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Toolbox of recommended interventions to assist drivers in maintaining a safety tolerance zone

Safe tolerance zone calculation and interventions for driver-vehicle-environment interactions under challenging conditions

iDREAMS

Project identification

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Glossary and abbreviations

Word / Abbreviation	Description
ADAS	Advanced Driver Assistance Systems
BCTT	Behaviour Change Techniques Taxonomy
CO	Change Objective
COM-B	Capability, Opportunity, Motivation - Behaviour
CPC	Certificate of Professional Competence
CSA	Compliance, Safety & Accountability
GDE	Goals for Driving Education
HMI	Human-Machine Interface
IM	Intervention Mapping
IM -TBCM	Intervention Mapping – Taxonomy of Behavior Change Methods
IQD	Interquartile Deviation
OEM	Original Equipment Manufacturer
OHS	Occupational Health and Safety
PAYD	Pay-As-You-Drive
PO	Performance Objective
PSD	Persuasive Systems Design
SO	Safety Outcome
SPO	Safety Promoting Goal
STZ	Safety Tolerance Zone
TDF	Theoretical Domains Framework
UMDA	Unified Model of Driver Acceptance
V2V	Vehicle-to-Vehicle

Executive summary

The i-DREAMS project aims at setting up a framework for the definition, development, testing and validation of a context-aware safety envelope for driving called the 'Safety Tolerance Zone'. Taking into account driver background factors and real-time risk indicators associated with the driving performance as well as the driver state and driving task complexity indicators, a continuous real-time assessment will be made to monitor and determine if a driver is within acceptable boundaries of safe operation. Moreover, safety-oriented interventions will be developed to inform or warn the driver in real-time as well as on an aggregated level after driving, through an app- and web-based gamified coaching platform (post-trip intervention). Furthermore, a user-license Human Factors database with anonymized data from the simulator and field experiments will be developed.

The conceptual framework of the i-DREAMS platform integrates aspects of monitoring (such as context, operator, vehicle, task complexity and coping capacity), to develop a Safety Tolerance Zone for driving. In-vehicle interventions and post-trip interventions will help to maintain the safety tolerance zone as well as provide feedback to the driver. This conceptual framework will be tested in simulator studies and three stages of on-road trials in Belgium, Germany, Greece, Portugal and the United Kingdom with a total of 600 participants representing car, bus, truck, tram and train drivers.

The main purpose of this deliverable is to elaborate on the more precise operationalization of the in-vehicle and the post-trip interventions provided by the i-DREAMS platform. The more specific objectives are:

- To identify the objectives targeted by the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To select methods for behavioural change which are appropriate for the achievement of the objectives targeted by the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To identify critical parameters for the way in which the selected methods will be practically applied in the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To translate the selected methods for the in-vehicle interventions inside the i-DREAMS platform into material designs (i.e. front-end) that take the critical use parameters into account.
- To translate the selected methods for the post-trip interventions inside the i-DREAMS platform into gamification mechanisms and features (i.e. front-end) that take the critical use parameters into account.

This Deliverable is structured as follows: after a general introduction, Chapter 2 provides more background on the i-DREAMS platform. The three main components inside this platform (i.e. the risk monitoring module, the Safety Tolerance Zone envelope, and the intervention module) are briefly presented. Attention in this Deliverable will go to the interventions module. More in detail, a paradigmatic classification of the in-vehicle and post-trip interventions is proposed. In terms of behavioural change, the in-vehicle interventions will be categorized as nudging while the post-trip interventions align more with the principles of coaching. The key-characteristics of nudging and coaching are discussed, and the important point will be made that in-vehicle and post-trip interventions actually are meant to

complement and mutually reinforce each other, which is why they will be combined in an integrated framework. More in particular, the in-vehicle interventions (i.e. nudging) are operational during a trip and primarily meant to steer vehicle operators' decision-making while driving. Post-trip interventions (i.e. coaching) are operational prior to or after a trip and primarily meant to empower vehicle operators in taking appropriate decisions while driving. Nudging and coaching are complementary in a sense that nudging aims to improve the vehicle operator's safety via manipulation of the driving context (i.e. creating a safer driving environment), while coaching aims to improve the vehicle operator's safety via manipulation of the human operator him or herself (i.e. creating a safer driver).

When developing interventions to change behaviour, like in the case of the i-DREAMS project, numerous choices have to be made. These choices revolve around a series of important questions about which interventions work to create behavioural change, for instance: how to logically assess a road safety problem? How to get from goals and objectives to intervention strategies? How to decide which intervention methods to use? How to link intervention design with implementation? Chapter 3 is dedicated to Intervention Mapping. This is a six-step protocol, providing a vocabulary for intervention program planning, procedures for organizing activities, and assistance in making evidence-based choices in terms of objectives to be targeted, and methods to achieve these. It maps the path from recognition of a need or problem to the identification of a solution, and the evaluation of that solution. Intervention Mapping was used as a roadmap to organize and structure the operational toolbox for the in-vehicle and post-trip interventions that follows later in Chapter 6.

Chapter 4 is devoted to the theoretical foundations of behavioural change to be considered when designing the operational toolbox for the i-DREAMS interventions. As such, Chapter 4 can be seen as the theoretical evidence-base of this Deliverable. It departs from a taxonomical overview of available behaviour-based safety intervention formats that can be found in the literature on transportation and safety. Based on review work in Deliverable 2.2, three formats are selected as relevant for and matching with the scope of the i-DREAMS project, i.e. real-time in-vehicle persuasive feedback without active intervention from technology, vulnerable road user protection, and persuasive feedback via an app and a web-based dashboard prior to or after trip completion. Eight theoretical frameworks essential for behavioural change follow next.

- The first framework (i.e. the Eco-feedback design behaviour framework) relates to the use of real-time messages and how to effectively design these. According to the framework, display, timing and information are crucial design criteria to consider.
- The second framework (i.e. the COM-B Model) introduces the idea that for behavioural change to be possible, the individual needs to have the opportunity to do so, possess the necessary capabilities, and be sufficiently motivated. These are in other words, three psychological domains to be considered when developing an appropriate behavioural change strategy, irrespective of whether the focus is on in-vehicle or post-trip interventions.
- The third framework (i.e. the Behavioural Change Techniques Taxonomy v1) provides an expert consensus-based overview of methods for behavioural change.
- The fourth framework (i.e. the IM Taxonomy of Behavior Change Methods) is not just a descriptive inventory of available methods to change behaviour, but a decision-tool

meant to help intervention planners in how to appropriately select and use change methods.

- The fifth framework (i.e. the Periodic Table of Gamification Elements) is a structured categorization of gamification mechanics and is useful for the translation of change methods into practical applications.
- The sixth framework (i.e. the Transtheoretical Model of Behaviour Change) makes the point that behavioural change is to be understood as a multi-staged process, and that adopted change methods and strategies should be tailored to where in this process of behavioural change an individual is situated.
- The seventh framework (i.e. Self-Determination Theory) adds to that the idea that people are motivated differently depending on where they are in the process of behavioural change. These differences in turn, have important implications for the selection of methods meant to influence a person's motivation to change behaviour.
- The eighth framework (i.e. the Goals For Driving Education Matrix) states that modifying a person's driving style, implies an improvement of the vehicle operator's driving performance and of the vehicle operator's deeper-situated and more stable safety-related dispositions (e.g., attitudes, norms, values, life-goals, et cetera). Depending on a person's current performance (e.g. novice vs experienced) and overall safety-related disposition (more safety concerned vs less safety concerned), he or she can be situated in a hierarchically structured learning process that moves from simpler 'lower order competences' to more complex 'higher order competences'. The point is also raised that the Goals for Driving Education (GDE) -matrix served as a kind of blueprint for those specific EU Directives that regulate the minimum requirements for the obtainment of a private car driver licence, and for the initial qualification and periodic training of professional drivers (i.e. Directive 2006/126/EC, Directive 2003/59/EC, both amended by Directive 2018/645). Linking the post-trip interventions to the competences implied by the GDE-matrix and the EU Directives just mentioned, would substantially increase their adoption potential.

Chapter 5 further completes Chapter 4 with two important preliminary considerations that apply across the different modes in the i-DREAMS project (i.e. car, bus, truck, tram, train). The first is that the adoption and effectiveness of technology-mediated interventions (like the ones that are being planned in the i-DREAMS project) is critically dependent upon whether users have the intention to and are open for using a new system (i.e. acceptability), and how they experience the actual use of a new system (i.e. acceptance). The Unified Model of Driver Acceptance is used to identify the key-variables that determine user acceptance. Since the post-trip interventions will be supported by a web-based platform, reference is also made to the Research-Based Web Design & Usability Guidelines as proposed by the U.S. Department of Health and Human Services and the U.S. General Services Administration. Another preliminary consideration of importance for a successful implementation of the i-DREAMS interventions, is the crucial difference between a private driver context and a professional driver context. For the latter, changing individual employees' behaviour requires an approach that is solidly embedded in the professional work context. Successful interventions in the field of occupational health and safety actually require a strong safety-oriented corporate culture and climate with strong management commitment, fleet safety management, and communication regarding safety. The i-DREAMS interventions that will take place in a professional work context will need active involvement of key-stakeholders in the workplace environment surrounding professional vehicle operators (e.g. fleet safety manager, planner, in-company coach or buddy).

Chapter 6 further builds upon insights coming from the previous chapters, and elaborates on the toolbox for the i-DREAMS interventions itself, which was developed according to Intervention Mapping. The toolbox consists of six compartments.

- The first compartment is where the safety outcomes can be found. These represent the highest level of impact targeted by the i-DREAMS interventions.
- The second compartment contains the safety promoting goals. These represent the behaviours that need to change in order for the safety outcomes to be realized.
- The third compartment is dedicated to the performance objectives, i.e. the more specific actions or behavioural parameters that need to change in order for the safety promoting goals to be achievable.
- The fourth compartment includes the change objectives. These apply to the underlying behavioural determinants that need to change for the performance objectives to become realizable.
- The fifth compartment contains the change methods that will be selected for application in the i-DREAMS interventions. Substantial attention will go to the so-called “critical design parameters”. These refer to properties of the selected change methods that will determine their effectiveness.
- Compartment six includes the practical applications, i.e. the translation of the selected change methods into practically applicable formats.

Also part of this Deliverable, are first drafts or mock-ups of what users of the i-DREAMS interventions will receive at the front-end of the in-vehicle and post-trip interventions.

Chapter 7 is the final chapter of this Deliverable that brings together the most important conclusions and recommendations for future steps in the i-DREAMS project. Logically, the recommendations mostly relate to the critical design parameters that will determine the effectiveness of the methods selected for application in the i-DREAMS interventions. Several work packages and project tasks connect to and depart from ideas included in this Deliverable. Key-recommendations are:

- For Work Package 4: Technical implementation of the i-DREAMS interventions:
    - In respect to the in-vehicle interventions:
        - As for the selection of a suitable display for the delivery of in-vehicle messages, the most preferred option taking into account feasibility and ease of installation would be a (cost affordable) nomadic device allowing visual and auditory feedback.
        - The design of this display would preferably be based on the guidelines for Human-Machine Interfaces, as proposed by Naujoks et al. (2019).
        - In terms of message timing, preference should go towards a situation-adaptive approach with an intelligent, personalized, and multi-staged activation of in-vehicle messages.
        - Regarding message information, a multi-sensory approach that combines visual information and sound is the preferred option with level of intrusiveness and information specificity changing in

function of how critical a detected risk is for the safety of the vehicle operator. To guarantee instant comprehension and persuasion, it is recommended to opt for highly guessable (i.e. self-explanatory) icons and symbols and appropriate manipulation of the acoustic properties of sound (i.e. loudness, pitch, and tone).

    - In respect to the post-trip interventions:
        - Differences in both the quantity (i.e. how much you want to change behaviour) and quality (i.e. why it is you want to change behaviour) of motivation plead in favour of a person-tailored and a stage-matched use of the change methods.
        - Not only in terms of intervention efficacy, but regarding successful adoption as well, it is of strategic importance to use the GDE-matrix as a guiding instrument to determine and structure the competences to be targeted, as the GDE-matrix gave direction to the requirements proposed in the EU Directives that regulate the minimum requirements for obtaining a private car driving licence, and for initial qualification and periodic training of professional drivers.
        - In a professional work context, the post-trip intervention platform should function as a kind of automated expert system, meant to provide support to the different key-stakeholders that are actively involved in the process of coaching professional vehicle operators to improve their driving style (e.g. company management, outdoor service providers coordinating fleet safety interventions, indoor planners and coaches or buddies, end-users).
        - In order to maximize user engagement and retention, it is recommended to take into account the factors identified in the studies by Brouwer et al. (2008) and Crutzen et al. (2008).
- For Work Package 5: 5-country experiment:
    - For successful implementation of the i-DREAMS interventions in a professional working context, it is important to have an implementation protocol that clarifies which stakeholders will be involved, what their role will be, what is expected from them, and how they are to interact with the app and/or web-based platform. Preferably, such a stakeholder implementation plan is to be developed in Deliverable 3.4 (Experimental protocol).
    - The post-trip interventions as outlined in this Deliverable are to be seen as a multi-modular program (i.e. vehicle operators can work on competences situated at different levels of the GDE-matrix, like vehicle control, road user interaction, speed management, driver fitness and use of safety devices), meant to engage and retain vehicle operators for several weeks or even months. In terms of time and duration, the empirical framework of the i-DREAMS project will not allow the post-trip interventions to be fully deployed for all participants involved (i.e. participants in the field trials will only be exposed to the post-trip interventions for a few weeks). Taking into account these time constraints, it is advisable to adopt a modular implementation strategy with different sub-groups of participants being exposed to specific modules that match with their baseline profile in terms of current performance (e.g. novice vs experienced) and personal safety-orientations (e.g. safety-related opinions and attitudes, sensation-seeking inclination, et cetera).

- For Work Package 7: Evaluation of safety interventions:
    - In this Deliverable, several safety outcomes have been proposed at the highest (i.e. epidemiological) level of impact. For now, these have been stated in terms of crash types. However, more specific and suitable (surrogate) measures will have to be proposed to appropriately operationalize objectives set at this highest level of impact. This is an important consideration for Deliverable 7.1 (Methodology for the evaluation of interventions).
    - In order not to lose the logic strength of the change strategy proposed in this Deliverable (i.e. change objectives → performance objectives → safety promoting goals → safety outcomes), it is important that suitable measures for each of the links in this causal chain are proposed and considered in relation to each other when assessing intervention effects. This does not only apply to Deliverable 7.1 but to Deliverable 3.4 as well.
    - For the interventions taking place in a professional work setting, data analysis and interpretation of results will have to take companies' safety climate into account, as this is expected to be a crucial environmental factor influencing intervention effectiveness.
    - In line with corporate safety climate, individual user acceptance is to be included in the analysis and interpretation of intervention effectiveness.
- For Work Package 8:
    - For successful adoption of the i-DREAMS post-trip interventions, it could be a strategic advantage to stress their alignment with the EU Directives that regulate the minimum requirements for obtaining a private car driving licence, and for initial qualification and periodic training of professional drivers.

