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18-21/05/26

**Predicting driver behaviour  
in a cross-country  
naturalistic driving study  
using machine learning  
techniques**

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# Introduction

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Road crashes remain a major public health challenge, and driver behaviour is a key contributing factor. Within the EU Horizon 2020 i-DREAMS project, the **Safety Tolerance Zone (STZ)** concept supports real-time and post-trip interventions by categorizing driving into **three safety levels (Normal, Dangerous, Avoidable Accident)**. This work investigates whether interpretable machine-learning models can classify **trip-level driving behaviour into STZ levels** using naturalistic driving data from Belgium and the United Kingdom, while identifying the most influential predictors of unsafe driving.



# Objectives

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The objectives of this study are to:

- Develop and evaluate interpretable machine-learning models for **trip-level STZ classification into three safety levels**
- Compare model performance **across Belgium and UK** datasets under a consistent evaluation procedure
- Use **SHAP** to interpret predictions and identify **key safety-relevant predictors**

# Study Context

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This study was conducted within the framework of the **EU Horizon 2020 i-DREAMS project**, using **naturalistic driving data** collected from **real-world field trials**. The dataset includes observations from **Belgium and the United Kingdom**, selected due to sufficient sample size and complete availability of **trip-level variables** required for the modelling pipeline.

Data sources included:

- **Vehicle telemetry (via OBU and Mobileye):** speed, distance, harsh braking/acceleration, speed limit compliance
- **Physiological data (via Empatica E4):** heart rate and inter-beat interval (IBI)
- **Contextual features:** time of day, trip duration, road type, driver ID



# Methodology

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- **Data:** Naturalistic driving field trials. Each trip = 1 observation labelled with an STZ level
- **Pre-processing:** Label-defining variables excluded to reduce label leakage
- **Feature selection:** Random Forest variable importance (9 key features selected)
- **Models:** Random Forest, CatBoost, LightGBM, MLP
- **Evaluation:** Confusion matrices, accuracy, precision, recall, F1-score, false alarm rate
- **Interpretability:** SHAP used as post-hoc tool to explain feature contributions



# Classification Results

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UK					
	Accuracy	Precision	Recall	f1-score	False Alarm Rate
Random Forest	77%	78%	73%	75%	14%
LightGBM	76%	79%	69%	72%	16%
CatBoost	75%	75%	71%	73%	15%
MLP	68%	69%	61%	64%	21%
Belgium					
	Accuracy	Precision	Recall	f1-score	False Alarm Rate
Random Forest	74%	70%	65%	67%	18%
LightGBM	71%	67%	59%	61%	20%
CatBoost	71%	64%	63%	63%	19%
MLP	63%	53%	50%	50%	26%

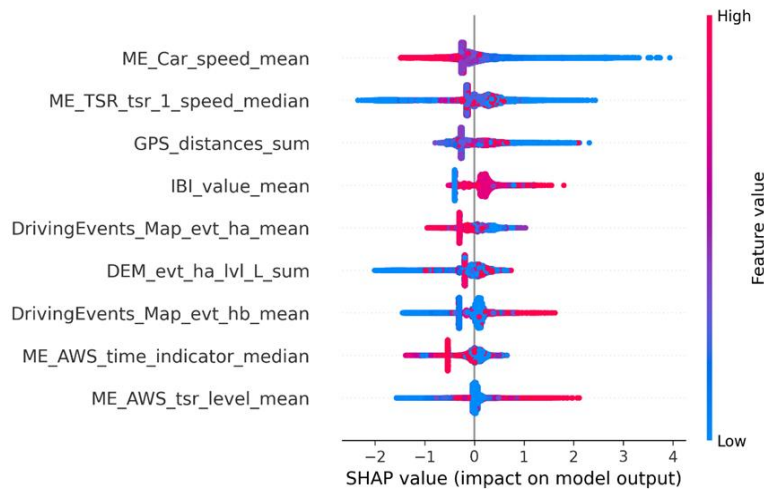
**Key findings:** Tree-based models consistently outperformed MLP on imbalanced data. Cross-country differences suggest driving context influences classification outcomes.

