10th Transport Research Arena Conference
Advancing Sustainable and Inclusive Mobility
Dublin, Ireland, April 15-18, 2024

Unveiling driving behavior patterns during a naturalistic driving experiment

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Together with:
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The i-DREAMS project

- 13 Project partners:
  - National Technical University of Athens

    Universiteit Hasselt, Loughborough University, Technische Universität München, Kuratorium für Verkehrssicherheit, Delft University of Technology, University of Maribor, OSeven Telematics, DriveSimSolutions, CardioID Technologies, European Transport Safety Council, POLIS Network, Barraqueiro Transportes S.A.

- Duration of the project:
  - 48 months (May 2019 – April 2023)

- Framework Program:
  - Horizon 2020 - The EU Union Framework Programme for Research and Innovation - Mobility for Growth

Introduction

- The primary cause of road crashes is attributed to driving behavior factors
- Risky driving factors include speeding, aggressive or impaired driving, distraction etc.
- Naturalistic driving studies have been extensively documented, as effective and accurate means of assessing driving behavior
- Automotive telematics and driver monitoring systems leverage technology for safety interventions and driver feedback

Objectives

- The provision of a detailed overview of driving behavior indicators during the implementation of the i-DREAMS safety interventions in Greece

- The identification of safe or dangerous driving behavior patterns exploiting indicators such as speeding events, harsh braking and accelerating events, and distraction events

Experiment Phases

- i-DREAMS aims to setup a framework for the definition, development and validation of a context-aware 'Safety Tolerance Zone (STZ)' for driving
- The STZ includes 3 different severity levels: 'normal driving', 'danger' and 'avoidable crash' level
- The fundamental goal is to keep the driver in the normal driving level for as long as possible
- The experimental design of the on-road study consists of 4 Phases during which real-time and post-trip interventions are provided to the drivers

Phase 1
-Baseline-
- **Intervention:** No
- **Duration:** 4 weeks

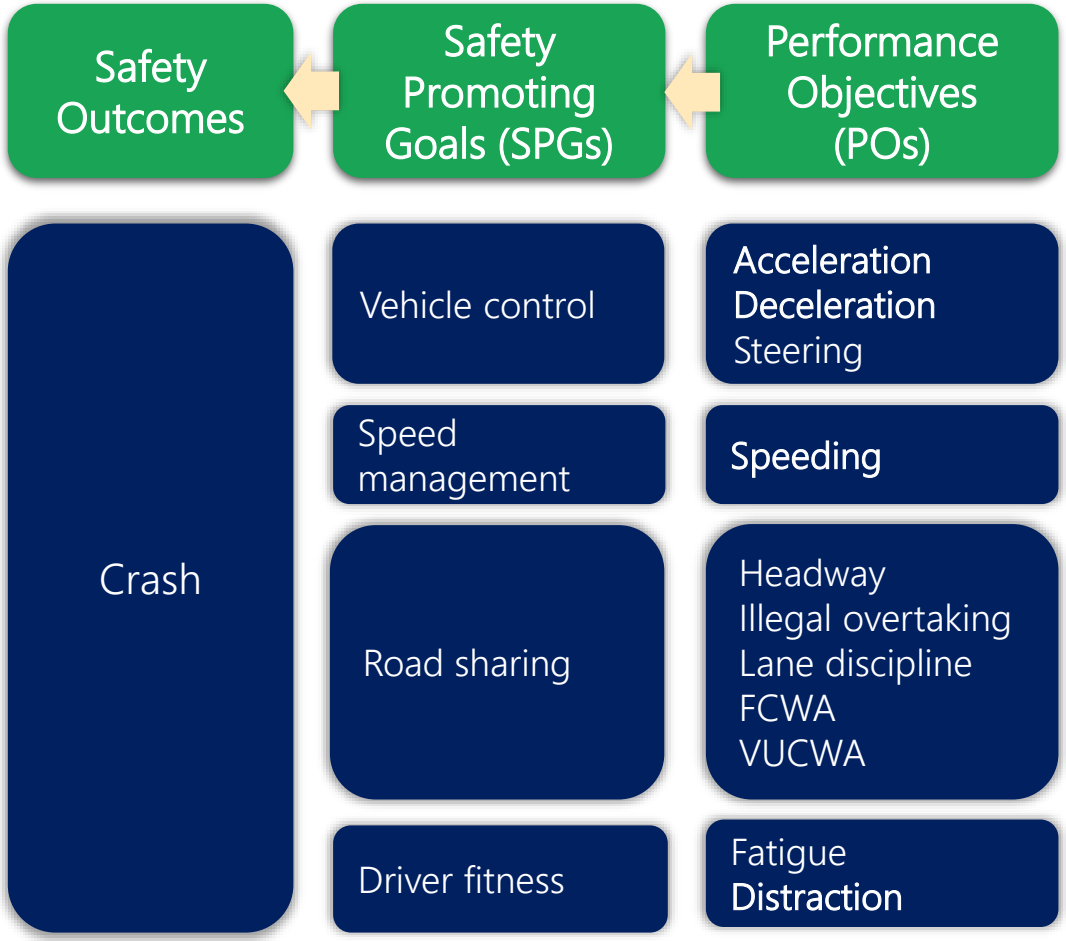
Phase 2
- **Intervention:** Real-time
- **Duration:** 4 weeks