1 Introduction

The goal of this section is to provide a brief outline of the objectives of the specific deliverable, how those are aligned and relevant with the overall project, and which approach was followed in order to achieve them.

1.1 About the project

The overall objective of the i-DREAMS project is to setup a framework for the definition, development, testing and validation of a context-aware safety envelope for driving ('Safety Tolerance Zone'), within a smart Driver, Vehicle & Environment Assessment and Monitoring System (i-DREAMS). Taking into account driver background factors and real-time risk indicators associated with the driving performance as well as the driver state and driving task complexity indicators, a continuous real-time assessment will be made to monitor and determine if a driver is within acceptable boundaries of safe operation. Moreover, safety-oriented interventions will be developed to inform or warn the driver real-time in an effective way as well as on an aggregated level after driving through an app- and web-based gamified coaching platform. Figure 1 summarizes the conceptual framework, which will be tested in a simulator study and three stages of on-road trials in Belgium, Germany, Greece, Portugal and the United Kingdom with a total of 600 participants representing car, bus, truck and tram/train drivers.

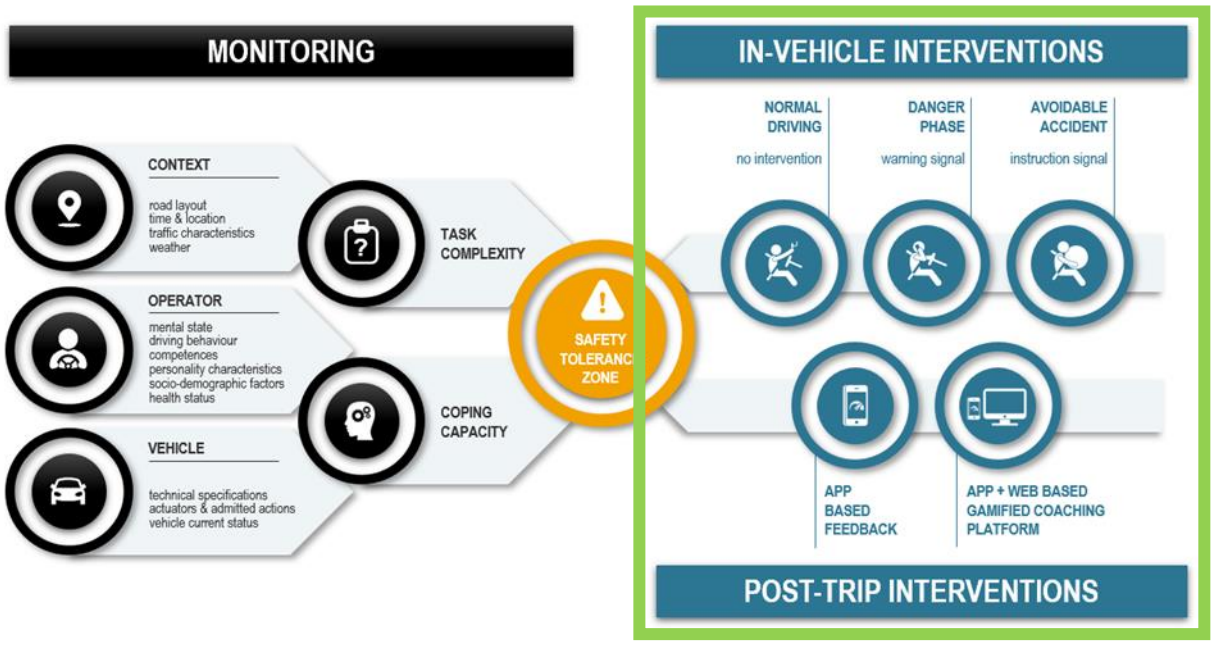


Figure 1: Conceptual framework of the i-DREAMS platform. The green frame indicates the thematic scope of this deliverable (see section 1.2)

Expected by the end of the project in 2022, the key output of the project will be an integrated set of monitoring and communication tools for intervention and support, including in-vehicle assistance and feedback and notification tools as well as a gamified platform for self-determined goal setting working with incentive schemes, training and community building tools. Furthermore, a user-license Human Factors database with anonymized data from the simulator and field experiments will be developed.

1.2 About this report

The work presented in this deliverable relates to the right part of Figure 1 (see green box), i.e. the intervention pillar of the to-be-developed i-DREAMS platform. As can be seen, one of the key-targets of the i-DREAMS platform is to keep vehicle operators as much as possible within the Safety Tolerance Zone (STZ) while driving. In order to do so, a combination of in-vehicle interventions and post-trip interventions will be deployed.

The in-vehicle interventions are meant to assist and support vehicle operators in real-time (i.e. while driving). Depending on how imminent crash risks are, a distinction can be made between a 'normal driving' phase, a 'danger' phase, and an 'avoidable accident' phase. In the normal driving phase, no abnormalities in a vehicle operator's driving style are detected by the monitoring pillar of the i-DREAMS platform, and no sign of a crash course initiating is present. Consequently, no real-time intervention is required. In the danger phase, abnormal deviations from the vehicle operator's driving style are detected by the i-DREAMS monitoring module, and the potential for a crash course to unfold is present. A warning signal is to be issued in that case. In the avoidable accident phase, deviations from normal driving have evolved even further, and the risk for a crash to occur will become imminent if the vehicle operator does not adapt appropriately to the present circumstances. A more intrusive warning signal is to support vehicle operators in avoiding a collision.

The post-trip interventions are not operational while driving, but they are based on what happens during a trip. They hinge upon all the raw data that is captured by the i-DREAMS sensors, which is further processed and fused into information about a vehicle operator's driving style, how it evolved during a trip, how many (safety-critical) events occurred, and in which circumstances these events happened. This information can be further translated into feedback consultable for vehicle operators via an app in a pre- or post-trip setting. To establish a longer-term relationship with individual vehicle operators, app-supported feedback can be combined with the use of a web-based coaching platform, containing so-called gamification features meant to motivate drivers to work on a gradual and persistent improvement of their driving.

The main purpose of this deliverable is to elaborate on the more precise operationalization of the conceptual ideas contained by the above mentioned descriptions of the in-vehicle and post-trip interventions which together, constitute the second pillar of the i-DREAMS platform. In more specific terms, **the deliverable aims to address the following objectives**:

- To identify the objectives targeted by the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To select methods for behavioural change which are appropriate for the achievement of the objectives targeted by the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To identify critical parameters for the way in which the selected methods will be practically applied in the in-vehicle and post-trip interventions inside the i-DREAMS platform.
- To translate the selected methods for the in-vehicle interventions inside the i-DREAMS platform into material designs (i.e. front-end) that take into account the critical use parameters.
- To translate the selected methods for the post-trip interventions inside the i-DREAMS platform into gamification mechanisms and features (i.e. front-end) that take into account the critical use parameters.

In addressing these objectives, the deliverable wants to make the step from (evidence-based) abstract and theoretical principles of behavioural change to a set of practical applications (i.e. material designs, gamification mechanisms and features) brought together in an architectural blueprint that can be technically implemented later on in the project. As such, **this deliverable is to be considered as the operational 'toolbox' for the in-vehicle and post-trip interventions inside the i-DREAMS platform.**

To situate it in the overall framework of the i-DREAMS project, deliverable 3.3 falls under work package 3 'operational design of the i-DREAMS platform', and relates more specifically to task 3.3 'Selection of intervention approaches'. As can be derived from Figure 2 below, work package 3 (this deliverable included therein) takes a quite central position. This deliverable to an important extent hinges upon findings coming from work package 2 where deliverable 2.2 established the state-of-the-art in terms of in-vehicle and post-trip interventions in the field of road safety. Deliverable 3.3 itself in turn, will be the guideline for work to be carried out in work package 4 where the focus is on the technical implementation of the i-DREAMS platform. Although this deliverable is not primarily focused on field implementation-related procedures (this is discussed in deliverable 3.4 'experimental protocol'), it does propose a few considerations to be taken into account when rolling out the in-vehicle and post-trip interventions during the 5-country experiment in work package 5. It can be expected that experiences from the 5-country experiment will put into perspective some of the insights proposed in work package 3, and so in this deliverable as well.

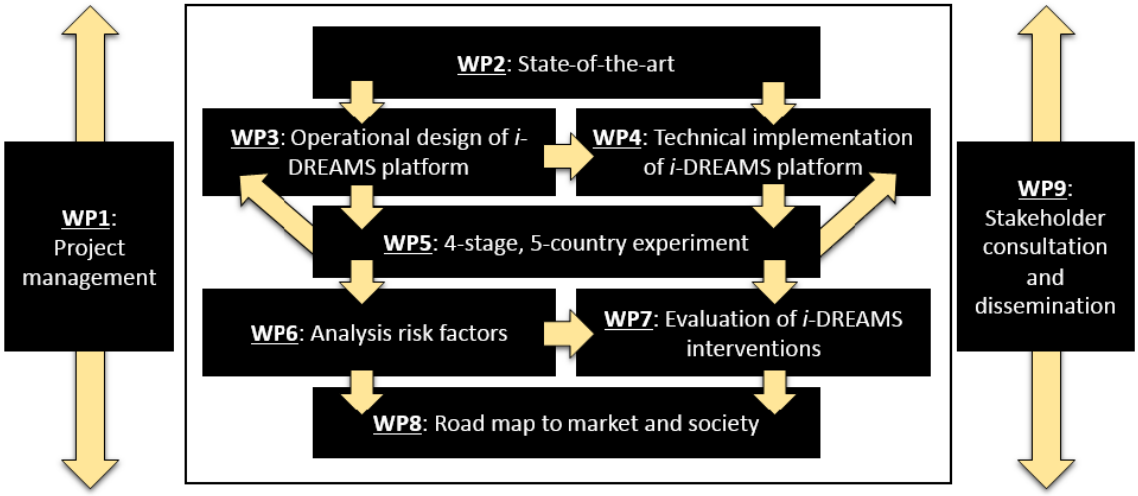


Figure 2: Framework for the implementation of the i-DREAMS project (Pert Chart)

This deliverable will be structured as follows. The first four sections (i.e. section two-five) contain preliminary considerations helpful to understand the organization of this deliverable, and important for the to-be-developed operational toolbox. Section two provides a bit more background on the theoretical foundations of the i-DREAMS platform. Moreover, it highlights and demonstrates the complementarity of the in-vehicle interventions on the one hand, and the post-trip interventions on the other hand. Section three briefly discusses Intervention Mapping which served as a protocol to organize the activities related to this deliverable, and provided us with a useful blueprint to structure the contents of this report. Section four is dedicated to some theoretical foundations of behavioural change, to be considered throughout the remainder of this deliverable. Section five addresses a few preliminary cross-

modal considerations since the i-DREAMS project has a multi-modal dimension, targeting cars, trucks, buses, and trams/trains. Section six is the most important part of this deliverable. Following Intervention Mapping, we stepwise develop each of the operational tools we need for the technical implementation of the in-vehicle and post-trip interventions inside the i-DREAMS platform (see Work Package four). Finally, we summarize the most important insights in section seven.

1.3 Reader guideline

This Deliverable is a public document targeting readers from different backgrounds, e.g. academic experts, practictioners, policy makers, interested lay people, et cetera. Planning interventions for behavioural change is however, a highly specialized scientific discipline with its own technical jargon, executive protocols, and methodological specificities. Reconciling this diversity of reader backgrounds and interests with the academic nature of the objectives addressed in this Deliverable, was not evident. Notwithstanding, a good balance between an acadmic orientation on the one hand, and a more practice-oriented perspective on the other hand, was envisaged.

Readers more interested in practical aspects and technical details of how the interventions proposed in this Deliverable will be implemented, are recommended to focus on chapter six where the operational toolbox for the i-DREAMS interventions is proposed. More specifically, sections 6.3.2 (i.e; critical design parameters), 6.3.3 (i.e. practical application) and 6.4 (i.e. intervention production) will be relevant for those readers. People with a background in policy making will also be primarily interested by chapter six, and more specifically, by section 6.1 which is where the targeted objectives of the i-DREAMS interventions are outlined, and motivated. Academic experts and people more interested in the theoretical foundations of the proposed interventions are advised to go through chapters two, four and five before reading chapter six. In chapter six, sections 6.2 (i.e. logic model of change) and 6.3.1 (i.e. change methods) will be of particular interest for those readers. In chapter two, sections 2.1 to 2.4 are relevant for readers who first need more background about the i-DREAMS platform in general, and about the purpose of the i-DREAMS intervention module more in particular. Chapter three is helpful for readers who want to learn more about the protocol that was used to operationalize the i-DREAMS interventions (i.e. Intervention Mapping).

2 The i-DREAMS platform: background

The i-DREAMS project 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 (in)balance between imposed **task demand** and available **coping capacity** (Fuller, 2005). 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. Also, studies show that what is 'acceptable' as a safety tolerance zone, is subjective with differences not only between individuals but within the same individual (across different situations and time) as well (Fuller, 2011). These phenomena together undermine the effectiveness of self-regulative actions, resulting in an increased crash risk.

2.1 Control Theory: implications for conceptual design

According to experts working within the Control Theory Paradigm, important for a deeper understanding of frameworks such as the Task-Capability Interface Model, is the time window used for interpretation (Carver & Scheier, 1982). As Horrey et al. (2015) explain, on the one hand, there is the **'local' perspective**, considering the mechanisms contained by the Model to be operating constantly and in real-time while driving. On the other hand, the **'general' perspective**, 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' perspective relates the mechanisms contained by the Model to factors more global and stable across time, such as age, experience, personality traits (e.g., sensation seeking, impulsivity), etc.

