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Investigating the effect of driver-vehicle-environment interaction with risk through naturalistic driving data

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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

- Road traffic crashes result in the deaths of approximately **1.19 million people** around the world each year
- **Human behaviour** plays a critical role in road safety
- Factors such as **speeding,** distraction, aggressive or impaired driving and non-compliance with traffic regulations can increase the crash risk
- **Poorly designed roads**, absence of pedestrian crossings, lack of proper lighting and insufficient maintenance have a direct impact on road safety
- Environmental conditions and **safety features of vehicles** can also contribute to crashes and injuries

Objectives

- Identification of the most critical indicators of risk from both the task complexity and the coping capacity (vehicle and operator state) side

- Investigation of the effect of vehicle, operator and context characteristics on risk under several conditions and phases

- Development of an integrated model for understanding the effect of driver-vehicle-environment interaction with risk

- Comparison of the performance of such model on different countries

Data Description

- **Task complexity** relates to the current status of the real world context in which a vehicle is being operated:
  - road layout (i.e. highway, rural, urban)
  - time and location
  - traffic volumes (i.e. high, medium, low)
  - weather conditions

- **Coping capacity** is dependent upon two underlying factors and it consists of several aspects:
  - vehicle state (e.g. technical specifications, actuators & admitted actions, current status)
  - operator state (e.g. mental state, behaviour, competencies, personality, sociodemographic profile)

Task complexity	Coping capacity – vehicle state	Coping capacity – operator state		Risk
Car wipers	Vehicle age	Distance	Inter Beat Interval	Headway map levels
Car high beam	First vehicle registration	Duration	Headway	Speeding map levels
Time indicator	Fuel type	Average speed	Overtaking	Overtaking map levels
Distance	Engine Cubic Centimeters	Harsh acceleration/ braking	Fatigue	Fatigue map levels
Duration	Engine Horsepower (HP)	Forward collision warning (FCW)	Gender	Harsh acceleration
Month	Gearbox	Pedestrian collision warning (PCW)	Age	Harsh braking
Day of the week	Vehicle brand	Lane departure warning (LDW)	Educational level	Vehicle control events

Experiment Phases

Phase 1 (Baseline)

- **Intervention:** No
- **Description**: a reference period after the installation of the i-DREAMS system in order to monitor driving behavior without interventions
- **Duration**: 4 weeks

Phase 2

- **Intervention**: Real-time
- **Description**: a monitoring period during which only in vehicle real-time warnings provided using adaptive ADAS
- **Duration**: 4 weeks

Phase 3

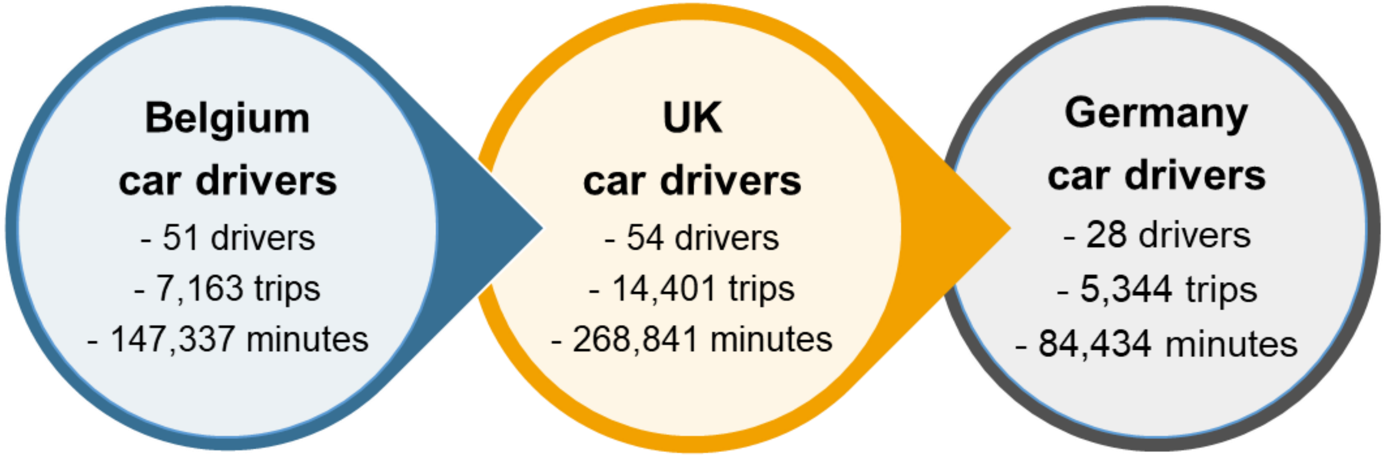
- **Intervention**: Real-time + Post-trip
- **Description**: a monitoring period during which in addition to real-time in vehicle warnings, drivers received feedback on their driving performance through the app
- **Duration**: 4 weeks

