car drivers (male 46%, female 54%)

Experiment Phases	Percentage of mobile use	Harsh accelerations per 100km	Harsh brakings per 100km	Speed above the speed limits	Percentage of speeding time
Phase 1	3.85%	6.42	15.78	3.89km/h	5.32%
Phase 2	2.84%	6.26	13.74	3.19 km/h	3.12%
Phase 3	2.08%	6.26	13.94	2.31 km/h	2.60%
Phase 4	2.28%	6.96	12.54	2.34 km/h	2.45%
Phase 5	2.19%	6.24	12.14	1.85 km/h	2.13%
Phase 6	2.48%	8.26	16.34	2.60 km/h	3.34%

Preliminary Analysis

- Before the development of the SEM model, the **Wilcoxon signed-rank test** was used to assess behavioral changes across feedback phases, as it is appropriate for:
    - non-parametric methods
    - within subjects design studies

- From **Phase 1 to Phase 2, feedback reduced** mobile use by 26.20%, speeding by 41.40%, and harsh braking by 12.90%

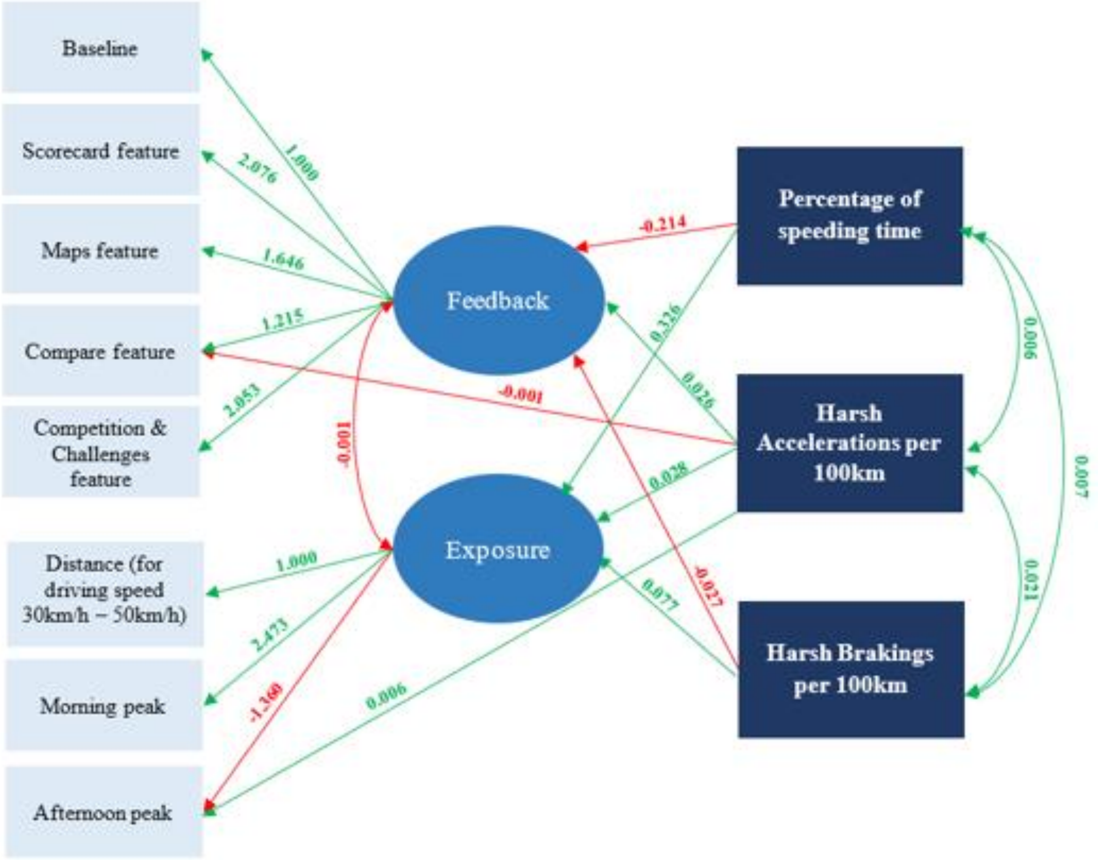
- **Mixed outcomes** were observed between Phase 2 and Phase 4, with decreases in speeding but increases in harsh braking