This difference between a 'local' and a 'general' interpretation of the Model has important implications for safety management. A 'local' or 'in real-time' interpretation of the Model implies that the closed-loop process of sampling, judging, and acting upon the world is constantly ongoing while driving, and that if a response on behalf of the driver is required, this is always a response to an acute, momentary need. Since human operators are vulnerable to the commission of errors when monitoring and processing information related to the objective 'state-of-the-world' their behavioural self-regulation will suffer from inadequacies. To lower the risk for such inadequacies, drivers need assistance while driving by instruments that allow a more accurate sampling and responding to the objective state-of-the world. **In sum, a 'local' interpretation of the Task-Capability Interface Model implies that interventions aimed at increasing safety have to take place in real-time, while driving.**

The important complement of the 'general' view to the 'local view', is in the more holistic idea that sampling, judging and acting upon the world while operating a vehicle is also dependent on factors more stable across time. Typically however, car assistance systems do not really take into account such stable factors. It is for instance, not common that such systems are tailored to features such as personality, driving experience, safety attitudes, etc. (e.g. Horrey et al., 2012; the gamECAR-project). **In fact, research shows that in order to have impact on the influence of those more stable characteristics, other interventional approaches**

are required, often running over longer time episodes and targeting for a gradual and stepwise change process in the vehicle operator (e.g., Karlsson et al., 2017).

As for the conception of the i-DREAMS project, the above presented ideas have two implications. First, 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 project'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 project's second pillar (i.e. safety interventions).

The three next sections briefly outline how the three key-components of the i-DREAMS platform (i.e. the risk monitoring module, the Safety Tolerance Zone envelope, and the interventions module) are to be understood.

2.2 The i-DREAMS risk monitoring module

Pillar I of the i-DREAMS platform focusses on the assessment of task complexity and coping capacity. From the **state-of-the-art reported in Deliverable 2.1** (Kaiser et al., 2020), it became clear that both task complexity and coping capacity are to be understood as **multi-dimensional concepts**, entailing a variety of endogenous and exogenous factors (see Figure 3).

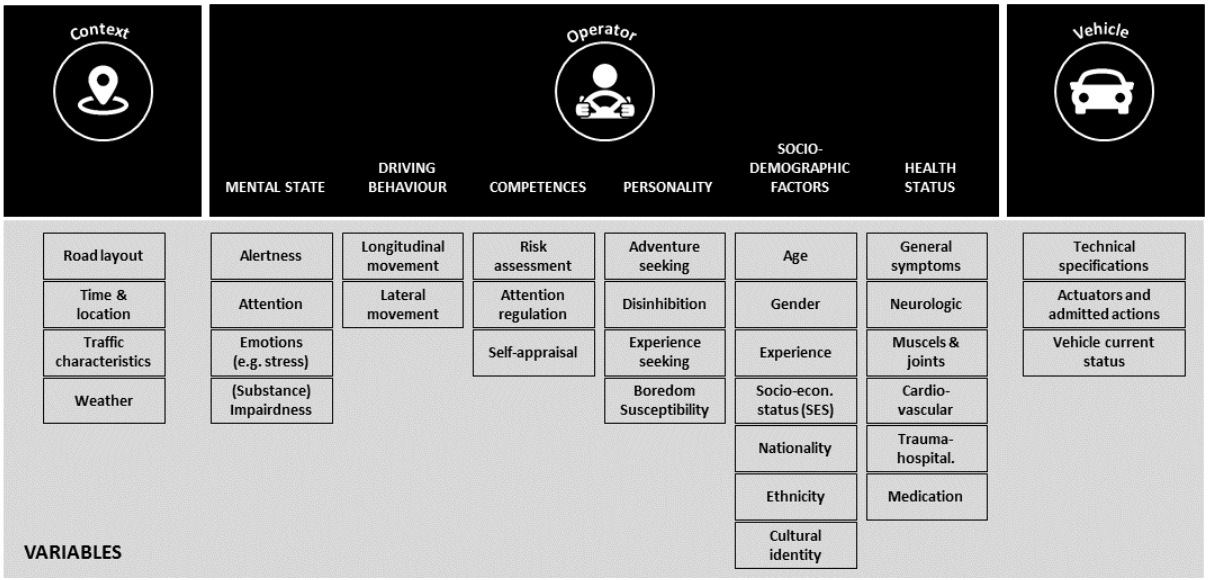


Figure 3: Monitoring task complexity ('context') & coping capacity ('operator' and 'vehicle')

As can be seen in Figure 3, task complexity relates to the current status of the **real world context** in which a vehicle is being operated. More in detail, the literature review carried out in Deliverable 2.1 indicated that relevant factors for monitoring context are road layout, time & location, surrounding traffic, and weather. **Coping capacity** was found to be dependent upon two underlying factors, i.e. **operator and vehicle status**, with the latter two are also multi-dimensional in nature. Six more specific aspects were identified during the literature review as relevant for measuring operator status, i.e. mental state, behaviour, competences,

personality, socio-demographic background, and health status. The factor 'vehicle' could be related to three different aspects, i.e. technical specifications, actuators & admitted actions, and current status. In **Deliverable 3.2** (Katrakazas et al., 2020) more detailed specifications can be found on the **sensors and instruments** that will be used in the i-DREAMS project to collect data for the different variables appearing in Figure 3, and how this input data will be **mathematically modelled** to come to a **real-time and dynamic calculation** of where in the Safety Tolerance Zone (i.e. the 'normal driving' phase, the 'danger' phase or the 'avoidable accident' phase) a vehicle operator can be situated. This in turn, will determine the type of real-time intervention to be issued.

2.3 The i-DREAMS Safety Tolerance Zone envelope

As explained in **Deliverable 3.1** (Talbot et al., 2020), the term 'Safety Tolerance Zone', although abstract in nature, refers to a real-world phenomenon, i.e. **self-regulated control over transportation vehicles by (technology assisted) human operators in the context of crash avoidance**. Conceptually, the STZ is made up of **three phases**:

Normal driving

The label 'normal driving' refers to the phase of the STZ where, based on current conditions in the objective state-of-the world, there is **no indication that a collision scenario is likely to unfold at that time**. Under conditions of normal driving, no real-time interventions are required. From a conceptual point of view, this implies that, for as long as a moment-to-moment registration of the current state-of-the-world does not detect the potential for a crash course to start developing, the STZ is conceptually to be understood as time-space window where the human operator's self-regulated vehicle control can be qualified as 'normal driving'.

Danger phase

The label 'danger phase' refers to the phase of the STZ where, based on current conditions in the objective state-of-the-world, **the potential is detected for the start of a collision scenario**. Within the i-DREAMS system the 'danger phase' subzone can only be initiated if firstly a change is detected between the current-state-of-the-world and the state-of-the-world immediately preceding it, and, secondly, that detected change in the state-of-the-world now indicates conditions which suggest that a crash may develop. In case such a change in the objective state-of-the-word takes place, the STZ changes its conceptual status from 'normal driving' to 'danger phase'. In more detail, the latter means that the human operator's self-regulated vehicle control has become less safe in a sense that the potential for a crash course to start developing, has been initiated. This may have been because of decreased driver capability or external conditions creating greater task demand or some combination of driver related and external factors.

Avoidable crash phase

The label 'avoidable crash phase' refers to that particular subzone of the STZ where, based on current conditions in the objective state-of-the-world, **a collision scenario is actually starting to develop, but the vehicle operator still has the potential to intervene and avoid a crash**. If such a change in the objective state-of-the-world takes place, the STZ changes its conceptual status from 'danger phase' to 'avoidable crash phase'. More specifically, this means that the human operator's self-regulated vehicle control has become even less safe in the sense that the potential for a crash to happen has been initiated. Again,

this may be influenced by external events within the road traffic system or a deterioration in the operators' capability, or a combination.

In sum, **the conceptual status of the STZ dynamically changes** depending on how the objective state-of-the-world evolves, and the status of the vehicle operator included therein. Changes in the objective state-of-the-world are not only caused by the movements controlled by the vehicle operator, but by other phenomena outside of the vehicle operator's control as well (e.g., movements controlled by other human operators, physical conditions of the road environment or the vehicle being operated, climatological circumstances, etc.) (Katrakazas et al., 2015). **The STZ envelope** is that specific component inside the i-DREAMS platform which is responsible for the **real-time and dynamic calculation** of where in the Safety Tolerance Zone a vehicle operator can be situated.

One of the key-ambitions targeted by the i-DREAMS project is to create the STZ envelope in such a manner that the dynamically changing status of the STZ is determined in function of **flexible thresholds instead of so-called 'fixed thresholds'**, as it is currently done by most Advanced Driver Assistance Systems (ADAS). Indeed, the traditional ADAS-approach is to activate warnings or instructions based on thresholds that are predefined and set in such a manner that they cannot vary depending on what the more precise driving circumstances are in terms of imposed task complexity and available coping capacity. To illustrate in simple terms, irrespective of what road surface conditions or the vehicle operator' s mental state are like, a standard forward collision warning system triggers warning signals based on a pre-set and fixed headway time threshold. However, under rainy conditions for instance, it could be a substantial safety advantage to trigger a warning signal sooner than under dry road surface conditions, widening the time window for the vehicle operator to undertake the necessary corrective actions to avoid a collision. The possibility to determine the STZ status based on flexible (i.e. variable across driving conditions) thresholds requires an artificially intelligent estimation approach (Katrakazas et al., 2019).

2.4 The i-DREAMS interventions module

The i-DREAMS intervention module combines a real-time approach with a post-trip approach. As for the real-time approach, both intervention timing (i.e. when should an intervention be activated?) and functionality (i.e. what is the purpose of the activated intervention?) are dependent upon where inside the STZ a vehicle operator is to be situated. In the normal driving phase, no sign of a crash course initiating is present and thus, no real-time intervention is required. In the danger phase, the potential for a crash course to unfold is present, and a warning signal is to be issued. In the avoidable accident phase, the risk for a crash to occur can become imminent, requiring an instruction signal to support vehicle operators in avoiding a collision. Overall, the real-time intervention approach is to support vehicle operators in performing their primary task (i.e. driving) as safely as possible. Paraphrased in terms of how the STZ is conceptualized, the i-DREAMS real-time interventions want to keep vehicle operators as much as possible in the normal driving phase, or prevent that they transition from the danger phase to the avoidable crash phase. Since the **real-time interventions** are to provide this support *while driving* and under constantly changing circumstances, the time window within which they operate is limited to (milli)seconds, and eventual corrective actions are to be decided upon and executed in an almost automatic way since there simply is no time to think over possible alternatives for action. From a paradigmatic point of view, this implies that the real-time interventions align mostly with a so-called **'nudging' approach** (see section 2.4.1 for more details).

Even though in the end, the i-DREAMS **post-trip interventions** serve the same purposes as the real-time interventions (i.e. to keep vehicle operators as much as possible in the normal driving phase, or to prevent that they transition from the danger phase to the avoidable crash phase), their operational time window is much wider. This allows the use of methods targeting more stable factors that rather indirectly affect the vehicle operator's moment-to-moment decisions and actions during a trip (e.g. safety-related attitudes, locus of control, mastery of safety-related driving skills, perceived social norms related to road safety et cetera). Changing such more stable factors is known to be time and effort consuming and requires more continuous engagement and follow-up (Bouton, 2014; Kelly & Barker, 2016). Paradigmatically, this requires a **'coaching' approach** (see section 2.4.2 for more details).

The i-DREAMS real-time and post-trip interventions are thus **complementary** rather than overlapping. This point will be further illustrated in the following two sections where nudging and coaching are presented as two clearly different, but **mutually reinforcing paradigms for behavioural change**.

2.4.1 Real-time interventions: a nudging approach

Over the last decade, 'nudging' has received massive attention as a paradigm for behavioural change (Thaler & Sunstein, 2008). The basic principles behind nudging actually are based on insights obtained by neuroscientific research on human judgement and decision making (Hansen, 2016). These insights led to the surge of a whole new discipline in applied neuropsychology, i.e. Behavioural Economics. One of its basic tenets is that **humans are not always perfectly rational** in the way they make judgments and take decisions in everyday life (e.g., Ariely, 2009, 2010; Glimcher & Fehr, 2014; Raue et al., 2018). Rather, they often are guided by so-called **heuristics (mental shortcuts)**, especially in situations where the opportunity to reflect is limited, and where available information or options to assess, are ambiguous or complex and future outcomes are uncertain or difficult to predict (e.g. Chaiken & Trope, 1999; Strack & Deutsch, 2004; Kahneman, 2013). It is also very well known that **humans are (unconsciously) sensitive to social settings or to manipulations of how the physical environment is designed** when they have to take behaviour-related decisions (for a review of work on implicit social cognition, see Gawronski and Payne, 2010).

Insights from Behavioural Economics led scholars to innovative approaches in terms of behavioural change, the most popular one thus probably being the so-called nudging approach (e.g. Loewenstein & Chater, 2017; Samson, 2018). As highlighted by van Gent et al. (2019: p. 206), nudging strategies have also been applied in the field of transportation, such as to the design of travel information systems (Avineri, 2011), the promotion of safe driving behaviours (Millar & Millar, 2000; Mortimer et al., 2018), methods for the analysis of travel behaviour (Metcalfe & Dolan, 2012), and the safety-promoting design of road infrastructure (Charlton, 2007; Ariën et al., 2017; Charlton & Starkey, 2017; Hussain et al., 2018).

Over the years, several suggestions have been made to formally define nudging (e.g. Hausman & Welch, 2010; Hansen & Jespersen, 2013). The working definition proposed by Marchiori et al. (2017: p.3) lends itself very well for this deliverable and goes as follows: "*Nudging is an umbrella term for deliberate and predictable methods for changing people's behaviour by modifying the cues in the physical and/or social context in which they act. It uses these cues to activate nonconscious thought processes involved in human decision-*

making. Nudging implies that none of the choices should be difficult to avoid, made mandatory, significantly incentivized economically or socially, and made significantly more costly in terms of time or trouble."

In the context of the i-DREAMS project, **a nudge is thus understood as any aspect of the choice architecture (in the case of the i-DREAMS real-time interventions, this refers more specifically to the vehicle cockpit's interior design) that can influence a vehicle operator's choice of a certain behaviour at a specific time and the spot where the nudge is implemented**, which is line with the interpretation by Karlsson et al. (2017). Below, Table 1 gives an overview of some of the key-characteristics of a nudging approach, as proposed by Karlsson et al. (2017: p. 76).