Phase 3
- **Intervention:** Real-time + Post-trip
- **Duration:** 4 weeks

Phase 4
- **Intervention:** Real-time + Post-trip + Gamification
- **Duration:** 6 weeks

Data Description

- The collected data concern a variety of factors about:
  - Safety Promoting Goals (SPGs) which encompass driving behaviors linked to safety outcomes
  - Performance Objectives (POs) which are specific actions or behavioral parameters necessary to achieve the SPGs
- For each PO, events were detected categorized as 'low', 'medium', 'high'.
  - 'low' crash risk: the crash risk is minimal
  - 'medium' crash risk: the crash risk increases as internal/external events occur
  - 'high' crash risk: the crash risk is further increased if no preventative action taken by driver
- This research investigates 'medium' and 'high' risk events related to harsh acceleration, harsh deceleration, speeding, and driver distraction (mobile-phone use)



Methodological Overview

- A naturalistic driving experiment was carried out involving 56 car drivers from Greece
- The design of the experiment in Greece consisted of 3 Phases
- 11,731 trips was collected and analyzed
- Data was cleaned:
  - removing trips that were 'outside phase'
  - excluding drivers who did not have trip data in all phases
  - removing the trips that were outliers (defined as the mean +/- 3 STD)
  - excluding the trips with less than 1 km
- The analysis utilized a K-Means clustering approach to identify clusters based on safe or dangerous driving behavior
- The Silhouette method is used to determine the optimal number of clusters beforehand

Descriptive Analysis

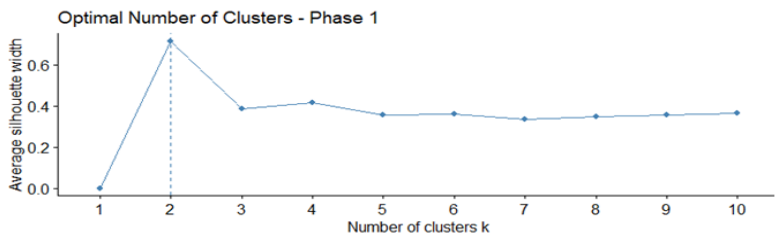
- The mean frequency of high risk and medium risk events per 100 km showed a declining trend from the baseline phase to the final phase, accompanied by a decrease in STD
- High risk speeding events, and mobile phone use have the highest occurrence rates compared to other event types
- All types of events, especially distraction events, showed notable variation, revealing diverse driving behaviors that were most pronounced during the baseline phase

