Identifying the Impact of Task Complexity and Coping Capacity on Driving Risk: Comparison among Different Countries and Transport Modes

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Introduction

Road safety is a critical concern worldwide, as road crashes claim the lives of millions and cause countless injuries each year. Factors such as human behavior, road design, vehicle safety features, environmental conditions and socioeconomic disparities significantly influence the occurrence and severity of road crashes. Despite advancements in technology and infrastructure, human error remains a significant contributor to traffic collisions.

The ongoing progress in autonomous vehicles holds promise for enhancing road safety by reducing reliance on human drivers. Moreover, **intelligent monitoring systems**, equipped with real-time interventions, have shown remarkable effectiveness in enhancing road safety. By combining the benefits of autonomous vehicles and monitoring systems, there is a strong potential for mitigating the impact of human error and creating a safer road environment for all road users.

Objective

This paper endeavours to **model the inter-relationship** among task complexity, coping capacity (i.e. vehicle and operator state) and crash risk.

Experimental Design

A **naturalistic driving experiment** was carried out involving 80 drivers and data from Belgian truck drivers, German drivers and Portuguese bus drivers were analyzed, as shown in Figure 1.

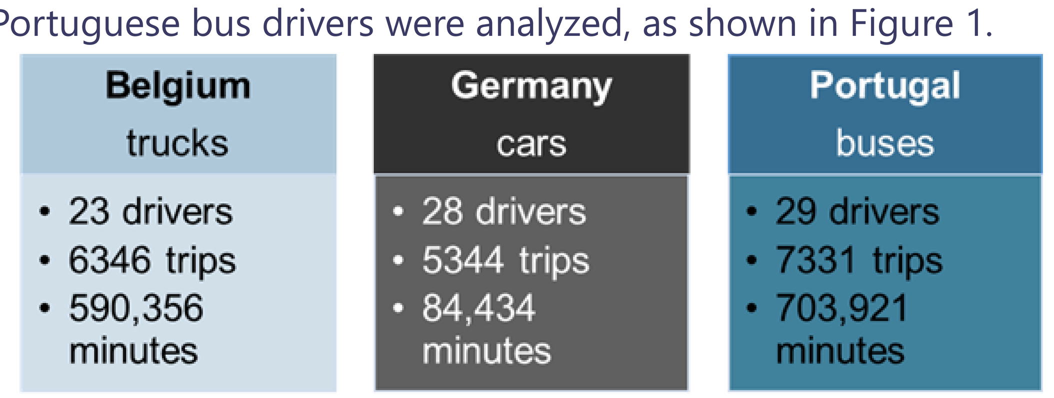

Figure 1: *Number of drivers, trips and minutes per country and transport mode*

The on-road trials focused on monitoring driving behavior and the impact of **real-time interventions** (i.e., in-vehicle warnings) and **post-trip interventions** (i.e., post-trip-feedback and gamification) on driving performance. Figure 2 provides an overview of the different phases of the experimental design.