Table 1: Key-characteristics of a nudging approach. Source: Karlsson et al. (2017: p.76)

Nudging	
Aim	Supports automatic behaviour and decision making in a specific situation
Overall intervention type	Supportive choice architectures (humans influence by the context, technology, et cetera)
Window of opportunity	Narrow: must influence behaviour in a specific situation
Frequency of influence	Influences behaviour directly every time the situation arises
Duration of influence	Momentary or short: influences behaviour in a specific situation
Location of influence	Specific to location: influences behaviour at the location where the supportive choice architecture is provided
Key-prerequisite for successful influence	Requires that the vehicle operator attends to or makes use of the specific choice architecture

2.4.2 Post-trip interventions: a coaching approach

Referring to the work by Hawkins (2008), Karlsson et al. (2017: p. 54) indicate that various definitions have been proposed for the term 'coaching' without any of these receiving general acceptance. Despite marked differences, there are a few noticeable elements these definitions have in common, such as the idea that coaching is about (1) a **one-to-one** relationship, (2) rather focusing on **facilitation** (i.e. helping to achieve) than on instruction (i.e. transfer of knowledge), (3) targeting both **behavioural change *and* personal growth** (i.e. self-awareness, reflection, et cetera), and (4) securing a **longer-term** relationship between **equals**. Karlsson et al. (2017) consider the definition by Grant (2001) as interesting as it is formulated in a generic way, thereby being applicable to a broad variety of settings. It goes as follows: "*Workplace* ***coaching is a collaborative solution-focused, results-orientated systematic process, used with normal, non-clinical populations, in which the coach facilitates the enhancement of work performance and the self-directed learning and personal growth of the coachee***." (Grant, 2001: p. 33). Even though this definition explicitly refers to a 'workplace' context, Karlsson et al. (2017) consider it relevant to be applied to private contexts as well.

The definition proposed by Grant (2001) actually aligns well with the definition that was forwarded in the i-DREAMS **Deliverable 2.2** (Katrakazas et al., 2020). More in detail, the

definition presented in that Deliverable was adopted from Schulte et al. (2014: p.46) who described coaching as "[…] *designed to improve existing skills, competence and performance, and to enhance [coachees'] personal effectiveness or* ***personal development*** *or personal growth.*"

The idea of coaching matches very well with the most recent paradigm for behavioural change as it is proposed in the field of behavioural science, i.e. so-called **'boosting'** (Grüne-Yanoff & Hertwig, 2016). Hertwig & Grüne-Yanoff state the objective of boosting is *"[…] to foster people's competence to make their own choices – that is, to exercise their own agency.*" Hertwig & Grüne-Yanoff (2017: p. 1).Table 2 gives an overview of some of the key-characteristics of a coaching or 'boosting' approach, as proposed by Karlsson et al. (2017: p. 76).

Table 2: Key-characteristics of a coaching approach. Source: Karlsson et al. (2017: p.76)

Coaching	
Aim	Supports reflective learning to influence behaviour in various situations
Overall intervention type	Supportive coaching experiences (humans influenced by humans, but sometimes mediated by technology)
Window of opportunity	Wide: can influence behaviour both in a specific situation and beyond
Frequency of influence	Can influence behaviour directly during a coaching event and indirectly in situations in-between events
Duration of influence	Short or long: influences behaviour over time with repeated coaching but requires a willingness to learn and change
Location of influence	Independent of location: can influence behaviour at other places than where the coaching is provided
Key-prerequisite for successful influence	Requires development of a quality relationship between coach and coachee built on trust and commitment

With the context of the i-DREAMS project in mind, two important things are to be noticed in terms of how the coaching approach will be implemented in the post-trip interventions.

Firstly, in terms of **coaching delivery** the i-DREAMS post-trip interventions will be **technology-mediated to a substantial extent**. More in detail, the i-DREAMS post-trip interventions can be qualified as digital- or internet-based interventions, running on a combination of an app and a web-based dashboard. This by itself is not in conflict with the idea of coaching as a developmental relationship between people. Indeed, even though empirical studies on the effectiveness of technology-mediated interventions for behavioural change did not always find consistent results, there is considerable (meta-analytical) evidence available suggesting that computer-based formats can stimulate such a relationship and improve both coachee's personal effectiveness and development (see i-DREAMS Deliverable 2.2 by Katrakazas et al. (2020) for more precise details and references). Moreover, openness to virtual coaching (i.e. human coaches working via the web) or e-coaching (coaching fully web-mediated) has been reported in the literature, for instance, in a study cycle targeting professional truck drivers (Roetting et al., 2003; Huang et al., 2005;

Zhang et al., 2006; Huang et al., 2008). Overall, it was found that professional truck drivers were willing to accept feedback from technology, if properly designed.

Secondly, further along this Deliverable, it will become clear that the i-DREAMS post-trip interventions will not be implemented as a stand-alone-solution, i.e. as a total replacement of human coaching. The latter applies especially in those cases where the post-trip interventions will be deployed in a professional or occupational context, (see section 5.2). As such, the i-DREAMS post-trip interventions are to be understood as **combining e-coaching with virtual coaching**.

To summarize, from a paradigmatic perspective, the i-DREAMS real-time interventions can be categorized as nudging while the post-trip interventions qualify as a combination of virtual- and e-coaching. The next section elaborates on the complementarity of both approaches for behavioural change.

2.5 Link between real-time interventions and post-trip interventions

The issue addressed in this section is whether the i-DREAMS real-time and post-trip interventions can be usefully combined to complement and reinforce each other, despite the fact they represent quite different approaches towards behavioural change (i.e. nudging and coaching). The least one can say is that lately, this question has received much attention and still is intensively debated in the field of behavioural science (e.g. Samson, 2016, 2019). Coaching matches with the idea of 'boosting' (i.e. empowering decision making), while nudging (i.e. steering decision making) refers to a totally different type of interventions, i.e. guiding people in a particular direction while preserving their freedom of choice. At first sight, the difference between the two approaches stands out, rather than their potential complementarity. According to Hertwig & Grüne-Yanoff (2017: p. 2) nudging and boosting can be mutually distinguished on seven different dimensions (see Table 3).

Table 3: Seven dimensions on which nudging and boosting approaches can be distinguished. Source: Hertwig & Grüne-Yanoff (2017: p.2, Table 1)

Dimension	Nudging	Boosting
Intervention target	Behaviour	Competences
Roots in research programs and evidence	Show decision maker as systematically imperfect and subject to cognitive and motivational deficiencies	Acknowledge bounds but identify human competences and ways to foster them
Causal pathways	Harness cognitive and motivational deficiencies in tandem with changes in the external choice architecture	Foster competences through changes in skills, knowledge, decision tools, or external environment
Assumptions about cognitive architecture	Dual-system architecture	Cognitive architectures are malleable
Empirical distinction criterion (reversibility)	Once intervention is removed, behaviour reverts to preintervention state	Implied effect should persist once (successful) intervention is removed
Programmatic ambition	Correct momentous mistakes in specific contexts – "local repair"	Equip individuals with domain-specific or generalizable competences

Normative implications	Might violate autonomy and transparency	Necessarily transparent and require cooperation – an offer that may or may not be accepted

At the same time however, Reijula et al. (2018), and Hertwig & Grüne-Yanoff (2017) make it explicit that the domains for the application of boosts are not completely orthogonal to those of nudges. As the authors state themselves: "***Boosts and nudges are, of course, not perfect substitutes****. […] there are* ***domains in which either nudges or boosts could be used****, including food choices, financial decisions, and self-control problems. In each of these classes, individuals' competences can be boosted, nudged, or both. […] Our goal* ***is not to champion one over the other*** *but to highlight the need for an analysis of the respective circumstances and goals, allowing policy makers to select the more appropriate intervention.*" (Hertwig & Grüne-Yanoff (2017, p. 11). With the conceptual model proposed by Horrey et al. (2015) in mind (see section 2.1), it becomes clear that the **calibration of skill and judgement in driving (which is an essential ingredient of the i-DREAMS project), lends itself perfectly to a combined nudging-coaching approach.** This idea will be elaborated further in the next section.

2.5.1 An integrated framework combining nudging and coaching

As already explained, Horrey et al. (2015) consider driver calibration (i.e. the closed-loop process of sampling, judging, and acting upon the world) as constantly ongoing while driving, but at the same time, under the influence of factors more stable over time. Influencing calibration *while driving*, implies an intervention that operates within a (milli)second time window, and that triggers the appropriate response in an almost automatic way every time the situation would require so. This aligns with the key-characteristics of the nudging approach.

Different from that, influencing the more stable factors that are known to affect driver calibration (in)directly is not limited to a specific situation or context, and typically requires reflective learning. This aligns with the key-characteristics of the coaching approach. An integrated approach where nudging and coaching are combined to promote road safety has been proposed by Karlsson et al. (2017). Their ideas served as a blueprint to come to the integrated framework visualized in Figure 4.

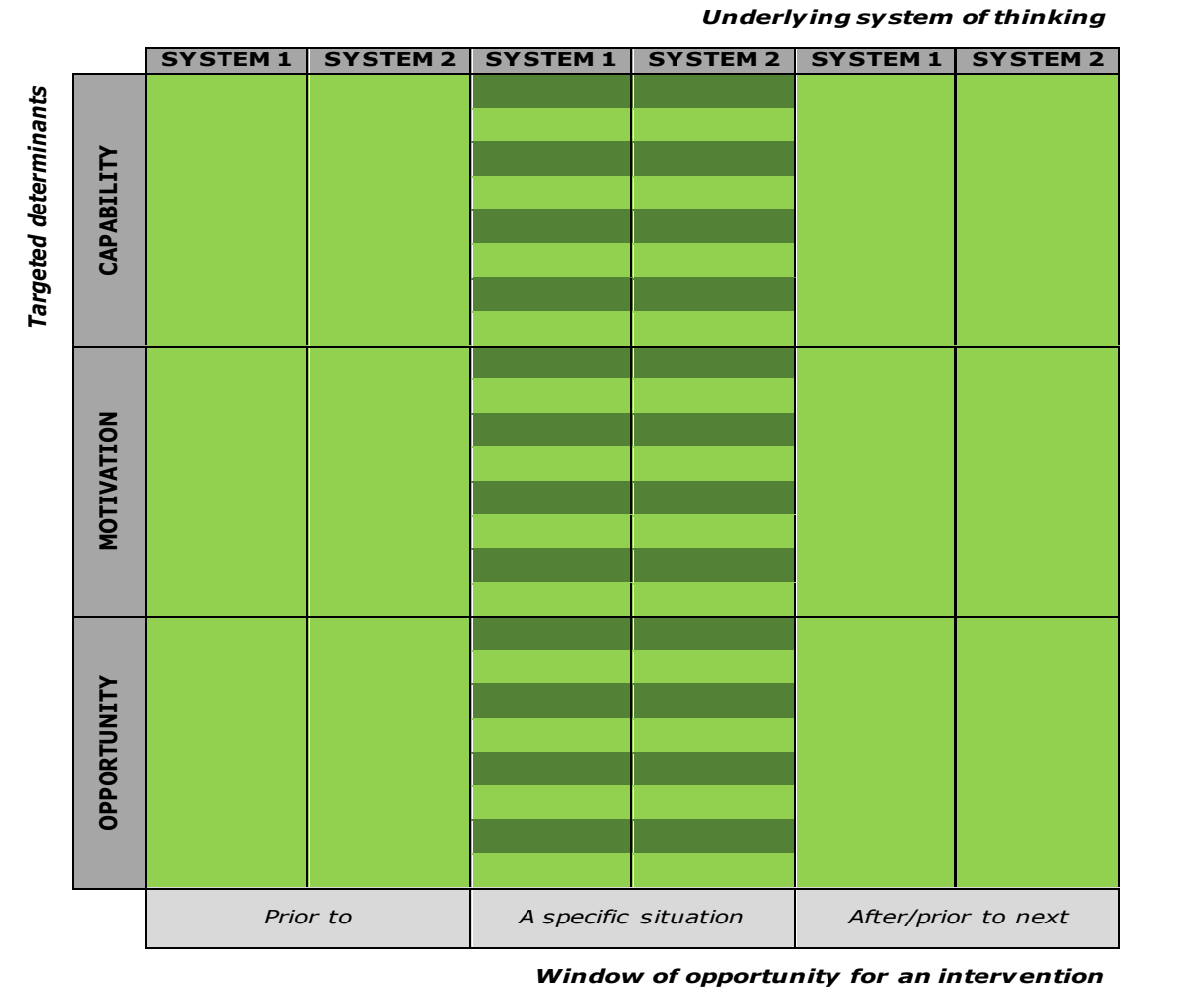


Figure 4: Integrated framework combining nudging & coaching. Source: adapted from Karlsson et al. (2017: p. 80)

As can be seen, the framework is defined in function of three dimensions, i.e. the window of opportunity, the underlying system of thinking, and the targeted behavioural determinants. Regarding **the window of opportunity**, it can be seen that nudging is operational **in specific situations**, while coaching primarily takes place **outside the context of a trip (i.e. after or prior to a trip)** although it can influence a vehicle operator's decision making indirectly in specific situations as well. As for **the underlying system of thinking**, a distinction is to be made between the so-called **'system 1' (i.e. the automatic system) and 'system 2' (i.e. the reflective system)** (see Kahneman, 2013). Table 4 gives an overview of the most important differences between the two systems.

Table 4: Differences between system 1 & system 2. Source: Karlsson et al. (2017: p.32, Figure 4.1)

System 1 (Automatic)	System 2 (Reflective)
Unconscious reasoning	Conscious reasoning
Implicit	Explicit
Automatic	Controlled
Low effort	High effort
Large capacity	Small capacity
Rapid	Slow
Default process	Inhibitory
Associative	Rule-based
Contextualized	Abstract
Domain specific	Domain general
Evolutionary old	Evolutionary recent
Nonverbal	Linked to language
Recognition, perception, orientation	Rule following, comparisons, weighing of options
Modular cognition	Fluid intelligence
Independent of working memory	Limited by working memory capacity
Nonlogical	Logical
Parallel	Serial

As can be derived from Figure 4, both system 1 and 2 can be operational in each of the three different areas inside the window of opportunity dimension. Both nudging and coaching can thus make use of the two systems of thinking. Nonetheless, due to the fact that decision-making in specific situations while driving often entails no more than a few (milli)seconds, nudging will more frequently operate via system 1 than via system 2. This however, does not mean system 2 is totally irrelevant for nudging during a trip. Timely warning signals for instance, can stimulate (conscious) reflection, and activate the appropriate procedural knowledge schemes on how to safely adapt behaviour to the current driving circumstances.

Following the same line of thinking, coaching will operate to a substantial extent via system 2, since the prevailing time window (i.e. after or prior to a trip) is simply much wider, creating the opportunity to stimulate conscious and more effortful reflection. Notwithstanding, coaching can also call on system 1 to reach its objectives. This happens for instance, when part of a coaching intervention, is the implementation of a so-called Compliance, Safety and Accountability (CSA) program where good behaviour is rewarded and undesired behaviour punished (e.g. Stock, 2001). Punishment and reward are well established methods to reinforce good behaviour or to extinguish undesired behaviour, but they rely on operant conditioning as the underlying learning mechanism. Operant conditioning in turn, is based on the formation associations between a particular behaviour, and the consequences of that behaviour (i.e. more typical for system 1) (see Murphy & Lupfer, 2014), rather than on in-depth logical reasoning creating deeper insight into the cause-effect mechanisms linked to a particular behaviour (i.e. more typical for system 2).