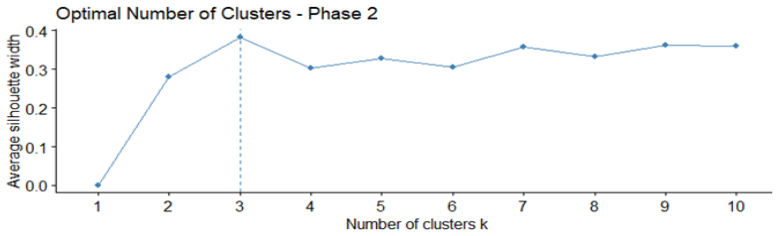
Safety Promoting Goals	Performance Objectives	Severity Level	Events per 100 km: Baseline Phase Mean	Baseline Phase STD	Post-trip Phase Mean	Post-trip Phase STD	Post-trip & Gamification Phase Mean	Post-trip & Gamification Phase STD
Speed Management	Speeding	Medium	7	15	6	14	6	13
		High	25	33	24	32	21	29
Vehicle Control	Acceleration	Medium	3	10	4	13	2	9
		High	2	11	2	9	2	9
	Deceleration	Medium	6	15	6	14	5	13
		High	3	11	3	11	3	9
Driver Fitness	Distraction	n/a	23	60	23	57	17	48
Distance (km) per trip		n/a	9	15	8	15	10	18
Duration (min) per trip		n/a	17	15	17	14	18	15

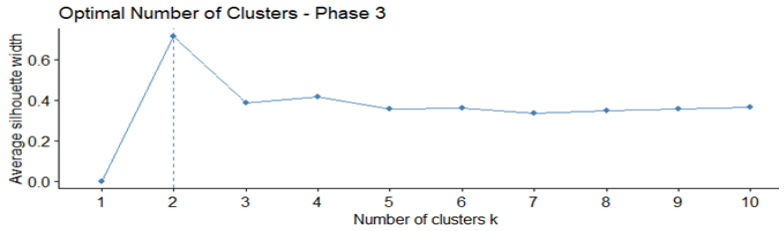
Clusters

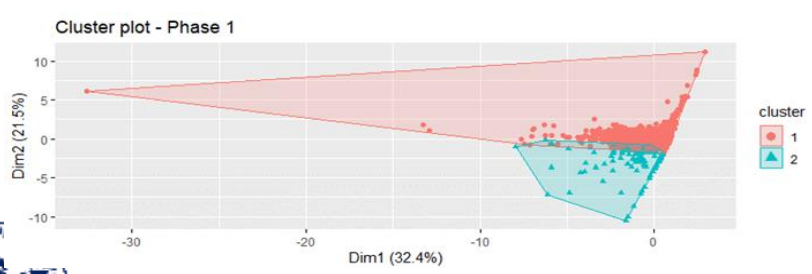
- The analysis considers the total of "medium" and "high" risk events per trip
- Based on the Silhouette method, the optimal number of clusters is:
  - 2 clusters for "Baseline" Phase & "Post-trip interventions & Gamification" Phase
  - 3 clusters for "Post-trip interventions" Phase
- The overall models' quality is considered good (average Silhouette width>0.4)

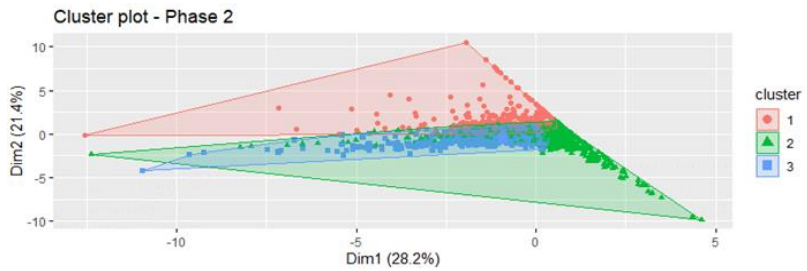
Baseline Phase	Post-trip interventions Phase	Post-trip interventions & Gamification Phase