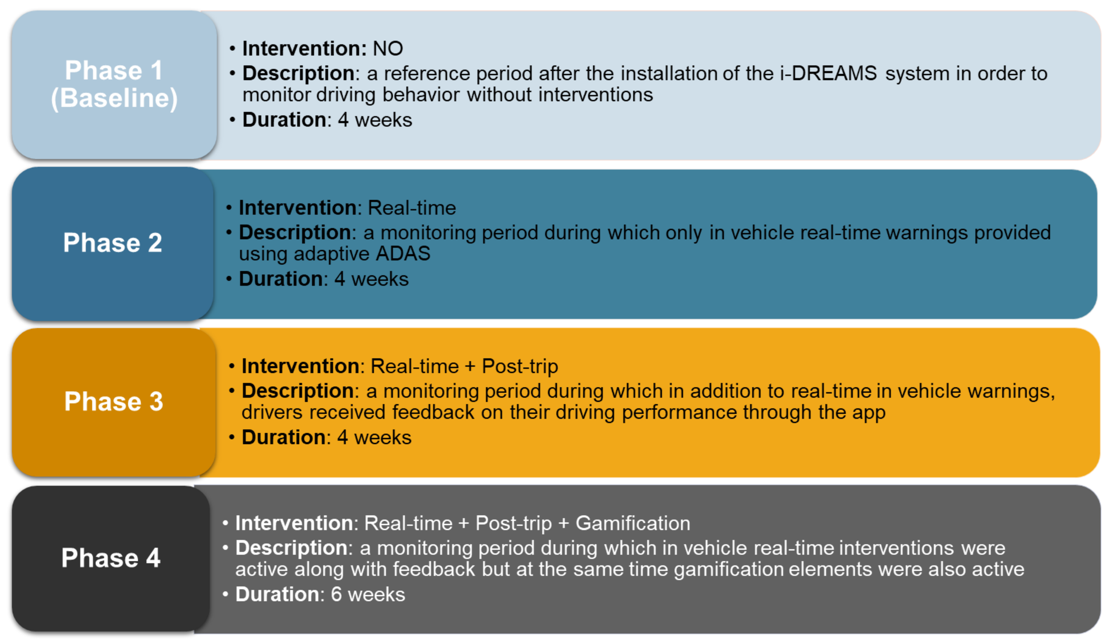

Figure 2: *Overview of the different phases of the experimental design*

Methodology

- **Generalized Linear Models (GLMs)** were developed and the most appropriate variables associated to the latent variable task complexity and coping capacity were estimated.
- **Structural Equation Models (SEMs)** were used to explore how the model variables were inter-related, allowing for both direct and indirect relationships to be modelled.
- **Comparisons** on the performance of such models, behaviors and driving patterns across different countries and transport modes were also provided.
- **Explanatory variables of risk** and the most reliable indicators, such as time headway, distance, speed, forward collision, time of the day or weather were assessed, as depicted in Figure 3.

