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i-DREAMS: an Intelligent Driver and Road Environment Assessment and Monitoring System

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Abstract

The objective of the Horizon2020 project i-DREAMS is to setup a framework for the definition, development and validation of a context-aware ‘safety tolerance zone’. Taking into account, on the one hand, driver-related background factors and real-time risk-related physiological indicators, and on the other hand, driving task-related complexity indicators a real-time assessment will be made to determine if a driver is within acceptable boundaries of safe operation. Additionally, interventions will be developed to prevent drivers from getting too close to the boundaries of unsafe operation. These will be composed of in-vehicle interventions, and interventions aimed at enhancing the knowledge, attitudes and behavioural reaction of drivers. A holistic approach will be taken suitable for use in multiple transport modes. Initial testing will take place in a driving simulator after which promising interventions will be tested and validated under real-world conditions in a testbed of 600 drivers across 5 EU countries.

Keywords: task complexity, coping capacity, driver monitoring, interventions

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1. Introduction

In the era of digitization, the rapid steps in transport automation bring new challenging conditions, transforming the framework of operator/vehicle/environment interactions, and the need for increased understanding of the human factors affecting the behaviour of operators. Several factors of driver state have been persistently demonstrated in the literature as critical for safe transport systems. Distraction, in-vehicle or external, remains a serious threat to road safety (Lee et al., 2009). Fatigue and drowsiness are not limited to professional drivers, they emerge as critical risks for all drivers (Zhang et al., 2016). Fitness-to-drive becomes a key question for all operators, with respect to health concerns (e.g. illness, frailty, cognitive state) especially in an ageing, yet technologically challenged society (Eby et al., 2008). Extreme emotions, e.g. anxiety, stress, anger have received so far notably less attention (Mesken et al., 2007). Moreover, differences in socio-cultural factors, are still among the main determinants of road risks. At the same time, technology developments make massive and detailed operator performance data easily available (e.g. new in-vehicle sensors that capture detailed driving style and contextual data, increase in the penetration and use of information technologies by drivers, Internet of Things). This creates new opportunities for the detection and design of customised interventions to mitigate the risks, increase awareness and upgrade performance, constantly and dynamically (Toledo et al., 2008; Horrey et al., 2012). The optimal exploitation of these opportunities will allow the EU to address the new challenges and to manage timely the new developments in order to achieve its ambitious goals on road safety.

The European Horizon 2020 funded project i-DREAMS (2019-2022) aims to address the challenges raised above by creating a framework for the definition, development and validation of a context-aware ‘safety tolerance zone’ for on-road driving. Taking into account, on the one hand, driver-related background factors and real-time risk-related physiological indicators, and on the other hand, driving task-related complexity indicators a real-time assessment will be made to determine if a driver is within acceptable boundaries of safe operation. Additionally, interventions will be developed to prevent drivers from getting too close to the boundaries of unsafe operation. These interventions will be composed of real-time (in-vehicle) interventions, and interventions aimed at enhancing the knowledge, attitudes, perceptions and behavioural reaction of drivers with respect to safety-related technologies, situations and behaviours. The following section describes the background of the conceptual i-DREAMS framework.

2. i-DREAMS conceptual framework

2.1. Overall concept

The i-DREAMS framework hinges upon the Task-Capability Interface Model (Fuller, 2000). Central in this model is the aspect of calibration, which stands for the idea that road users self-regulate their behaviour in function of personal estimations of the (im)balance between imposed task demand and available coping capacity. Both task demand and available coping capacity are multi-dimensional concepts dependent upon a multitude of (endogenous and exogenous) variables. Research demonstrates perceptions of experienced task demand and available coping capacity are subjective (Michon, 1989). As a consequence, the personally estimated critical safety tolerance zone (i.e. the time/distance available to implement corrective actions safely) often does not correspond to objective safety margins. On the one hand, there is a ‘local’ interpretation of the Task-Capability Interface Model, considering the mechanisms contained by the Model to be operating constantly and in real-time while driving (Horrey et al., 2015). On the other hand, the ‘general’ interpretation, considers these mechanisms to be operating within a larger time frame, namely, across the multitude of individual trips which together constitute a person’s driving history. Furthermore, the ‘general’ interpretation relates the mechanisms contained by the Model to factors more global and stable across time, such as age, experience, personality traits, etc.

As for the conception of the i-DREAMS framework, the above presented ideas have two implications. First of all, for interventions aimed at increasing driver safety to be effective, we need an as-accurate-as-possible risk monitoring instrument. This issue will constitute the i-DREAMS framework’s first pillar (i.e. risk monitoring). Second, impact on driver safety can be expected to be higher, if proposed interventions in some way combine the local perspective (i.e. in-vehicle assistance with instant impact on driving) with the general perspective (i.e. longer-term support for a gradual change process in the vehicle operator). This will be the i-DREAMS framework’s second pillar (i.e. safety interventions). Altogether, the objective will be to develop, implement and test a technological solution (i.e. the i-DREAMS platform) that brings together the functionalities just described under pillar I and II (Figure 1).