- **Risky behaviors increased after feedback removal**, emphasizing the need for sustained interventions to maintain safe driving

SEM Results

SEM model of Percentage of speeding time, Harsh Brakings per 100km & Harsh Accelerations per 100km

SEM Components		Parameters	Estimate	S.E.	z-value	P(>|z|)
Latent	Feedback	Baseline	1.000	–	–	–
Variables		Scorecard feature	2.076	0.014	148.640	**0.000**
		Maps feature	1.646	0.010	157.864	**0.000**
		Compare feature	1.215	0.029	41.754	**0.000**
		Competition & Challenges feature	2.053	0.038	54.447	**0.000**
	Exposure	Distance (for driving speed 30km/h – 50km/h)	1.000	–	–	–
		Morning peak	2.473	0.350	7.072	**0.000**
		Afternoon peak	-1.360	0.129	-10.579	**0.000**
Regressions	Percentage of speeding time	Intercept	0.409	0.003	138.941	**0.000**
		Exposure	0.326	0.043	7.627	**0.000**
		Feedback	-0.214	0.014	-15.655	**0.000**
	Harsh Accelerations per 100km	Intercept	0.099	0.001	95.037	**0.000**
		Exposure	0.028	0.010	2.769	0.006
		Feedback	0.026	0.004	6.493	**0.000**
		Competition & Challenges feature	-0.001	0.000	-2.748	**0.000**
		Afternoon peak	0.006	0.002	3.095	**0.002**
	Harsh Brakings per 100km	Intercept	0.184	0.001	158.258	**0.000**
		Exposure	0.077	0.014	5.542	**0.000**
		Feedback	-0.027	0.005	-4.976	**0.000**
Covariances	Percentage of speeding time	Harsh Brakings per 100km	0.007	0.001	7.686	**0.000**
	Harsh Accelerations per 100km	Percentage of speeding time	0.006	0.001	9.526	**0.000**
	Harsh Brakings per 100km	Harsh Accelerations per 100km	0.021	0.000	75.739	**0.000**
	Feedback	Exposure	-0.001	0.000	-5.558	**0.000**
Goodness-of-fit measures	CFI		0.940			
	TLI		0.944			
	RMSEA		0.049			0.845
	SRMR		0.025			