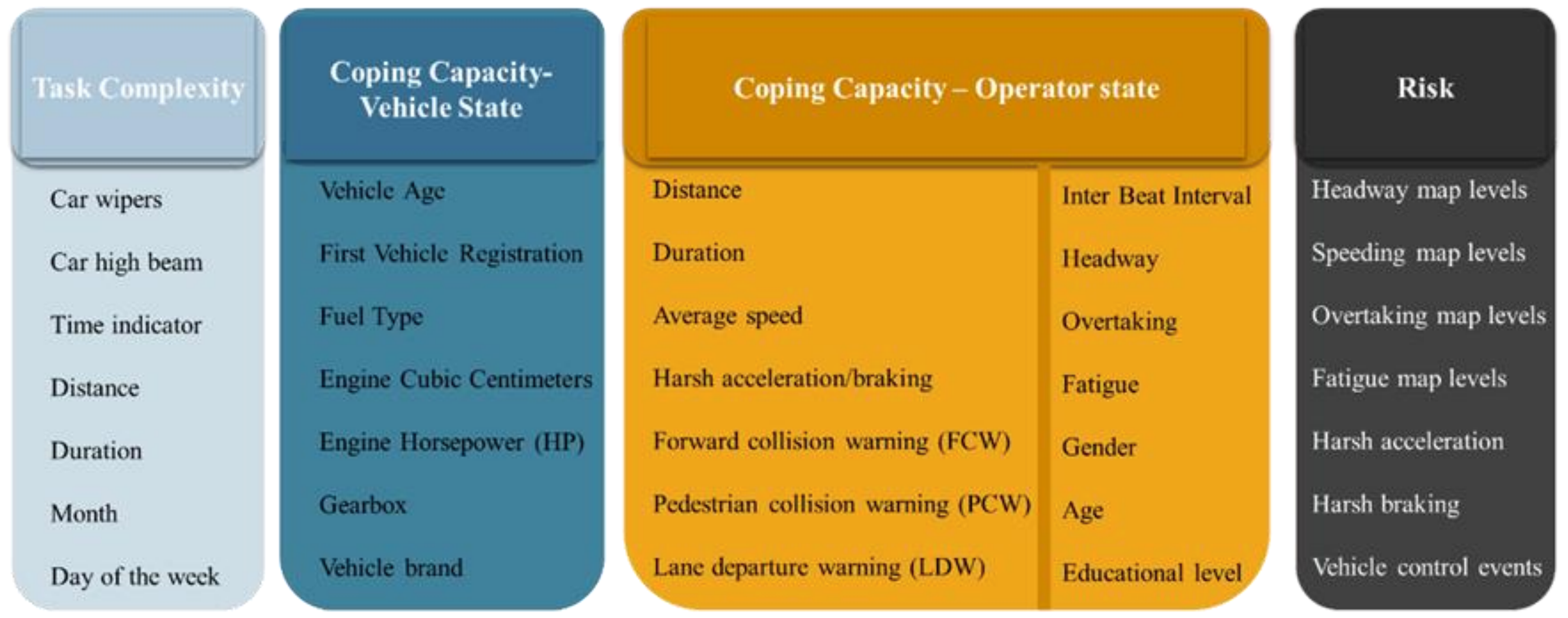

Figure 3: *Variables for task complexity and coping capacity (vehicle and operator state) and risk*

GLM Results

GLMs were employed to investigate the relationship of key performance indicator of speeding for Belgian truck drivers, German car drivers and Portuguese bus drivers. For all models applied, the **dependent variable is the dummy variable "speeding"**, which is coded with 1 if there is a speeding event and with 0 if not. It can be observed that all explanatory variables are **statistically significant at a 95% confidence level**; there is no issue of multicollinearity as the VIF values are much lower than 5. The model parameter estimates are summarized Table 1.

- For ***Belgian trucks***, the indicators of task complexity, such as time indicator and wipers were positively correlated with speeding, which means that higher speeding events occur during adverse (e.g. rainy) weather conditions. Distance travelled was negatively correlated with speeding which may be due to the fact that the longer a person drives, the more fatigued they may become, causing them to drive slower and more cautiously.
- For ***German cars***, fuel type and vehicle age were positively correlated with speeding. Taking into consideration socio-demographic characteristics, results showed that the vast majority of male drivers displayed less cautious behavior during their trips and exceeded more often the speed limits than female drivers. Moreover, young drivers appeared to have a riskier driving behavior than the elderly and were more prone to exceed the speed limits.
- For ***Portuguese buses***, higher speeding events occur at night compared to during the day. This may be due to fewer cars on the road, lower visibility and a false sense of security that comes with driving in the dark. Lastly, fatigue was negatively correlated with speeding which implies that the more fatigued the driver is, the slower they drive.

Variables	Estimate	Standard Error	z-value	Pr(|z|)	VIF
Belgian (Trucks)					
(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	1.47
Harsh acceleration	2.661	0.181	14.689	< .001	1.013
Distance	-65.28	7.273×10-5	-8.426	< .001	1.678
German (Cars)					
(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	0.01	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
Age	-0.003	0.001	-2.289	0.022	1.076
Drowsiness	1.009×10^{-5}	2.656×10^{-6}	3.8	< .001	1.113
Time indicator	8.547×10^{-5}	1.925×10^{-6}	44.405	< .001	1.08
High beam - On	0.817	0.059	13.963	< .001	1.073
Portugal (Buses)					
(Intercept)	3.441	0.02	168.858	< .001	-
Time indicator	0.164	0.008	21.306	< .001	1.002
Harsh braking	0.294	0.082	3.594	< .001	1.051
Harsh acceleration	0.49	0.112	4.371	< .001	1.052
Fatigue	-0.095	0.008	-12.527	< .001	1.378
Distance	0.01	1.038×10^{-4}	99.797	< .001	1.379

Table 1: *Parameter estimates and multicollinearity diagnostics of the GLM*

SEM Results

Four separate SEMs were estimated to explore the relationship between the latent variables of **task complexity, coping capacity and risk** (expressed as the 3 STZ levels).