# Interpretability Results

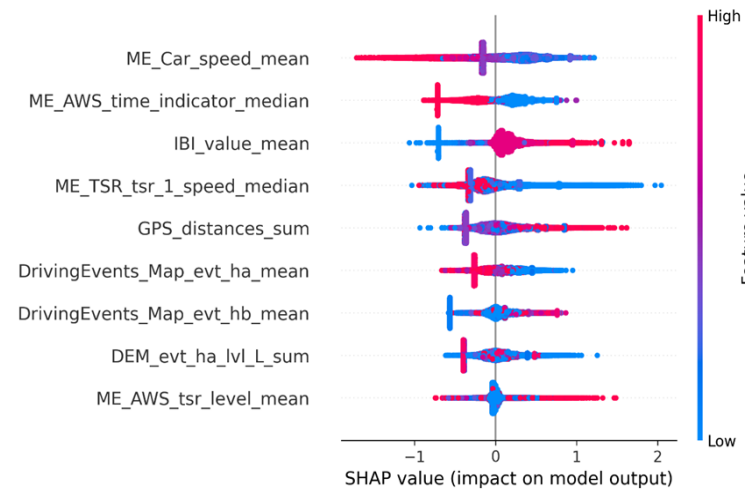
# SHAP Analysis (1/3)

SHAP summary plots per STZ level for the **United Kingdom** dataset

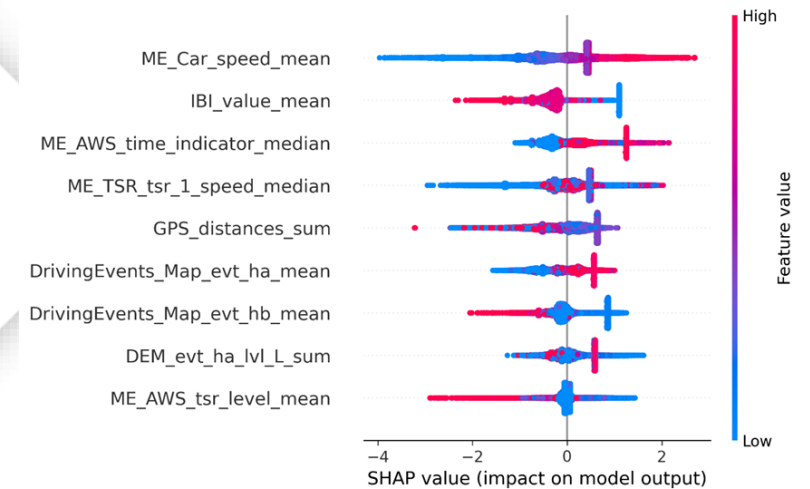
SHAP Summary Plot for STZ Level Normal



SHAP Summary Plot for STZ Level Dangerous



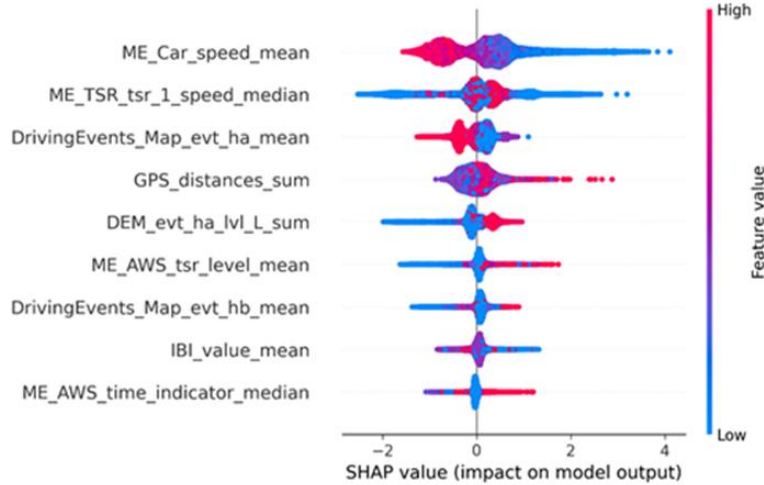
SHAP Summary Plot for STZ Level Avoidable Accident