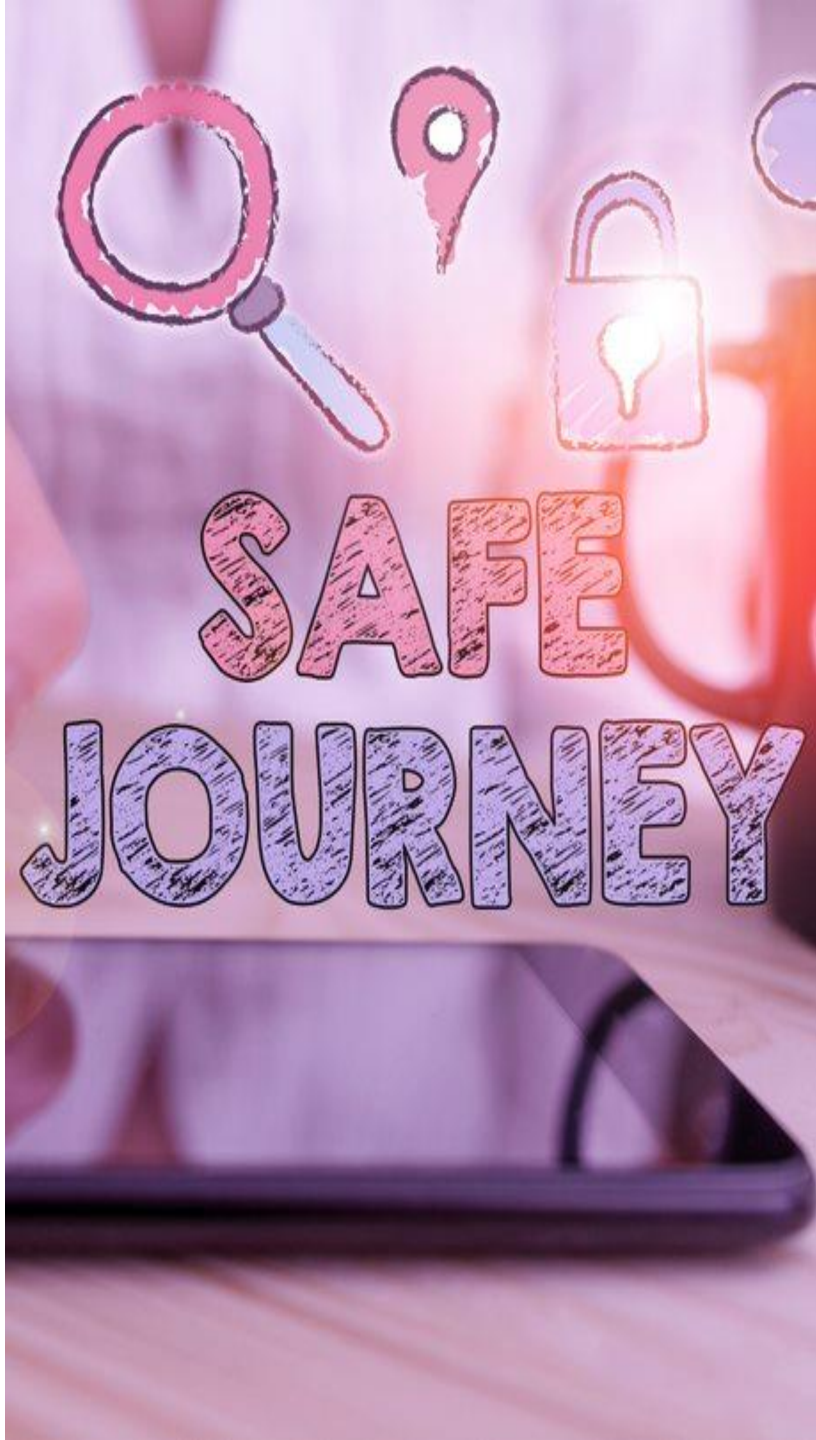
Discussion (1/2)

Feedback

- The scorecard feature has the highest positive estimate at 2.076 ($p < 0.001$), indicating its crucial role in modifying driving habits
- These feedback mechanisms are effective in reducing the percentage of speeding time and harsh braking incidents, although there is a slight increase in harsh accelerations

Exposure

- Exposure factors, particularly the times of day, play a significant role in driving behaviors
- Morning peak exposure is associated with increased driving aggressiveness



Discussion (2/2)