Belgian trucks

- Task complexity and coping capacity are inter-related with a **positive correlation**. This positive correlation indicates that higher task complexity is associated with higher coping capacity implying that drivers coping capacity increases as the complexity of driving task increases.
- Coping capacity is **negatively associated** with normal driving or inverse of risk. Coping capacity indicators include static demographic and self-reported behavior parameters and therefore are more representative of driver personality traits and general driving styles, and less so of the real-time operator state during the experiment.

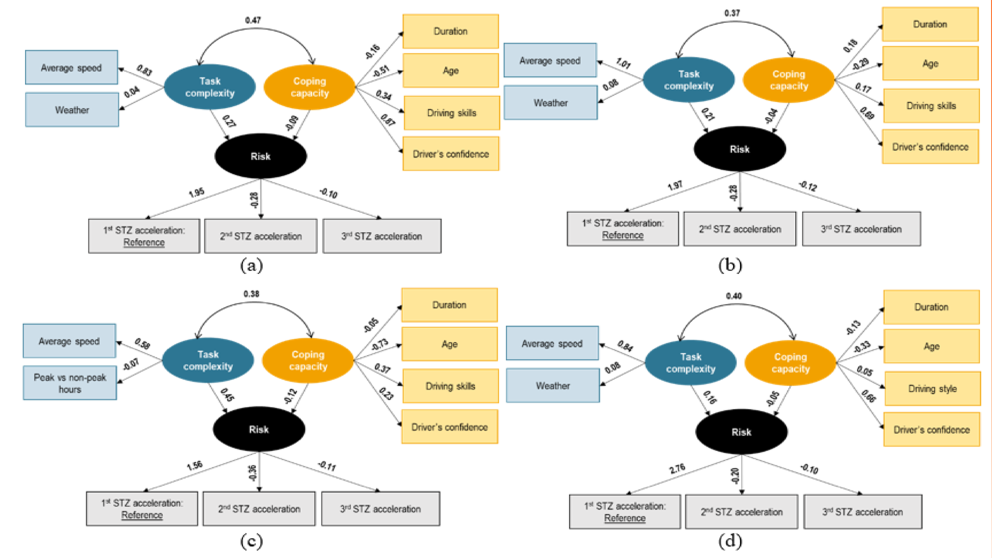

Figure 4: *Belgian trucks – experiment phase 1 (a), 2 (b), 3 (c), 4 (d)*

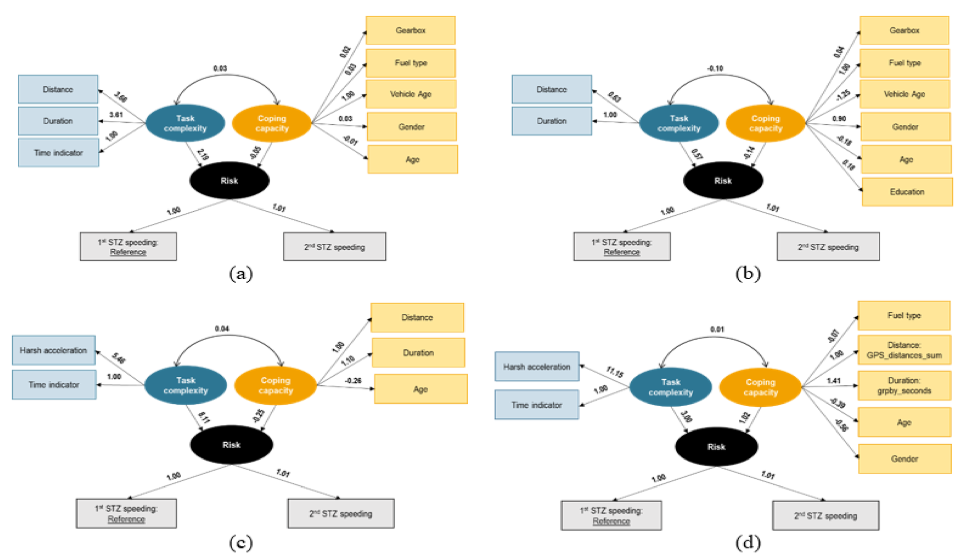

Figure 5: *German cars – experiment phase 1 (a), 2 (b), 3 (c), 4 (d)*

German cars

- Task complexity and coping capacity are inter-related with a positive correlation which reduces in magnitude as the driver's progress from phases 1 and 2 though phases 3 and 4. This positive correlation indicates that **higher task complexity is associated with higher coping capacity** implying that drivers coping capacity increases as the complexity of driving task increases.
- The structural model between task complexity and risk shows a positive coefficient, which means that **increased task complexity** relates to increased risk according to the model (regression coefficient=2.19).
- On the other hand, the structural model between coping capacity and risk shows a negative coefficient, which means that **increased coping capacity** relates to decreased risk according to the model (regression coefficient=-0.05).

Portuguese buses