Phase 4

- **Intervention**: Real-time + Post-trip + Gamification
- **Description**: a monitoring period during which in vehicle real-time interventions were active along with feedback but at the same time gamification elements were also active
- **Duration**: 6 weeks

Methodology

- A naturalistic driving experiment was carried out involving 133 car drivers from Belgium, UK and Germany and a large database consisting of 26,900 trips was collected and analyzed
- Questionnaire data were also collected both before and after the field trials
- Explanatory analyses such as Generalized Linear Models (GLMs) were performed
- Structural Equation Model (SEMs) were also developed in order to identify the relationship between observed (i.e. number of speeding events) and latent or unobserved variables (i.e. crash risk)



GLM Results

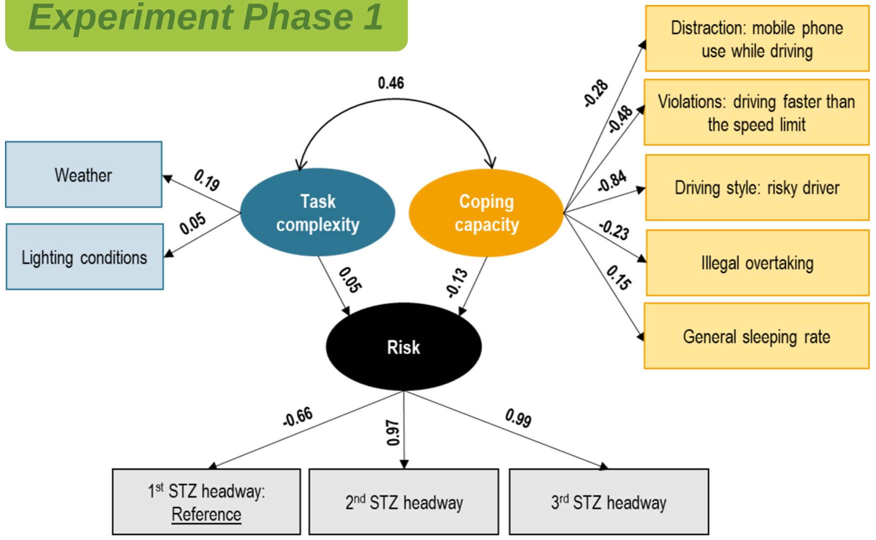
- GLMs were employed to investigate the relationship of the key performance indicator of speeding for Belgian, UK and German car drivers
- In Belgium, the indicators of task complexity, such as time indicator and wipers were positively correlated with speeding which means that higher speeding events occur at night compared to during the day
- In UK, the indicators of coping capacity, such as FCW and LDW) were positively correlated with speeding, while gender was a significant variable showing that male drivers are more prone to exceed the speed limits
- In Germany, the indicators of coping capacity – vehicle state such as fuel type and vehicle age were positively correlated with speeding