Regressions

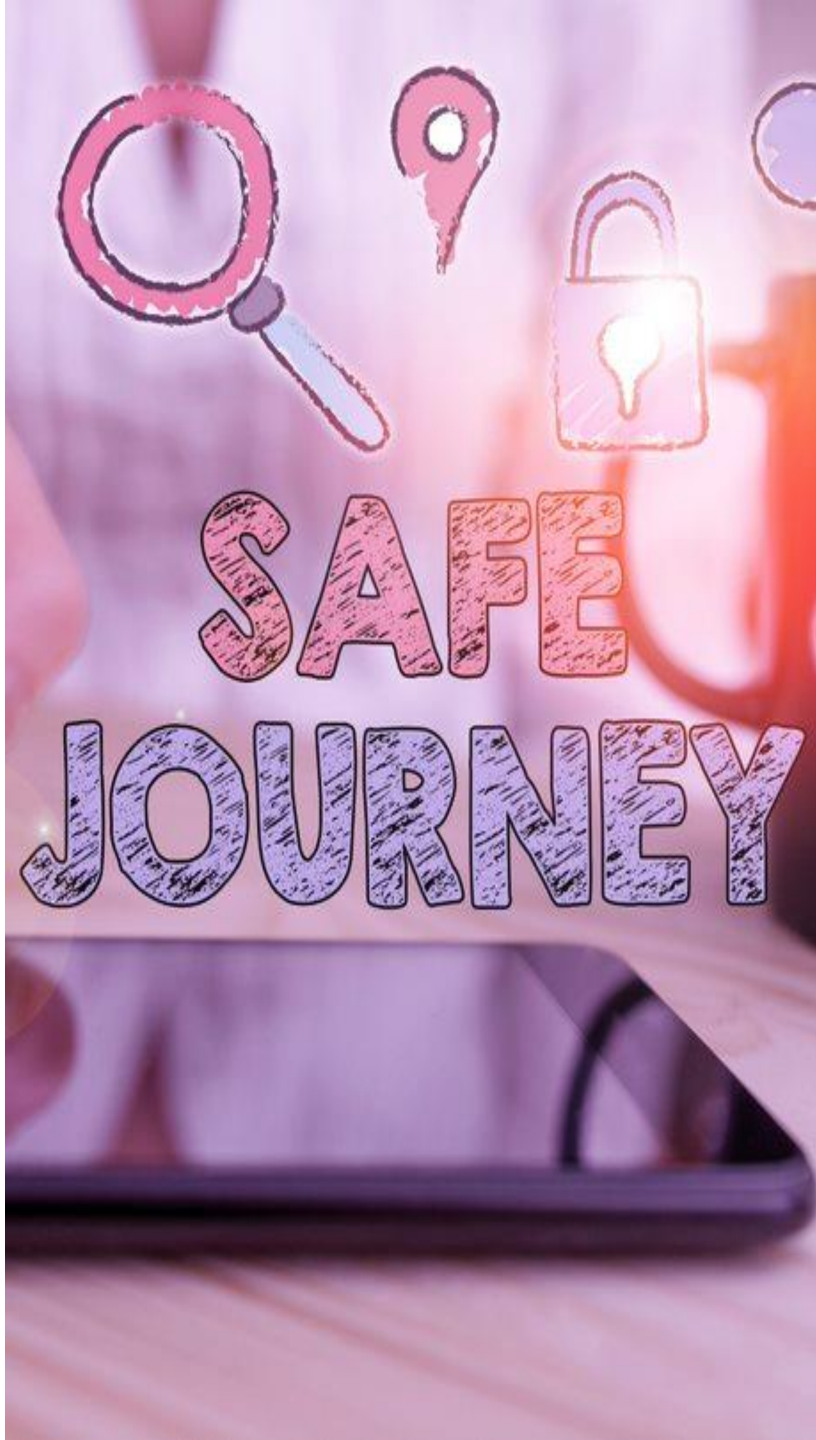
- Feedback mechanisms **significantly reduce speeding and harsh braking events**, underscoring their critical role in promoting safer driving practices

- While feedback **slightly reduces harsh accelerations during competitions**, it also shows a slight positive association with them

Covariances

- Covariance analysis highlights **strong positive correlations among all driving indicators**, illustrating how aggressive driving patterns often involve multiple risky behaviors

- A **negative correlation between feedback and exposure** indicates that increased feedback reduces exposure to risky driving conditions



Conclusions

- The ND experiment shows that driving behavior can be evaluated and communicated to drivers

- The influence of feedback increases across the various experimental phases, though it appears that there are some platooning effects for drivers towards the end of the experiment

- The ultimate goal of providing feedback to drivers is to activate the process of learning and self-assessment and to enable them to gradually improve their performance and monitor their progress

- This process may include establishing detailed cause-and-effect relationships between aggressive driving and risk, information on improving road safety

Future Challenges

- Integration of a multitude of IoT technologies, development of advanced know-how
- Development of new smartphone applications, for all road users and all transport modes
- Properly matching telematics metrics with crash risk
- Exploitation of know-how for the safe integration and monitoring of automated vehicles
- Enhancement of innovation capacity and creation of new market opportunities for driver behaviour telematics

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