As for the third dimension in the framework, i.e. **the targeted behavioural determinants**, the work by Michie et al. (2005), Michie et al. (2014), and Davis et al. (2015) showed that across a sample of 33 available psychological theories, a total of 84 theoretical constructs could be identified as candidate determinants for behavioural change. More in detail, an interdisciplinary group of experts in health psychology and behavioural change was consulted to simplify this multitude of candidate-determinants, clustering them into three basic domains, i.e. **capability** (relating to a person's ability to change behaviour)**, motivation** (relating to a person's willingness to change behaviour)**, and opportunity** (relating to the possibility for a person to change behaviour).

Both nudging and coaching can target each of these three basic domains for behavioural change, and do so prior to, during, or after a trip, with support of both systems of thinking, i.e. the automatic system and the reflective system. Thus, depending on which behavioural determinant is targeted and what the window of opportunity is, six different nudging strategies, and 18 coaching strategies can be distinguished. Table 5 gives an overview of these different strategies with a demonstrative example to illustrate what is meant more specifically.

Table 5: Overview of different nudging & coaching strategies

Determinant			Opportunity window			Nudging	Coaching
CAP	MOT	OPP	prior	during	after		
√	x	x	√	x	x		Probing for a vehicle operator's commitment to apply safe driving skills before the start of a new trip.
x	√	x	√	x	x		Promising a reward for safe driving to a vehicle operator behaviour before the start of a new trip.
x	x	√	√	x	x		Encouraging a vehicle operator to drive safely before the start of a new trip.
√	x	x	√	x	x		Offering a tip on how to drive safely to a vehicle operator before the start of a new trip.
x	√	x	√	x	x		Offering information on the pros of safe driving to a vehicle operator before the start of a new trip.
x	x	√	√	x	x		Warning a vehicle operator for a risk prone location before the start of a new trip.
√	x	x	x	√	x	Alerting a drowsy vehicle operator while driving.	Offering a vehicle operator a plan of action on how to drive safely (before the start of a new trip) prompts the appropriate skills to drive safely during a trip.
x	√	x	x	√	x	Prompting a threatening sound to warn a vehicle operator for an imminent danger while driving.	Challenging a vehicle operator to drive safely (before the start of a trip) prompts willingness to do so during a trip.

Determinant			Opportunity window			Nudging	Coaching
CAP	MOT	OPP	prior	during	after		
x	x	√	x	√	x	Signalling the presence of a vulnerable road user to a vehicle operator while driving prompts a potential opportunity for a hazardous event.	Offering a contextualized challenge to drive safely to a vehicle operator (before the start of a new trip) prompts appropriate skills to drive safely in the respective context during the trip.
√	x	x	x	√	x	Real-time feedback on headway time makes the vehicle operator consciously aware on how to keep a safe distance while driving.	Offering information on the symptoms of fatigue to a vehicle operator (before the start of a new trip) increases alertness for fatigue during the trip.
x	√	x	x	√	x	Sign recognition signalling the speed limit to a vehicle operator while driving raises consciousness for speed limit compliance.	Providing safety-supportive arguments to a vehicle operator (before the start of a new trip) raises consciousness to drive safely during the trip.
x	x	√	x	√	x	Sign recognition signalling a no overtaking road sign while driving keeps the driver aware of the fact that there is no (legal) opportunity to overtake.	Expression of social approval of safe driving (before the start of a new trip) sensitizes the vehicle operator during the trip.
√	x	x	x	x	√		Probing for a vehicle operator's reconfirmation to drive safely next trip.
x	√	x	x	x	√		Unlocking a new safety challenge for the vehicle operator to take up next trip.
x	x	√	x	x	√		Social appraisal of a vehicle operators' safe driving after trip completion.
√	x	x	x	x	√		Evaluative feedback obtained for driving behaviour after a completed trip gives the vehicle operator deeper insight into current performance.
x	√	x	x	x	√		Arguments against self-doubts following a trip persuade the vehicle operator to continue working towards targeted safety goals.
x	x	√	x	x	√		Showing critical events detected during a completed trip on a map provide the vehicle operator with deeper insight into risk-prone contexts.

In sum, **the i-DREAMS platform will integrate nudging strategies (i.e. the real-time interventions) and coaching strategies (i.e. the post-trip interventions)** to keep vehicle operators as much as possible within the STZ, preferably even in the normal driving phase. Nudging strategies are operational *during* a trip and primarily meant to steer vehicle operators' decision-making *while driving*. Coaching strategies are operational *prior to or after* a trip and primarily meant to empower vehicle operators in taking appropriate decisions while

driving. Nudging and coaching are complementary in a sense that **nudging**, as defined in this Deliverable, aims to improve the vehicle operator's safety via manipulation of the driving context (i.e. **creating a safer driving environment**), while **coaching** aims to improve the vehicle operator's safety via manipulation of the human operator him or herself (i.e. **creating a safer driver**).

The remainder of this deliverable serves to outline in more detail **how this strategic view on the i-DREAMS interventions, will be operationalized**. In other words: what will be the more specific objectives targeted by the real-time and post-trip interventions? Which more precise change methods will be used for nudging and coaching, and how will these be practically applied? Yet, before turning to the 'operational toolbox' itself, section 3 is dedicated to the protocol that was followed to design the structure of the toolbox.

3 Planning Behaviour Based Safety Interventions: a multi-step protocol

When developing interventions to change behaviour (like in the case of the i-DREAMS project), numerous choices have to be made. These choices revolve around a series of important questions about which interventions work to create behavioural change like for instance: how to logically assess a health or safety problem? How to get from goals and objectives to intervention strategies? How to decide which intervention methods to use? How to link interventions design with implementation? According to Bartholomew Eldredge et al. (2016: p. 7) consultation of available theoretical and empirical evidence is necessary *"[…] to ensure that we can describe and address the factors that cause health problems and the methods to achieve change.*" Experts have argued that more guidance on how to use theory to understand and address health and social problems, would be very beneficial to the field of health & safety promotion and education (e.g. Glanz & Bishop, 2010; Glanz et al., 2015). In response to this call, Intervention Mapping was developed. The purpose of **Intervention Mapping** (IM) (see section 3.1) is to provide planners of health and safety promotion interventions with **a framework for effective decision making at each step in intervention planning, implementation, and evaluation.**

3.1 Intervention Mapping

As highlighted by Bartholomew Eldredge et al. (2016), the keywords in IM are planning, research and theory. IM provides a vocabulary for program planning, procedures for planning activities, and technical assistance with identifying theory-based determinants and matching them with appropriate methods for change. **It maps the path from recognition of a need or problem to the identification of a solution.** This process is **iterative** rather than linear, as intervention planners are supposed to move back and forth between tasks and steps. Moreover, the protocol is **cumulative**: each step is based on previous steps, and inattention to a particular step may lead to mistakes and inadequate decisions. All together, IM consists of **six steps**, each step comprising a set of tasks to be carried out (see Figure 5).

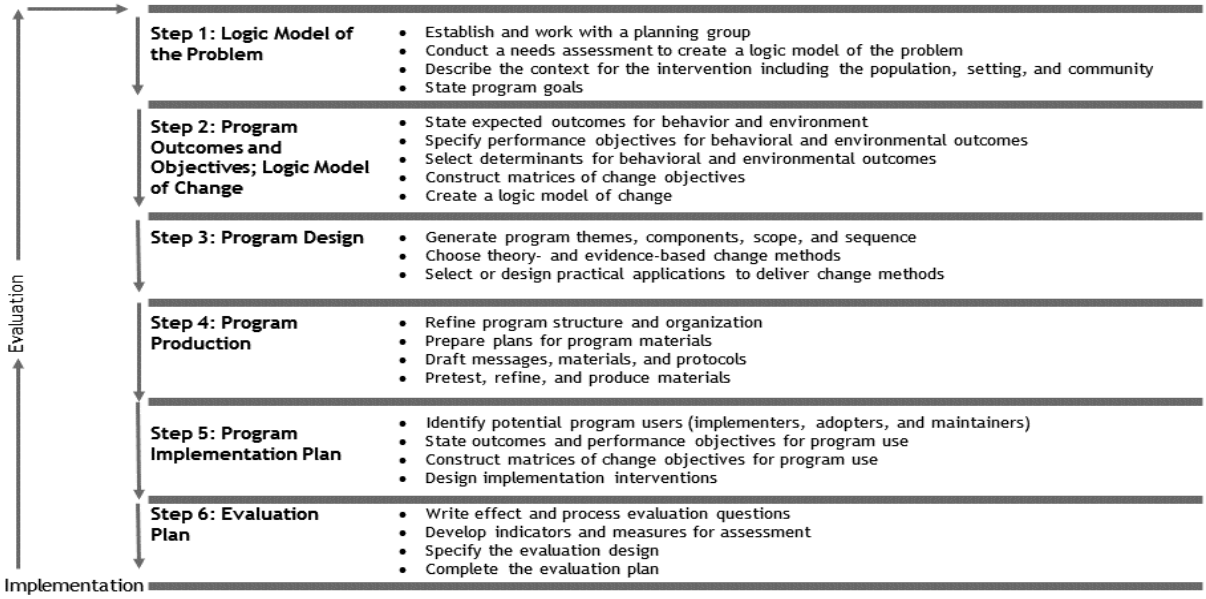


Figure 5: The six steps of Intervention Mapping. Source: www.interventionmapping.com

3.1.1 Step 1: Logic model of the problem

Stated in general terms, the health problem addressed in the i-DREAMS project, is road safety, and in more specific terms, the occurrence of road crashes with involvement of private car drivers or professional vehicle operators (i.e. bus, truck, tram and train). The first step of IM consists of **four subtasks**. Before starting to plan the actual intervention, a so-called **planning group** is to be composed. This is a diverse team consisting of different stakeholders like community members, policy makers, sector representatives, academic experts, et cetera, bringing together relevant know-how and expertise. In the i-DREAMS project, this task is part of work package 9 (stakeholder consultation and dissemination) where an Expert Advisory Board and a User Advisory Board are composed and consulted.

The key-task in step 1 is to conduct **a needs assessment** to create a logic model of the targeted health problem. More precisely, this model tries to determine which **behaviour factors** (e.g. prevalence, incidence, etc.), **environmental factors** (e.g. climatological conditions, roadway infrastructure, traffic conditions, societal factors, etc.) and their related **personal determinants** (i.e. what factors cause or modify the behaviour and environment of the at-risk group?) are relevant in the context of crash aetiology. In order to come to a full understanding, the **available assets, capacities and abilities** are also to be determined (i.e. which leverages for a successful intervention are present or needed?). After combining the previously determined factors, the expected outcomes can be stated. To illustrate, for the i-DREAMS project, a relevant **safety outcome** could be a reduction in the number of forward collisions.

In the i-DREAMS project the final three tasks have been addressed in work package 2 where a state-of-the-art has been summarized in terms of which factors related to the vehicle operator, the environmental context in which that operator is situated, and the vehicle being operated, determine crash risk (see Deliverable 2.1 by Kaiser et al., 2020). Furthermore, potential assets, capacities and abilities to address the problem of road crashes have been reviewed (see Deliverable 2.2 by Katrakazas et al., 2020). Of course, that expertise will be a crucial input for this deliverable (see section 6.1).

3.1.2 Step 2: Logic model of change

The second step of IM consists of **five subtasks**. Firstly, it has to be decided **which behavioural factors in the targeted population(s) have to change** in order to positively influence the targeted safety outcome(s). For instance, to reduce the number of forward collisions, it is necessary vehicle operators share the road safely with other road users. An improvement in terms of how vehicle operators share the road with others would be a to-be-targeted **safety promoting goal**. Also, especially in the case of professional vehicle operators (like bus, truck, tram and train drivers), the **environmental agents to be involved** in the intervention (e.g. planners, coaches, colleagues), must be identified.

Secondly, so-called **performance objectives** are to be formulated. These indicate what performance is required from both the members of the primary target groups (i.e. private car drivers and professional bus, truck, tram and train drivers), and the relevant environmental agents. In other words, performance objectives specify what members of the primary target groups and relevant environmental agents more specifically need to do in order for the planned interventions to be able to achieve the expected safety promoting goals. For example, to improve interaction with other road users, vehicle operators would have to

reduce risk-prone manoeuvres like tailgating. A reduction of tailgating incidents (by maintaining a safe headway distance) would be a to-be-targeted performance objective.

Thirdly, it is necessary to identify the **underlying determinants** that explain why current performance on the relevant behavioural factors is not satisfying. Typically, these determinants rest within individuals (e.g. mental or physical capabilities, motivation-oriented variables like beliefs, attitudes, norms, self-efficacy, et cetera) or relate to factors in the physical or social environment that currently encourage (or discourage) continuation of behaviour or facilitate (or hinder) behavioural change. To illustrate, tailgating might be explained in function of biased risk perception (e.g. a driver underestimating the danger of a too short headway distance). Correction of such a biased risk perception would be the so-called **change objective** to be targeted.

Fourthly, in order to be able to maintain the causal link that connects the different layers of objectives with each other (i.e. change objectives → performance objectives → safety promoting goals → safety outcomes) so-called **matrices of change** have to be composed. In these matrices, performance objectives (on the vertical axis) are crossed with their underlying determinants (on the horizontal axis) with the change objectives appearing in the crossing cells (see section 6.2). From these matrices**, a logic model of behavioural change** can be derived (i.e. task five).

3.1.3 Step 3: Intervention design

The third step of IM consists of **three subtasks**. First, it needs to be specified what will be the extent and length of the intervention and how the different intervention components or materials will be offered to users (what will be **the intervention's scope and sequence**?). In the i-DREAMS project, these issues will be addressed in two different work packages. In work package three, task 3.4 (i.e. design of the experimental protocol) will outline when and for how long the i-DREAMS interventions will run, and in which order they will be implemented. In work package four, task 4.3 (i.e. implementation of driver feedback and gamification interventions post-trip) and task 4.4 (i.e. implementation of active driving interventions during trip) will outline how the different components and sub-components of the real-time and post-trip interventions will be deployed. For instance, for the post-trip interventions, it will be indicated that these consist of several gamification features, and that those gamification features will not be activated all at the same time, but depending on when they are relevant for an end-user of the intervention.