Variables	Estimate	SE	z-value	Pr(|z|)	VIF
Belgium					
(Intercept)	3.668	0.043	85.768	< .001	-
Time indicator	0.908	0.078	11.683	< .001	1.882
Weather	0.009	4.217×10^{-4}	20.952	< .001	1.228
High beam - Off	-0.018	7.062×10^{-4}	-25.286	< .001	1.470
Harsh acceleration	2.661	0.181	14.689	< .001	1.013
Distance	-6.128×10^{-4}	7.273×10^{-5}	-8.426	< .001	1.678
UK					
(Intercept)	-3.824	0.014	-274.620	< .001	-
Duration	4.672×10^{-5}	7.877×10^{-7}	59.317	< .001	1.058
Harsh acceleration	-0.187	0.012	-15.377	< .001	1.014
Weather	-0.273	0.023	-11.713	< .001	1.008
Forward collision warning	10.603	2.479	4.276	< .001	1.001
Lane departure warning	0.357	0.014	25.348	< .001	1.026
Distance	0.002	1.876×10^{-5}	117.628	< .001	1.072
Gender - Male	0.373	0.012	31.757	< .001	1.056
Germany					
(Intercept)	1.105	0.057	19.549	< .001	-
Duration	0.003	3.414×10^{-5}	73.366	< .001	1.262
Distance	5.735×10^{-4}	3.723×10^{-5}	15.404	< .001	1.029
Harsh acceleration	1.282×10^{-4}	1.974×10^{-6}	64.951	< .001	1.222
Fuel type - Petrol	0.219	0.010	21.446	< .001	1.328
Vehicle age	3.162×10^{-5}	3.340×10^{-6}	9.469	< .001	1.277
Gender - Female	-0.275	0.021	-13.025	< .001	1.256
Drowsiness	1.009×10^{-5}	2.656×10^{-6}	3.800	< .001	1.113
Time indicator	8.547×10^{-5}	1.925×10^{-6}	44.405	< .001	1.080
High beam - On	0.817	0.059	13.963	< .001	1.073

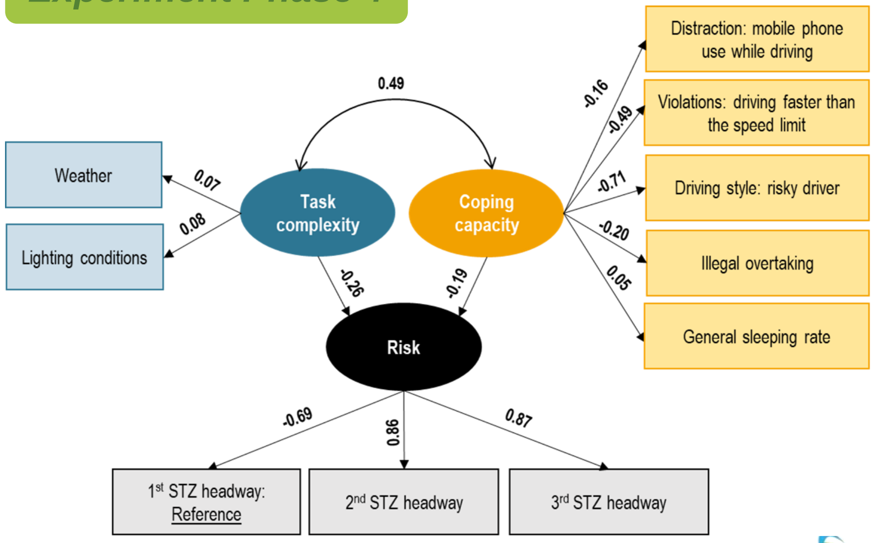
SEM Results

- The latent variable risk was measured by means of the STZ levels for speeding and headway
- The positive correlation of task complexity and coping capacity implied that drivers' coping capacity increased as the complexity of driving task increases
- In phase 1, task complexity is positively associated with risk while in phase 4, increased levels of driving task difficulty, related to weather and visibility conditions, are linked to lower levels of risk. This result could be interpreted by the fact that when drivers have to face more complicated road conditions such as rain or lower visibility, they could become more alerted and cautious
- A negative correlation between coping capacity and risk is identified in all phases

Experiment Phase 1



Experiment Phase 4



Discussion

- **Higher task complexity** levels lead to higher coping capacity by drivers. This means that drivers, when faced with difficult conditions, tend to regulate well their capacity to apprehend potential difficulties, while driving

- **Higher task complexity** was associated with an increased crash risk. Drivers could probably become overwhelmed by the demands of complex tasks, leading to reduced attention to the road and other traffic participants

- Conversely, drivers with **limited coping capacity** may struggle to effectively manage complex tasks, leading to higher crash risk. Reduced coping capacity can manifest as slower reaction times, impaired judgment, and difficulties in prioritizing information