- The measurement equations of task complexity and coping capacity are **consistent among the different phases**. The structural model between task complexity and inverse risk (normal driving) are positively correlated in phases 1, 3 and 4, while a negative correlation of phase 2 was identified. Coping capacity and risk found to have a negative relationship in all phases of the experiment.
- Task complexity was positively associated with the latent variable risk. The higher the complexity, the **higher the chance to drive normally** and more carefully. On the other hand, coping capacity was negatively associated with risk (or normal driving) which implied that higher coping capacity might encourage normal driving and reduce risk.

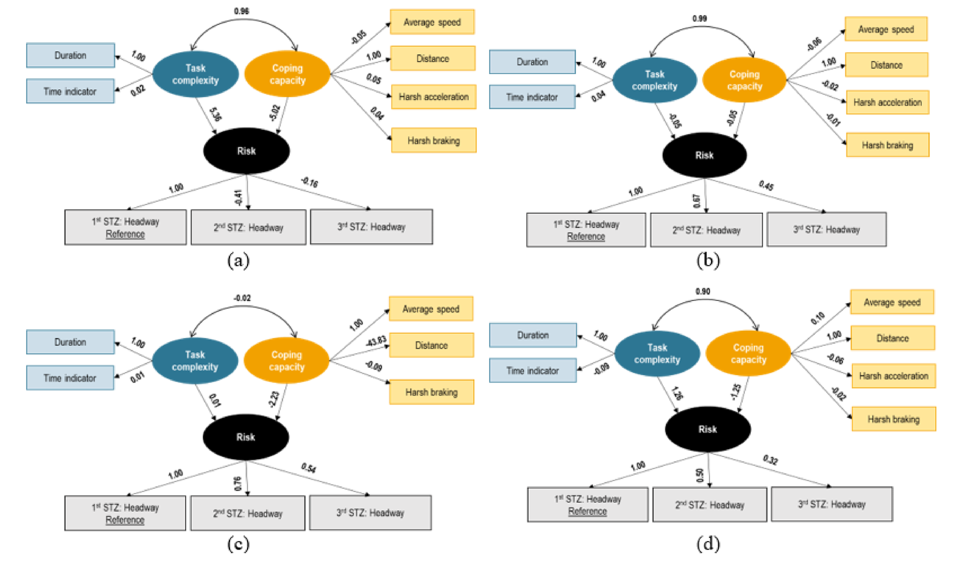

Figure 6: *Portuguese buses – experiment phase 1 (a), 2 (b), 3 (c), 4 (d)*

Conclusions

- **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 manage effectively 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 impact on risk, increasing the operators' coping capacity and reducing the risk of dangerous driving behavior.
- Further task complexity and coping capacity factors, such as road type, more personality traits and driving profiles could be utilized. Data could be enhanced by including **additional measurements** such as electrocardiogram and electroencephalogram readings, traffic conflicts and transport emissions. Finally, additional methodologies such as imbalanced learning and models taking into account unobserved heterogeneity could be explored for the understanding of the relationship between task complexity, coping capacity and crash risk.
- Lastly, **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 driving conditions.

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