The key-task in step 3 is **to select theory- and evidence-based change methods** to achieve the targeted change- an performance objectives. For instance, if according to our logic model of the problem, a reduction of tailgating events (i.e. performance objective) requires an improvement in terms of risk perception (i.e. change objective), the question to address in step 3 is to find out which methods are available and suitable to change risk perception.

The final task then is to translate these change methods into **practical applications** and to identify what are the main so-called **critical design parameters**, i.e. characteristics regarding how a change method is practically applied that determine whether the change method will be effective (or not). Applied to the illustrative example of tailgating and risk perception: to avoid the selected method to change risk perception would be practically

applied in an ineffective way, it needs to be explored whether the effectiveness of the selected method is dependent upon certain critical design parameters. The selection of change methods will be addressed in section 6.3.1 of this deliverable, and the identification of critical design parameters will be the focus of section 6.3.2. The transformation of change methods into practical applications is discussed in section 6.3.3.

3.1.4 Step 4: Intervention production

The fourth step of the Intervention Mapping protocol consists of **four subtasks**. The first task is to start **preparing designs for all the required materials or front-end functionalities** of the interventions. This task will be addressed in section **Error! Reference source not found.** of this deliverable. Those designs will guide **the production process** to make sure that all the materials stay relevant to the program objectives.

Each of the selected change methods will be **operationalized or practically applied** through different channels and the messages, required materials and protocols to do so should be drafted. The back-end data flows and protocols that support deployment of the real-time and post-trip interventions will not be addressed in this Deliverable, but in Deliverable 3.5 (i.e. Standard protocol for the handling of big data).

After drafting these different aspects, a **pre-test** is to be done to test the characteristics of the intervention materials with the intended participants. In the i-DREAMS project, a series of simulator experiments are foreseen to pre-test possible options for the real-time interventions (see Work Package five, task 5.3). Moreover, a pilot-test is foreseen within the field trial protocol, to gain exploratory experience with the implementation of both the real-time and post-trip interventions (see Work Package five, task 5.4).

3.1.5 Step 5: Intervention implementation

The fifth step of IM consists of **four subtasks**. The first task is **to select implementation partners** among several possible organizations that have a good potential to reach the intended program participants. As already indicated, this will be particularly important in the case of the professional vehicle operators in the i-DREAMS project (i.e. bus, truck, tram, and train), as research in the field of occupational safety has found that the safety-orientation of individual workers is substantially dependent upon whether or not the organization as a whole is safety-oriented or not (see section 5.2). The second and third task are to determine, **who of the implementation partners has to do what** to achieve the outcomes of the intervention. Strictly taken, the same procedure as the one outlined in step 2 is to be repeated (i.e. to develop matrices of performance and change objectives for the implementation partners). In the i-DREAMS project, the roles of the implementation partners involved in the interventions targeting professional vehicle operators will be described more in detail in another task of work package three, i.e. task 3.4. The final task then is to select methods appropriate to **promote the desired behaviour among the implementation partners** and to turn these into practical applications. This however, falls outside the scope of this deliverable where the focus will be primarily on what the planned i-DREAMS interventions imply for the primary target groups (i.e. private car drivers and professional bus, truck, tram, and train operators).

3.1.6 Step 6: Intervention evaluation

The sixth and final step of IM comprises **four subtasks**. Firstly, **effect and process evaluation questions need to be formulated**. Effect evaluation applies to whether targeted factors changed as a result of the intervention or not. Process evaluation aims to determine which parts of the intervention were effective and which not. To that end, the targeted objectives (i.e. safety outcomes, safety promoting goals, performance objectives, and change objectives) need to be **operationalized**. This requires a categorization of specific indicators and a further translation into (in)directly observable measures. The next step is to specify the **evaluation design**. Both qualitative and quantitative measures should preferably be included when evaluating an intervention. The last task is to **carry out the evaluation plan**. In the i-DREAMS project, a separate work package is dedicated to intervention evaluation (i.e. work package 7).

In sum, to develop the operational toolbox for the i-DREAMS interventions (i.e. main target of deliverable 3.3), IM will be applied. This is a six-step protocol going from a logic analysis of the problem targeted to the execution of an evaluation plan. For step one of the protocol (i.e. logic analysis of the problem), this deliverable will fall back substantially to work already carried out in work package 2 (i.e. Deliverable 2.1 and 2.2). Step two (i.e. logic model of change), step three (i.e. intervention design), and step four (i.e. intervention production) will be addressed in this deliverable. Step 5 (i.e. intervention implementation) will only be partially addressed, as it will be elaborated more in detail in deliverable 3.4. Step 6 falls outside the scope of this deliverable and will be discussed in work package 7. Before turning to a description of the operational toolbox for the i-DREAMS interventions itself, the next section will focus on some theoretical foundations of behavioural change that are to be considered.

4 Behaviour Based Safety Interventions: Theoretical foundations

This part of Deliverable 3.3 starts with a taxonomic overview of the different intervention strategies to promote road safety that can be found in the field of transportation (see section 4.1). The following three sections elaborate on theoretical foundations for behavioural change, to be taken into account when designing the operational toolbox for the i-DREAMS interventions. Section 4.2 will address theoretical principles specifically relevant for the design of the real-time interventions. Section 4.3 discusses a few frameworks that apply to both the real-time and the post-trip interventions. Finally, section 4.4 addresses theoretical principles that are to be considered for the design of the post-trip interventions.

4.1 Taxonomy of intervention strategies to promote road safety

Figure 6 brings the different intervention strategies to promote road safety that can be found in the literature together in **a taxonomic overview**.

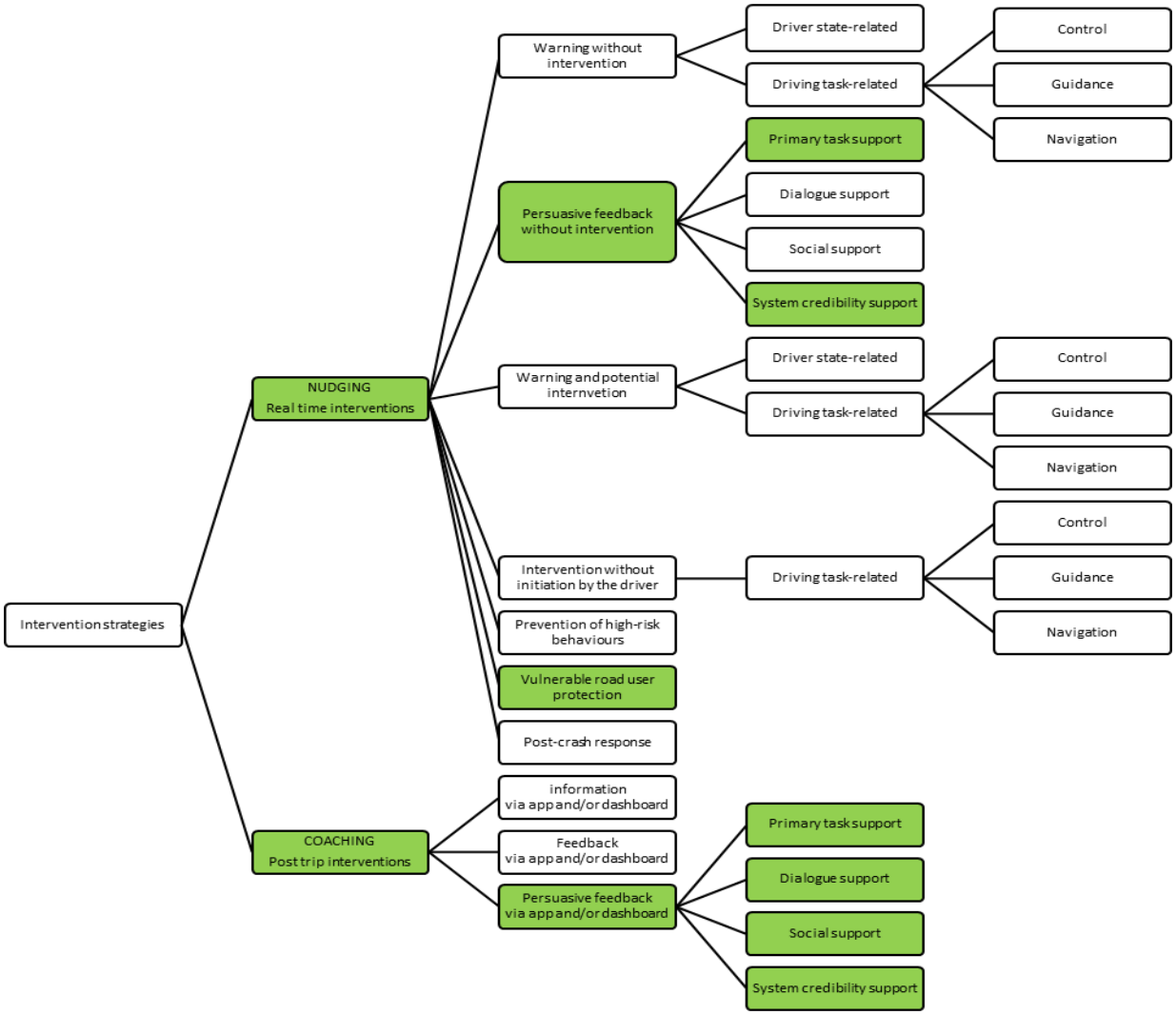


Figure 6: Taxonomy of intervention strategies to promote road safety (strategies selected for inclusion in the i-DREAMS project are marked in green)

Those intervention strategies that will be selected for development and implementation in the i-DREAMS project are marked in green. For a detailed description of the concepts appearing in this figure, we refer to **Deliverable 2.2 (see section 2.4. and section 3.1)**. As can be derived from Figure 6, **nudging and coaching** can be roughly considered as the two basic intervention paradigms for the promotion of road safety. The nudging paradigm refers to a real-time intervention approach, while the coaching paradigm refers to a pre- or post-trip approach. As discussed in section 2.5.1 of this Deliverable, the i-DREAMS intervention module will combine both nudging and coaching, which is why these two boxes have been marked in green.

Inside the nudging paradigm, seven more specific formats have been identified in the literature on Advanced Driver Assistance Systems (ADAS) (e.g. ADAS&ME-project). **Two formats will be selected** for inclusion in the i-DREAMS project, i.e. **persuasive feedback without intervention**, and **vulnerable road user protection**. Regarding the latter format, it is indeed the case that vulnerable road user protection is a possibility within the i-DREAMS project, as one of the sensor systems available (i.e. **Mobileye®**) has **a vulnerable road user (pedestrians and cyclists) collision warning functionality**.

Turning to the other format (i.e. persuasive feedback without intervention), it was already explained in Deliverable 2.2 (see section 2.7) that the key-characteristic of *persuasive* feedback is that it does more than just warning or informing a vehicle operator. Rather, persuasive feedback is aimed at reinforcing, changing or shaping attitudes or behaviours (or both), but without the use of coercion or deception (Oinas-Kukkonen & Harjumaa, 2008). As for 'persuasive feedback without intervention', one of the main reasons to opt for this format, was both theoretical as well as empirical evidence available, indicating that persuasive feedback is more effective than only offering warnings or purely informative feedback, especially when it comes to user retention, i.e. the ability to keep users engaged over longer time episodes (e.g. Musicant et al., 2015). Moreover, warnings or feedback alone do not necessarily activate the required self-regulatory processes targeted to realize the desired behavioural change (e.g., Bandura & Cervone, 1983; Cervone & Wood, 1995; Kluger & DeNisi, 1996; Hickman & Hanowski, 2011) (see Deliverable 2.2, section 2.4 and section 2.7 for detailed discussions on this topic). According to the Persuasive Systems Design (PSD) Model, a technological system can become persuasive if it supports the user in (one or a combination of) four possible ways, i.e., via delivery of primary task support, dialogue support, social support, or system credibility support (Oinas-Kukkonen & Harjumaa, 2009). In the i-DREAMS project, **primary task support** is actually aimed at as a successful and efficient completion of the driving task with a specific focus on how safely drivers operate their vehicle. Dialogue support is aimed at establishing a longer term connection with the driver as a way to keep him/her motivated to work on a more continuous improvement of his/her own driving style in terms of how safe it is. Social support hinges upon the idea that humans continuously crave for social connectedness, and individual behaviour in the context of social life phenomena (like participating in traffic) is significantly regulated by social norms. **System credibility support** is about fostering trust and acceptance in technology-provided feedback. As can be seen in Figure 6, the real-time interventions provided by the i-DREAMS platform will focus on primary task support and system credibility support. The potential for real-time in-vehicle interventions to safely persuade a driver to change his/her behaviour has been conceptually demonstrated in a study by van Gent et al. (2019). More in detail, in that study, a framework for driver persuasion at the tactical level (i.e. the level where vehicle manoeuvres like lane changing or car following are situated) was proposed. As for system credibility support, the importance of trust in the context of technology acceptability, has been

supported at various instances before (e.g. Risto & Martens, 2013; Regan et al., 2014; Rahman et al., 2018). Reasons for the i-DREAMS real-time interventions not to focus on dialogue support and social support, are distraction while driving and lack of appropriate technology, respectively. As already noticed by van Gent et al. (2019) keeping the vehicle operator engaged in an active dialogue *while driving*, would be in conflict with the idea that all available resources should be dedicated to the driving task. As for the possibility to provide social support while driving, work by Rakotonirainy et al. (2014) has shown that this requires V2V communication, which is not an option in the context of the i-DREAMS project.

The five other nudging formats will not be included in the i-DREAMS project. For the format based on warnings without active intervention, that decision is mainly based on empirical indications from the literature that in terms of effectiveness, this format seems to score rather low on the retention criterion. In other words, warnings only (without active intervention) seem to be losing effect quite quickly, sometimes even already after a few weeks, with vehicle operators starting to ignore or deactivate such systems (e.g. Toledo & Lotan, 2006; Musicant et al., 2007; Toledo et al., 2008; Musicant et al., 2011; Musicant et al., 2015; Musicant & Lotan, 2016). Three other formats are also excluded simply because they fall outside the scope of the i-DREAMS project. More in detail, the two formats labelled as 'warning and potential intervention', and 'intervention without initiation by the driver' imply the possibility for technology to actively intervene while driving and take over vehicle control from the human operator. This level of intrusiveness in terms of vehicle control is not what the i-DREAMS project is about. On the contrary, the i-DREAMS interventions are meant to assist and support drivers in their decision-making, but without taking over behavioural control. The format labelled 'post-crash response' is retained neither, because of the same reason: expressed in terms of the Haddon Matrix, the i-DREAMS interventions are targeting the pre-crash state, instead of the crash – or post-crash states (Haddon, 1980, 1999). Despite its relevance for road safety, the format labelled 'prevention of high risk behaviour' (like substance impaired driving, or non-use of seatbelt) is not included either, mainly because the required technology to implement this format is not available (as is the case for substance impaired driving), or already present in most vehicles (as is the case for instance for seatbelt reminders).