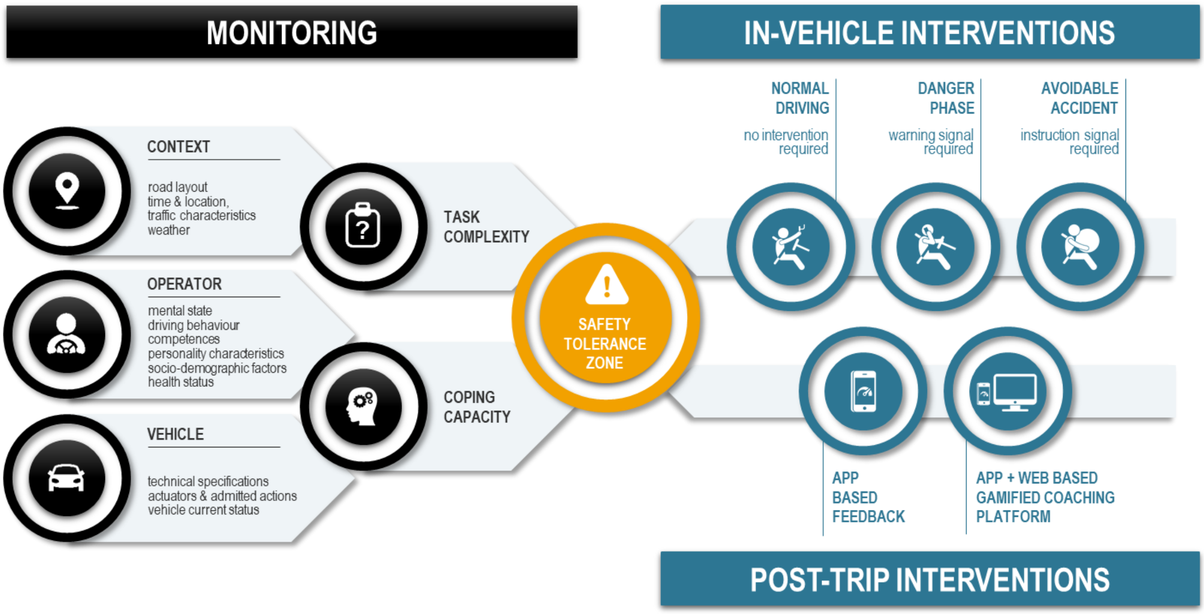

Fig. 1 The i-DREAMS framework with the monitoring module (pillar I-left) & interventions module (pillar II-right)

2.2. Conceptual framework pillar I: Monitoring

The most important functionality of pillar I is to determine the so-called ‘safety tolerance zone’, in function of a continuous and in-real-time monitoring of task complexity and coping capacity. Hence, Pillar I of the i-DREAMS framework focusses on the assessment of task complexity and coping capacity. As can be seen in Figure 1, task complexity relates to the current status of the real-world context in which a vehicle is being operated. Since this context is consistent of various individual elements which, together, determine the complexity of the task imposed on the vehicle operator, we will adopt a multi-dimensional approach in further operationalizing this concept. More in detail, we will monitor context via registration of road layout, time & location, surrounding traffic, and weather. As for coping capacity, Figure 1 shows that this concept is dependent upon two underlying factors, i.e. operator and vehicle status. These are also multi-dimensional in nature. The factor ‘operator’ entails six aspects, i.e. mental state, behaviour, competence, personality, socio-demographic background, and health status. The factor ‘vehicle’ consists of three aspects, i.e. technical specifications, actuators & admitted actions, and current status.

To extract the safety tolerance zone in real-time from the large amount of raw data collected while driving, a Big Data analysis framework will be developed. From a technological point of view, the methodological framework to determine the safety tolerance zone (pillar I) and to implement interventions (pillar II) will be supported by a new architecture that integrates a diverse set of data collection sensors, ranging from steering wheel sensors and dashboard-mounted cameras to OBD and smartphone.

2.3. Conceptual framework pillar II: Interventions

Pillar II of the i-DREAMS platform, focusses on the implementation of two different types of highly customized interventions. On the one hand, in-vehicle interventions will be proposed, designed to keep vehicle operators as much as possible within the safety tolerance zone. Depending on where within the safety tolerance zone a vehicle operator is situated, these in-vehicle interventions will function differently: in the ‘normal driving segment’, the monitoring module of the i-DREAMS platform (i.e. pillar I) will be active and following up in real-time on task complexity and available coping capacity, but without any (warning or instructional) feedback going back to the vehicle operator since there is no indication for a collision scenario to occur. If vehicle operators enter the ‘danger phase’ (i.e. there is potential for a collision scenario to start developing), the intervention module of the i-DREAMS platform (i.e. pillar II) will generate a warning message meant to alert operators and to prevent they might end up in a collision scenario emerging. If vehicle operators are in the ‘avoidable accident phase’ (i.e. a collision scenario is already developing but there is still potential to avoid a crash), the i-DREAMS intervention module will send an instructional message to operators on which corrective action to undertake. These in-vehicle interventions will be tailored to the specificities of the transport mode under consideration.