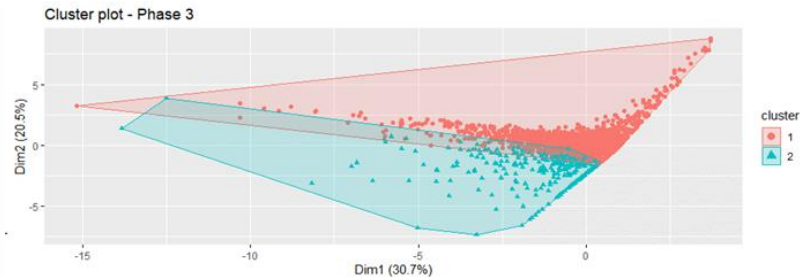












Centroid Centers

Baseline Phase

- **Cluster 1:** was characterized by mostly moderate driving behavior within longer trip distances
- **Cluster 2:** displayed distracted driving behavior during shorter trips

Post-trip interventions Phase

- **Cluster 1:** displayed distracted driving behavior, yet mobile phone use showed a reduction from the Baseline Phase
- **Cluster 2**: displayed improved driving behavior with fewer risky events, accounting for the majority of trips
- **Cluster 3**: defined by trips inclined towards higher frequencies of speeding

Post-trip interventions & Gamification Phase

- **Cluster 1:** displayed moderate driving behavior with fewer risky events from the Baseline Phase, and accounting for the majority of trips
- **Cluster 2**: displayed distracted driving; however, the frequency of mobile phone use declined compared to earlier phases