Inside the coaching paradigm, three different formats can be found in the literature. One of these, i.e. **post-trip persuasive feedback via smartphone app and/or an online web-dashboard** will be selected for development and implementation in the i-DREAMS project. The main reason to prefer this format over the other two, is related to what was already mentioned, i.e. the finding that persuasive feedback is considered as more effective than information or descriptive feedback only (i.e. feedback without an indication of what in terms of current performance needs to be improved (so-called 'feedup'), and how to achieve that improvement (so-called 'feedforward')). Due to the fact that post-trip interventions are operational in another window of opportunity and based on the extensive possibilities for social interaction offered by the internet, the option to **also provide dialogue- and social support** to vehicle operators, becomes a realistic target. Also regarding primary task support and system credibility, a post-trip setting offers additional opportunities. For instance, **credible and authoritative agents** (e.g. a coach, colleague, buddy, friend, et cetera) situated in the social environment of vehicle operators **can be actively involved in an online platform to share their experiences and expertise**, thereby increasing vehicle operators' motivation and capabilities to improve their current driving style. Moreover, in a post-trip setting, **primary task support should not be limited to the tactical level of the driving task**, as is the case in a real-time setting. Indeed, in a post-trip context, vehicle

operators can receive support in optimizing their performance on competences situated at other levels of the driving task, like **the strategic level**, which is more related to route choice-related decisions (e.g. when to start a trip, which route to follow, what travel modality to use, et cetera), and to strategies to cope with factors that relate to the trip context itself (for instance, how to deal with possible sources of distraction). It is even possible to work on the **highest levels of the driving task** as well, where the focus is more on safety-related opinions, attitudes, norms and values, self-assessment skills, social responsibility, et cetera (e.g. Michon, 1985; Hatakka et al., 2002).

The great potential in terms of effectiveness and user acceptance was also demonstrated in Deliverable 2.2 (see section 4). A structured multi-modal review of both academic literature as well as available commercial solutions found that for car, bus and truck, the use of post-trip persuasive feedback via smartphone app and/or an online web-dashboard is becoming the predominant coaching format.

To summarize, the i-DREAMS project will combine the two major intervention paradigms (i.e. nudging and coaching) that can be found in the literature on transportation and road safety. Within the **nudging paradigm**, the following two more specific formats will be adopted: **vulnerable road user protection**, and **persuasive feedback without active intervention** where the latter can also be targeted at the protection of vulnerable road users as one particular aspect of the driving task. Persuasion in real-time will focus on primary task support (i.e. **steering of human decision making at the tactical level of the driving task**), and system credibility support (i.e. **gaining trust through the provision of reliable feedback**). Within the **coaching paradigm**, the format where **persuasive feedback is offered in a post-trip setting via app and/or online web-dashboard** will be adopted. Four different support functionalities will be targeted, i.e. primary task support (i.e. **empowering human decision making at each of the hierarchical levels of the driving task**), dialogue support (i.e. **establishing a longer-term relationship with the end-user**), social support (i.e. **active involvement of relevant social agents**), and system credibility support (i.e. **gaining trust via reliable feedback and involvement of respected experts**). The next section will turn to the real-time interventions and will outline a set of theoretical principles for behaviour change that are specifically relevant for that intervention paradigm.

4.2 Real-time interventions

A crucial ingredient of the real-time interventions will be the offering of messages inside the vehicle and while driving as a way to steer the vehicle operator's tactical decisions in order to promote a safer driving style. In **Deliverable 2.2 (see section 2.4), a detailed review** has been presented of both theoretical and empirical research on what determines the effectiveness of in-vehicle messaging while driving. One specific model was referred to that summarizes the most important findings obtained so far in this specific research area, i.e. The Eco-feedback design-behaviour framework (Sanguinetti et al., 2017; Sanguinetti et al., 2018). Although originally developed for eco-driving, the model is very well suitable for application in other domains (such as road safety) as well.

4.2.1 Theoretical guidelines for effective design of real-time messages

The Eco-feedback design-behaviour framework is visualized in Figure 7. Summarized, the framework contends that for real-time messaging to be effective, it should be **salient** (i.e. it must attract attention), **precise** (i.e. it should trigger a learning process), and **meaningful**

(i.e. it should induce the appropriate motivation). These three requirements are primarily dependent upon three specific design features, i.e. **information**, **display**, and **timing**. For each of these three design features, more specific properties are proposed that are assumed to determine the effectiveness of real-time messaging (Sanguinetti, 2019). For more detailed information on these properties, we refer to Deliverable 2.2 (section 2.4).

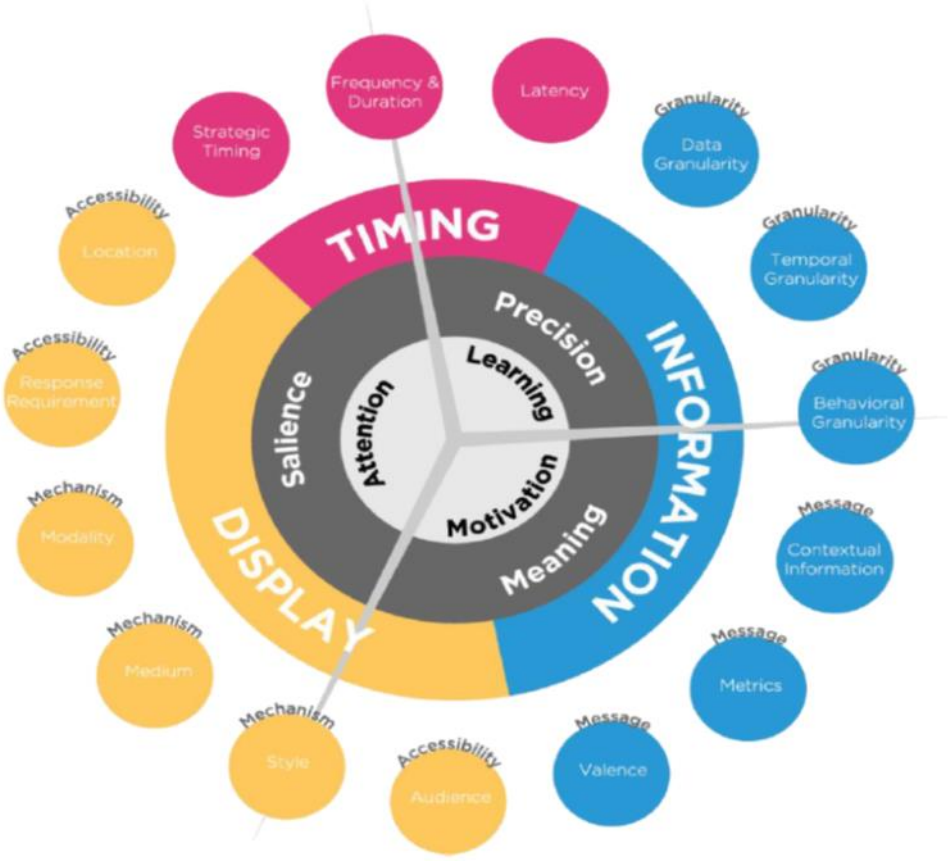


Figure 7: The Eco-feedback design-behaviour framework. Source: Sanguinetti (2018)

Sanguinetti (2018) also conducted a meta-analysis to formally test a set of fourteen hypotheses deducted from the proposed framework. All of these were supported by behavioural theory and past empirical research. Even though only one out of the fourteen hypotheses could be supported in a statistically significant way, i.e. the negative relationship between length of intervention (i.e. number of days drivers were exposed to feedback) and feedback effectiveness, lack of statistically significant support for the other hypotheses focusing on feedback design and context variables was likely related to small sample sizes. Notwithstanding, trends could be identified that aligned with the forwarded hypotheses, suggesting that **feedback should best:**

- be provided in **multiple modalities**,
- include **both fine- and course-grained** information,
- provide **standards of performance comparison**,
- integrate **game features** (like points, levels or badges), and
- be **combined with other behavioural change metods** such as education and/or rewards contingent on performance.

These findings were partially confirmed by the literature review that was reported in Deliverable 2.2 (see section 2.10 for more details). It seemed that **the best messaging strategy would be a multi-stage, multi-modal strategy** as visually illustrated by Figure 8.

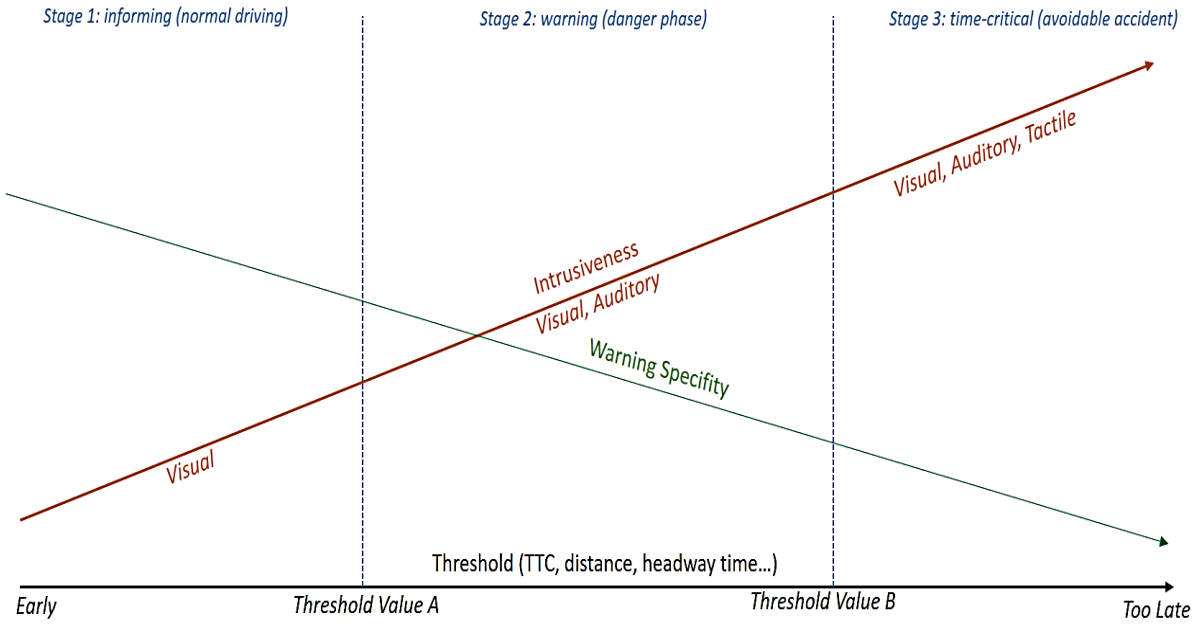


Figure 8: Real-time messaging strategy to keep drivers in the STZ. Source: Deliverable 2.2.

As can be seen **messaging** in the context of the i-DREAMS project would preferably be **adjusted to each specific stage of the STZ**, which aligns with the idea of **situation-adaptive driver assist systems** (e.g. Inagaki, 2007). Available literature showed it is beneficial for vehicle operators to be informed early, but in a non-intrusive way. By using visual (non-intrusive) and detailed messages in the first stage, the vehicle operator has all the information available. In case the vehicle operator is not adapting to the situation, he or she will move on to a second stage (i.e. the danger phase). In that second stage, messages should be made more intrusive, for instance, by adding auditory warnings and/or making the visual warning blink. In a third stage (i.e. avoidable crash), immediate action from the driver is required, and at this point warnings should not be specific at all and should be intrusive (without startling the vehicle operator) to immediately capture the vehicle operator's attention or even trigger an intuitive reaction. At all times, information or warnings should be presented in an intuitive way that does not overload the vehicle operator's current cognitive resources. The next section will be dedicated to three theoretical frameworks that are relevant for both the real-time and the post-trip interventions.

4.3 Real-time interventions & post-trip interventions

In this section, four theoretical frameworks will be presented that are relevant in the context of step 1 (i.e. development of a logic model of the problem), step 2 (i.e. development of a logic model for change) and step 3 (i.e. intervention design) of IM. The first framework (i.e. **the COM-B Model**) serves as a blueprint to inventory what according to the field of behavioural sciences are key-determinants to be considered in the context of analysing a behaviour-based problem, irrespective of whether the focus is on real-time or post-trip interventions. This model will thus be relevant later on in this Deliverable when step 1 of IM

will be applied (see section 6.1), and in step 2 where change objectives will have to be formulated (see section 6.2). The second and third framework are evidence-based support tools to be used in step 3 of IM where suitable methods to change behaviour and its underlying determinants have to be selected (see section 6.3.1). More in detail, the second framework (i.e. **the Behaviour Change Techniques Taxonomy v1**) is an inventory of available change methods or techniques. Different from that, the third framework (i.e. **the IM Taxonomy of Behavior Change Methods**) is not just a descriptive inventory, but a decision-tool, meant to help intervention planners in how to appropriately select and use change methods. The fourth framework (i.e. **The Table of Gamification Elements**) is also a decision support tool to be used in step 3 of the IM framework, more precisely when translating selected change methods into practical applications (see section 6.3.3).

4.3.1 Theoretical guidelines for identification of determinants: the COM-B Model

Changing human behaviour, whether in real-time or post-trip, **is a very complex challenge** because of the **multitude of variables or 'determinants' involved** (e.g., Kok et al., 2004; Michie & Johnston, 2012; Kok et al., 2016). Over the years, a wide variety of theoretical models has been developed in the field of behavioural sciences meant to explain the process of behavioural formation and to propose the key-determinants involved in that process. Though very helpful, the wealth of theory available does not always make it easy for intervention developers to make well-informed choices in terms of how to use theory. As argued by Michie et al. (2005: p. 26-27): "*This range of theoretical elaboration makes it difficult to know how to select and apply psychological theories.*" Davis et al. (2015) subscribe to this and agree that choosing a relevant theory can be a challenging task for intervention designers, especially given the large number of theories with many of these containing the same or overlapping constructs. This **lack of guidance on how to select an appropriate theory for a particular purpose**, has raised the need for clarification and simplification in order to increase the accessibility and usefulness of psychological theory (e.g. Stavri & Michie, 2012). The **COM-B Model** was intended as a response to this call for theoretical clarification and simplification and is to be understood as **a holistic summary** of more than thirty different psychological theories (Michie et al., 2011; Michie et al., 2014). The COM-B Model is visualized in Figure 9.