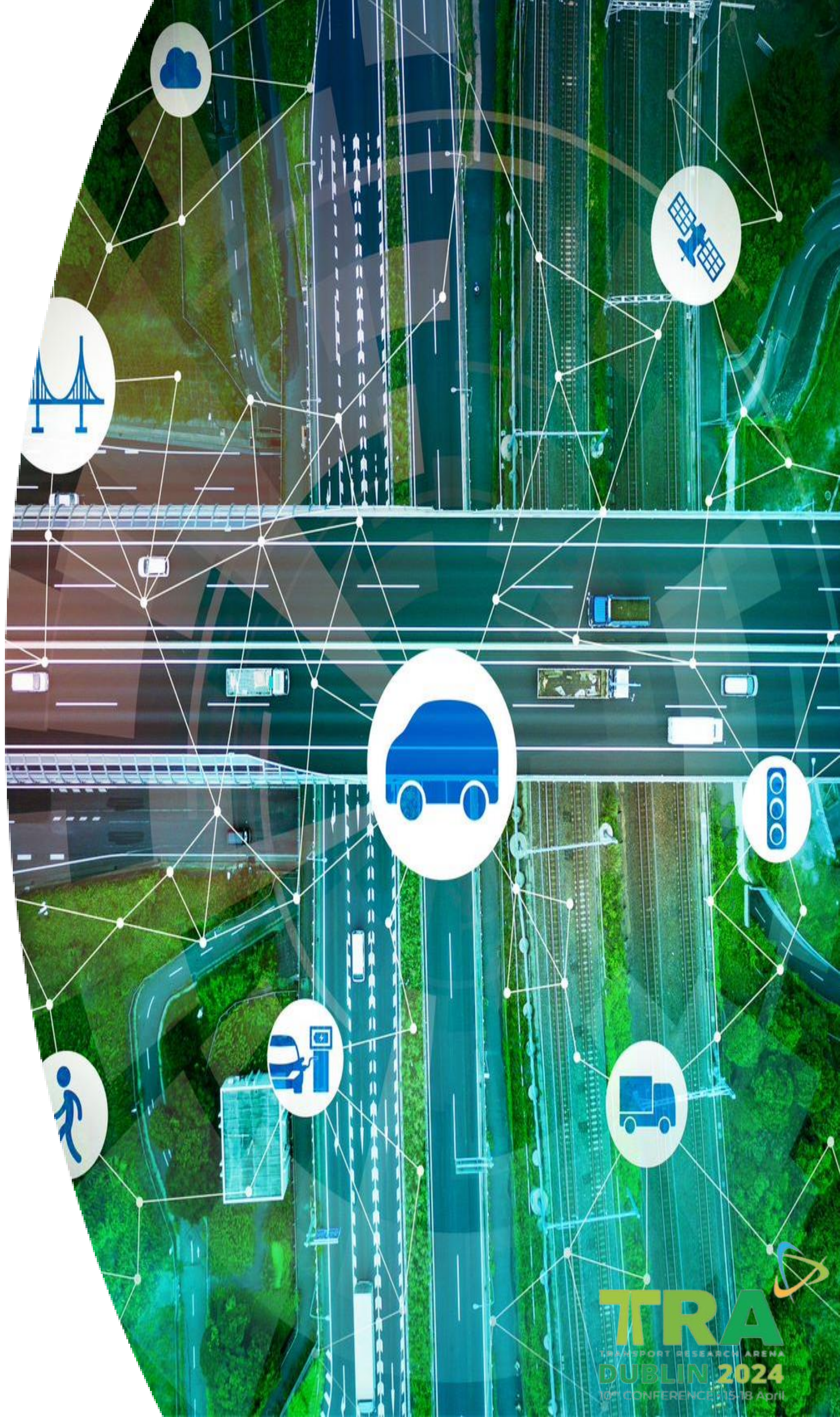
- The interventions had a **positive influence on risk**, increasing drivers' coping capacity and reducing risk driving behaviour

Conclusions

- The integrated treatment of task complexity, coping capacity and risk can improve behaviour and safety of all travellers, through the unobtrusive and seamless monitoring of behaviour

- Technological advancements in vehicle automation and driver assistance systems can play a role in mitigating crash risk by reducing the cognitive load associated with complex tasks and providing support to drivers in challenging conditions

- Authorities may use data systems at population level to plan mobility and safety interventions, set up road user incentives, optimize enforcement and enhance community building on safe travelling



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