In addition, the i-DREAMS platform will implement two different post-trip interventions. The first is based on Feedback Intervention Theory. The change method applied in this post-trip intervention is called 'behavioural self-monitoring' (Michie et al., 2014), and is evidence-based in the finding that behaviour can be regulated by offering persons (1) feedback on their current performance regarding the to-be-changed behaviour(s) and (2) a personal standard to compare with (for example, what personal past performance was like) (Musicant et al., 2014). In technical terms, the first post-trip intervention will be designed as a smartphone (Android) application, offering information to the user immediately after completion of a trip, allowing car, bus, truck and train operators to consult how 'safety tolerant' they operated their vehicle during that particular trip. This information will be under the form of scores, calculated at different levels of aggregation (i.e. users receive a general risk index together with scores on individual behavioural parameters that are conceptually related to that risk). Users will also be able to compare these trip-specific scores with their performance on previous trips, allowing them to monitor their own driving history.

The second post-trip intervention has its basic principles in Goal Setting Theory, and Self-Determination Theory. Goal Setting Theory considers feedback on task performance as a crucial leverage for behavioural change, but with the additional idea that such feedback should go together with 'goals', i.e. personally held targets that indicate and give direction about what needs to be done in the future and how. Self-Determination Theory adds to this, the evidence-based idea that behavioural change will be more likely (and sustainable over time) if a person is 'intrinsically motivated'. An individual is said to be intrinsically motivated if s/he feels (1) competent in achieving the targeted behavioural change, (2) autonomous in terms of taking the decision to change behaviour, and (3) closely and affectionately related to important social referents when implementing a behavioural change. As a way to operationalize the above described theoretical mechanisms for behavioural change, we will follow guidelines drawn from field of Persuasive Technology Design (Fogg, 2011). Persuasive technology applications often try to realize an intrinsically motivated change process via the use of so-called 'gamification' features (i.e. game-specific characteristics applied in a non-gaming context as a way to increase competence and motivation). We will apply 8 of those gamification features (i.e. scores, points, levels, status badges, (group) challenges/competitions, progress bars, leader boards, and rewards). From a technical point of view, the second post-trip intervention will run on a combination of a smartphone (Android) application and a web-platform. Immediately after trip completion, vehicle operators will be able not only to self-monitor their driving history, but to set goals in a self-determined manner within a gamified environment meant to gradually build up skills and keep users motivated to operate their vehicle in a 'safety tolerant' way over a longer period of time. These post-trip interventions will also be tailored to the specificities of the transport mode under consideration (i.e. car, bus, truck, train).

3. Empirical framework

The technological implementation of the *i*-DREAMS framework will also be empirically tested. More specifically, the empirical work will be organized in four stages, combining a series of simulator-based experiments (in lab) with an experimental field-trial in a test bed of 600 participants spread over four different modes (i.e. car, bus, truck, train) in five countries (i.e. Belgium, Greece, Germany, Portugal, and UK). The five-country study will cover a period of 12 months in total.

The purpose of driving simulator experiments is (1) to test, calibrate and further refine the accuracy of the safety tolerance zone monitor, (2) to test a pre-selected set of in-vehicle interventions and decide on which of these will be kept for implementation in the field trial, and (3) to explore user acceptance of the tested in-vehicle interventions. The purpose of the field tests is (1) to test, calibrate, refine and validate the accuracy of the safety tolerance zone monitor under real life circumstances for different transport modes, (2) to test implementation of both in-vehicle and post-trip interventions in a real-life setting, and (3) to explore user acceptance of the in-vehicle and post-trip interventions when used in real life conditions.

The final key-outputs of the i-DREAMS project are shown in Table 1 below:

Table 1. Key outputs of i-DREAMS project.

Type of output	Description
Methodologies	Methodologies to monitor operator capacity and task complexity to determine safety tolerance zone while travelling
Tools	An integrated set of monitoring and communication tools for intervention and support, including: in-vehicle assistance, feedback and notification tools, a gamified platform for self-determined goal setting, and training and community building tools
Database	A user-licensed Human Factors database
Exploitation plan	An exploitation plan for commercial use of the i-DREAMS platform
Policy recommendations	A series of policy recommendations for authorities on how to implement the i-DREAMS platform to improve safety

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