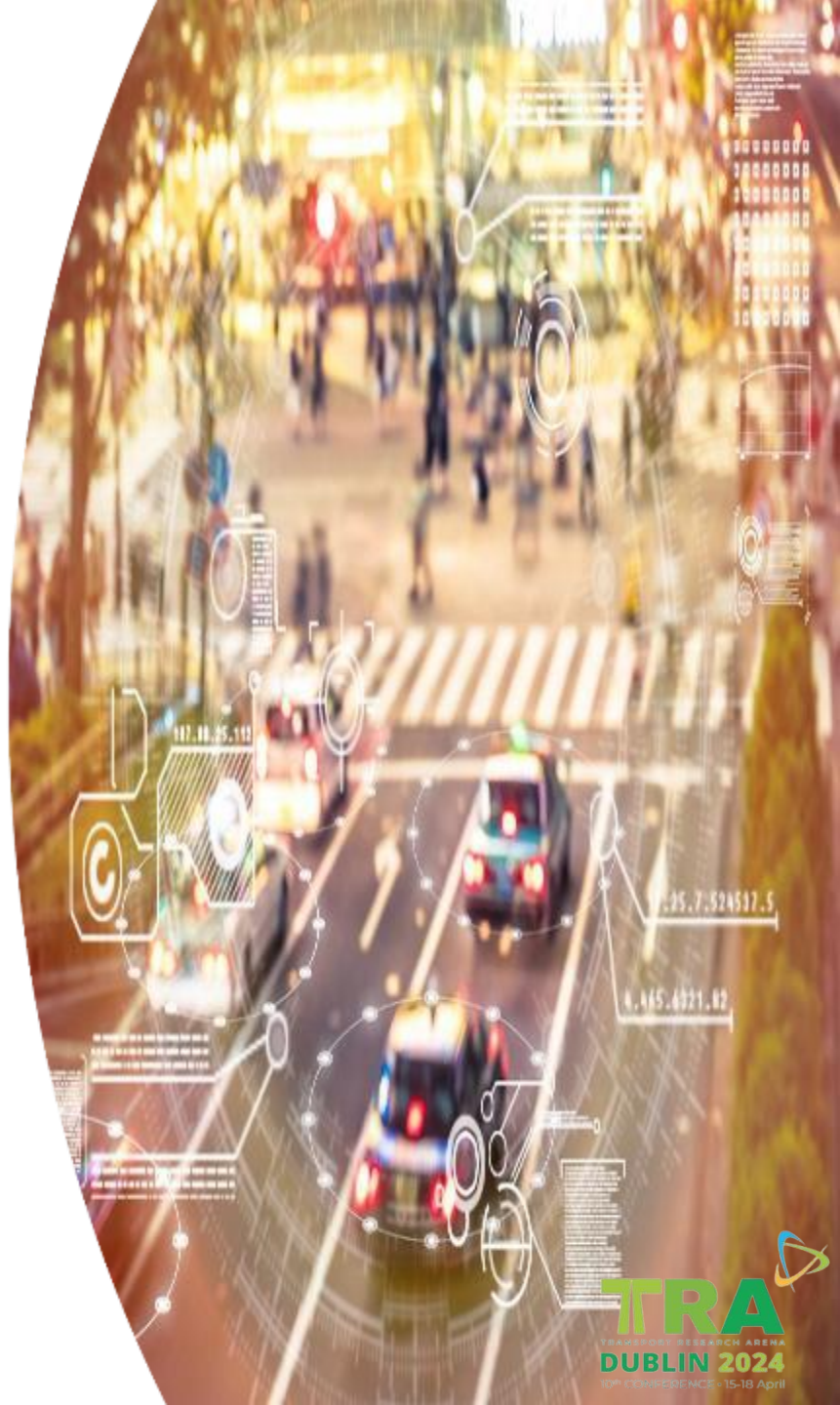
Cluster		Trip Distance	Events per 100 km				Cluster Size	
			Speeding	Acceleration	Deceleration	Distraction		
		km	medium + high	medium + high	medium + high	mobile phone use	Trips	%
Nr	Behavior	Baseline Phase						
1	moderate	9	33	4	9	12	2,827	95%
2	distracted	3	24	11	11	231	143	5%
		Post-trip interventions Phase						
1	distracted	4	27	8	11	179	310	8%
2	low risk	10	16	3	7	10	2,822	69%
3	speeding	7	79	10	14	17	964	24%
		Post-trip interventions & Gamification Phase						
1	moderate	11	30	4	8	10	4,334	93%
2	distracted	4	32	9	12	160	331	7%

Discussion

- Cluster analysis revealed the 4 driving behaviors during trips: "Distracted", "Speeding", "Low Risk" and, "Moderate"
- During the Baseline and final Phases, two driver profiles emerged:
  - one with moderate driving behavior on longer trips
  - one showing distraction on shorter trips
- However, the gamification and post trip interventions showed a decrease in risky driving behaviors, with a significant drop in mobile phone use
- Post-trip interventions resulted:
  - in a low-risk driving pattern, showing the lowest frequency of risky events and representing most trips
  - in a new cluster with speeding tendencies
- Throughout all Phases, distracted driving behavior was consistently observed, with notably high frequency of mobile phone use

Conclusions

- Understanding driving behaviors is essential for improving safety and more generally for promoting sustainable mobility
- High-risk speeding, and mobile phone use are crucial focal points for immediate safety measures in Greece
- The i-DREAMS interventions in Greece have contributed to a notable improvement in driving behavior, resulting in progressively safer trips
- Post-trip interventions result in a low-risk driving behavior cluster, showing the lowest frequency of risky events across Phases
- Post-trip interventions, when combined with gamification features, positively influence driving behavior, especially in reducing speeding and distraction events, though not as markedly as the initial post-trip safety interventions
- Overall, these findings emphasize the efficacy of specific safety intervention schemes and highlight the importance of addressing multiple risk indicators simultaneously to enhance driver behavior



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