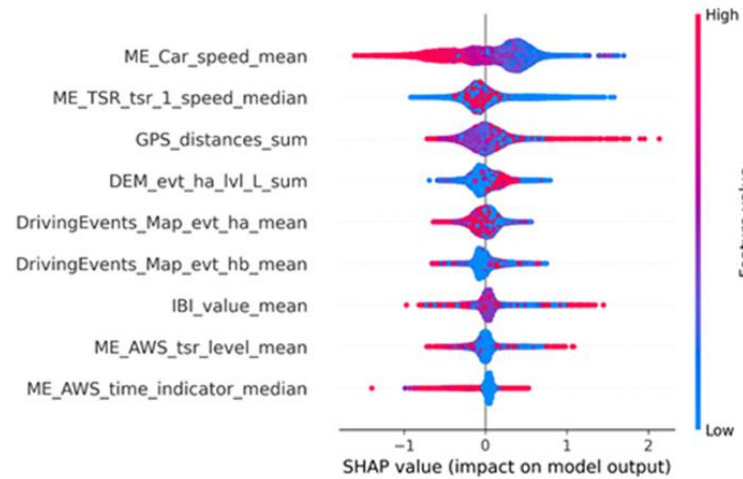
# SHAP Analysis (2/3)

SHAP summary plots per STZ level for the **Belgium** dataset

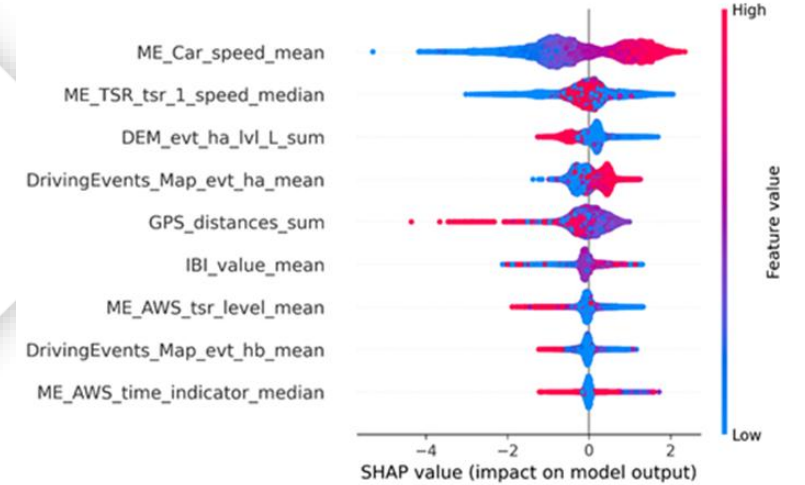
SHAP Summary Plot for STZ Level Normal



SHAP Summary Plot for STZ Level Dangerous



SHAP Summary Plot for STZ Level Avoidable Accident



## SHAP Analysis (3/3)

- **Average speed** is consistently the most influential predictor across all STZ levels and both countries
- **Harsh driving events** (braking, acceleration, cornering) play a key role in identifying dangerous behaviour
- **Cross-country differences:** Context-specific factors influence the contribution of behavioural and physiological variables
- Consistency across STZ levels highlights the **robustness of speed and harsh-event indicators**
- SHAP enhances **model transparency**, supporting use in real-time driver monitoring systems

# Conclusions

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- Interpretable ML models can effectively perform **trip-level STZ classification** using naturalistic driving data
- **Average speed and harsh driving events** are key predictors, supporting their integration into STZ-based monitoring
- Cross-country differences confirm that **driving context** affects model performance and feature importance
- **Limitations:** Moderate sample size; evaluation limited to two countries
- **Future work:** More diverse datasets, statistical robustness, and temporal validation

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**Re-Generation  
in transport**