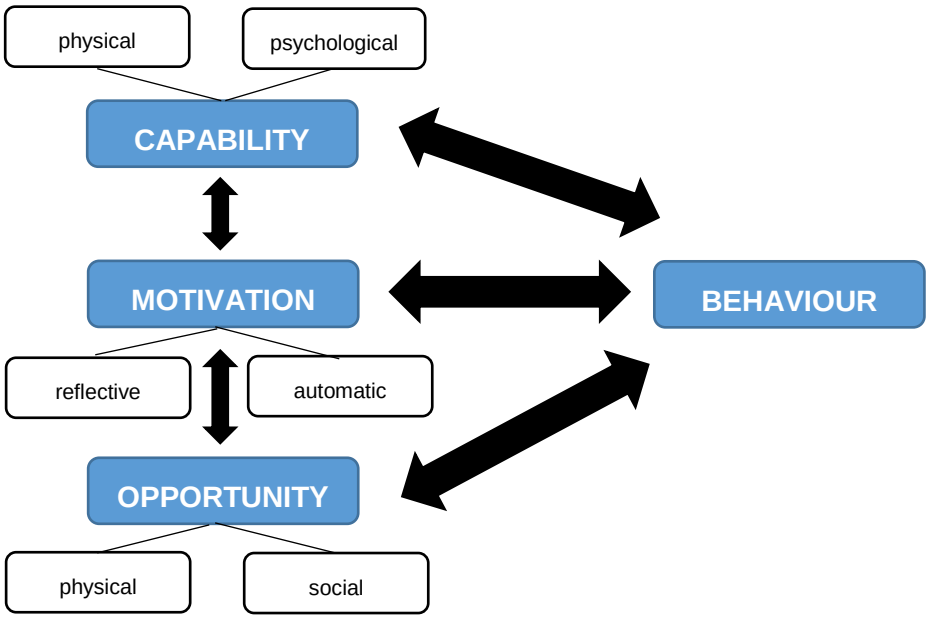


Figure 9: The COM-B Model. Source: adapted from Michie et al. (2014)

The acronym COM-B refers to capability, opportunity, motivation and behaviour. These **components interact** as illustrated by the interlinking arrows so that, for example, increasing opportunity or capability can increase motivation. Increased motivation can lead people to do things that will increase their capability or opportunity to perform, adopt or change a certain behaviour. For example, owning a bicycle (opportunity) or being able to ride a bicycle (capability) might increase motivation to ride a bicycle, but motivation alone will not improve riding skills or afford access to a bicycle unless the individual acts (behaviour) on this motivation to buy a bike or to practise bicycle riding. So, the central tenet of the model is that for any behaviour to occur, one or more of these three concepts are required:

- **Capability** actually refers to a person's ability to perform a certain behaviour, or not. As can be seen in Figure 9, the capability concept further splits up into two dimensions that represent the two human resources that determine a person's overall capability, i.e. **psychological capability** (e.g. having the knowledge, psychological skills, strength or stamina to perform the behaviour), and **physical capability** (e.g. having the physical skills, strength or stamina to perform the behaviour). Next to capability, motivation is a second key-concept in the context of behaviour formation and change.
- **Motivation** relates more to a person's willingness to perform a certain behaviour (or not). Depending on which system of thinking (i.e. the 'automatic' system 1 or the 'reflective' system 2, see section 2.5.1 for more details) generates motivation, a distinction is made between **automatic motivation** (e.g. processes involving wants and needs, desires, impulses and reflex responses) and **reflective motivation** (e.g. self-conscious planning and evaluations such as beliefs about what is good or bad).
- **Opportunity** is the third key-concept in the model and refers to whether there is a facilitator or inhibitor present that enables or prevents a person to perform a certain behaviour or not. **Physical opportunity** relates to what the environment allows or facilitates in terms of time, triggers, resources, locations, physical barriers, et cetera. **Social opportunity** refers to whether there are interpersonal influences, social cues or cultural norms present that could facilitate or inhibit performance of a certain behaviour.

To simplify the multitude of candidate-variables that could be used **to operationalize each of the six above mentioned concepts**, an interdisciplinary panel of experts was consulted to reduce a set of 128 individual variables derived from more than 30 theories into 14 so-called theoretical domains, i.e. the **Theoretical Domains Framework** (TDF). Table 6 gives formal definitions for each of the 14 theoretical domains, together with individual variables or 'constructs' that can be situated within each domain, and an illustrative question to better understand how to interpret the different theoretical domains and their respective constructs.

Table 6: The Theoretical Domains Framework. Source: Michie et al. (2014: p. 88-90, Table 1.5)

Domain **Definition**	**Theoretical constructs represented within each domain**	**Illustrative questions**
Knowledge An awareness of the existence of something	Knowledge (including knowledge of condition/scientific rationale); procedural knowledge; knowledge of task environment	*Do you know about x?*

Skills An ability or proficiency acquired through practice	Skills; skills development; competence; ability; interpersonal skills; practice; skill assessment	*Do you know how to do x?*
Memory, attention and decision processes The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives	Memory; attention; attention control; decision making; cognitive overload/tiredness	*Is x something you usually do?*
Behavioural regulation Anything aimed at managing or changing objectively observed or measured actions	Self-monitoring; breaking habit; action planning	*Do you have systems that you could use for monitoring whether or not you have carried x?*
Social/professional role and identity A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting	Professional identity; professional role; social identity; identity; professional boundaries; professional confidence; group identity; leadership; organisational commitment	*Is doing x compatible or in conflict with professional standards/identity?*
Beliefs about capabilities Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use	Self-confidence; perceived competence; self-efficacy; perceived behavioural control; beliefs; self-esteem; empowerment; professional confidence	*How difficult or easy is it for you to do x?*
Optimism The confidence that things will happen for the best or that desired goals will be attained	Optimism; pessimism; unrealistic optimism; identity	*How confident are you that the problem of implementing x will be solved?*
Beliefs about consequences Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation	Beliefs; outcome expectancies; characteristics of outcome expectancies; anticipated regret; consequents	*What do you think will happen if you do x?*
Intentions A conscious decision to perform a behaviour or a resolve to act in a certain way	Stability of intentions; stages of change model; transtheoretical model and stages of change	*Have they made a decision to do x?*
Goals Mental representations of outcomes or end states that an individual wants to achieve	Goals (distal/proximal); goal priority; goal/target setting; goals (autonomous/controlled); action planning; implementation intention	*How much do they want to do x?*
Reinforcement Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus	Rewards (proximal/distal, valued/not valued, probable/impossible); incentives; punishment; consequents; reinforcement; contingencies; sanctions	*Are there incentives to do x?*

Emotion A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event	Fear; anxiety; affect; stress; depression; positive/negative affect; burn-out	*Does doing x evoke an emotional response?*
Environmental context and resources Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour	Environmental stressors; resources/material resources; organisational culture/climate; salient events/critical incidents; person x environment interaction; barriers and facilitators	*To what extent do physical or resource factors facilitate or hinder x?*
Social influences Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours	Social pressure; social norms; group conformity; social comparisons; group norms; social support; power; intergroup conflict; alienation; group identity; modelling	*To what extent do social influences facilitate or hinder x?*

As already mentioned, the COM-B Model and the Theoretical Domains Framework will be useful support tools when developing a logic model of the problem (step 1 of IM), and proposing a logic model for change (step 2 of IM). The next section will address the BCTT v1 and the IM-TBCM, i.e. two frameworks, which are meant to make informed decisions on appropriate change methods.

4.3.2 Theoretical guidelines for identification, selection and use of change methods: the BCTT (v1) and the IM-TBCM

A behaviour change technique can be defined as an active component of an intervention designed to change behaviour (Michie et al., 2014). The term 'change technique' is sometimes used as a (debated) synonym of the word 'change method'. Throughout the remainder of this Deliverable, we will use the term change method to avoid unnecessary confusion. The BCTT (v1) is an **extensive, consensually agreed structured taxonomy of methods to change behaviour**. The BCTTv1 was developed based on a Delphi-type study where 14 experts rated labels and definitions of 124 behaviour change methods from six different published classification systems. In addition to that, another 18 experts grouped these different behaviour change methods together according to similarity of active ingredients in an open-sort task with inter-rater agreement assessed amongst six researchers coding 85 intervention descriptions by behaviour change methods. The result is a taxonomy containing **93 behaviour change methods, clustered together into 16 groups** (Michie et al., 2008; Michie et al., 2013; Carey et al., 2019; Connell et al., 2019). For a detailed overview of this taxonomy, we refer to Table 14 in Appendix 1.

As noted by Kok et al. (2016), the BCTT (v1) is actually a descritipve inventory, from which one can select change methods. However, it is not a decision-tool providing guidance on how to select and appropriately use change methods. The **Intervention Mapping-Taxonomy of Behavior Change Methods** was created exactly for that purpose. As Kok et

al. (2016) explain, the IM-TBCM indeed not only proposes formal defintions of change methods that have been described in the literature, but **couples change methods to specific determinants** to guide intervention planners in how to make appropriate decisions on what method(s) to select for behavioural determinants that require change. Moreover, evidence-based **critical parameters are proposed** that determine the effectiveness of change methods, when translated into suitable 'practical applications'. Thus, different from the BCTT (v1), **the IM-TBCM is meant to be a decision-tool**. Table 7 below shows an extract from the IM-TBCM to illustrate its content and structure. It shows a set of basic techniques suitable to influence behavioural determinants of individuals. For an overview of the complete taxonomy, see http://effectivebehaviorchange.eu.

Table 7: IM-TBCM: Table 1: Basic Methods at the Individual Level (Adapted from Bartholomew et al., 2011)
Source: http://effectivebehaviorchange.eu

Method (related theories & references)	Definition	Parameters
Participation (Diffusion of Innovations Theory; Theories of Power; Organizational Development Theories; Models of Community Organization; Cummings & Worley, 2015; McCullum, Pelletier, Barr, Wilkins, & Habicht, 2004; Rogers, 2003; WHO Regional Office for Europe, 2002)	Assuring high level engagement of the participants' group in problem solving, decision making, and change activities; with highest level being control by the participants' group.	Requires willingness by the health promoter or convener to accept the participants as having a high level of influence; Requires participants' group to possess appropriate motivation and skills.
Belief selection (Theory of Planned Behavior; Reasoned Action Approach; Fishbein & Ajzen, 2010)	Using messages designed to strengthen positive beliefs, weaken negative beliefs, and introduce new beliefs.	Requires investigation of the current attitudinal, normative and efficacy beliefs of the individual before choosing the beliefs on which to intervene.
Persuasive communication (Communication-Persuasion Matrix; Elaboration Likelihood Model; Diffusion of Innovations Theory; McGuire, 2012; Petty, Barden, & Wheeler, 2009; Rogers, 2003)	Guiding individuals and environmental agents toward tha adoption of an idea, attitude, or action by using arguments or other means.	Messages need to be relevant and not too discrepant from the beliefs of the individual; can be stimulated by surprise and repetition. Will include arguments.
Active Learning (Elaboration Likelihood Model; Social Cognitive Theory; Kelder, Hoelscher, & Perry, 2015; Petty et al., 2009)	Encouraging learning from goal-driven and activity-based experience.	Time, information, and skills.
Tailoring (Trans-Theoretical Model; Precaution Adoption Process Model; Protection Motivation Theory; Communication-Persuasion Matrix; Lustria, Cortese, Noar, & Glueckauf, 2009; McGuire, 2012; Weinstein, Sandman, & Blalock, 2008; Werrij, Ruiter, van 't Riet, & de Vries, 2012)	Matching the intervention or compoments to previously measured characteristics of the participant.	Tailoring variables or factors related to behaviour change (such as stage) or to relevance (such as culture or socioeconomic status).

Individualization (L.K. Bartholomew et al., 2000; L.K. Bartholomew, Czyzewski, Swank, McCormick, & Parcel, 2000; Prochaska, Redding, & Evers, 2015)	Providing opportunities for learners to have personal questions anwered or instructions paced according to their individual progress.	Personal communication that responds to a learner's needs.
Modeling (Social Cognitive Theory; Theories of Learning; Kazdin, 2008; Kelder et al., 2015)	Providing an appropriate model being reinforced for the desired action.	Attention, remembrance, self-efficacy and skills, reinforcement of model; identification with model, coping model instead of mastery model.
Feedback (Theories of Learning; Goal-setting Theory; Social Cognitive Theory; Kazdin, 2008; Kelder et al., 2015; Latham & Locke, 2007)	Giving information to individuals and environmental agents regarding the extent to which they are accomplishing learning or performance, or the extent to which performance is having an impact.	Feedback needs to be individual, follow the behavior in time, and be specific.
Reinforcement (Theories of Learning; Social Cognitive Theory; Kazdin, 2008; Kelder et al., 2015; McSweeney & Murphy, 2014)	Providing reinforcement: linking a behavior to any consequence that increases the behavior's rate, frequency or probability.	Reinforcement need to be tailored to the individual, group, or organization, to follow the behavior in time, and to be seen as a consequence of the behavior.
Punishment (Theories of Learning; Kazdin, 2008; McSweeney & Murphy, 2014)	Providing punishment: linking a behavior to any consequence that decreases the behavior's rate, frequency or probability.	Punishment need to be tailored to the individual, group, or organization, to follow the behavior in time, and to be seen as a consequence of the behavior. Punishment should be avoided because of negative side effects. If used, emphasis should be on positive reinforcement.
Motivational Interviewing, MI (Self-dtermination theory; Theories of self-regulation; Miller & Rollnick, 2012; Ng et al., 2012; Ryan & Deci, 2000)	Providing a collaborative, goal-oriented style of communication with particular attention to the language of change; designed to strengthen personal motivation for and commitment to a specific goal by eliticing and exploring the person's own reasons for change within an atmosphere of acceptance and comparison.	A supportive relationship between client and professional combined with the evocation of patient change talk. Professionals must recognize that MI involves collaboration not confrontation, evocation, not education, autonomy rather than authority, and exploration instead of explanation.
Facilitation (Social Cognitve Theory; Bandura, 1986)	Creating an environment that makes the action easier or reduces barriers to action.	Requires real changes in the environment instead of in the perceptions of the environment. Requires the identification of barriers and facilitators and the power for making the appropriate changes. Facilitating conditions on one environmental level are usually

		dealt with by intervening on a higher environmental level.
Nudging (Theories of Automatic, Impulsive, and Habitual Behavior; de Ridder, 2014; Thaer & Sunstein, 2008)	Simple changes in the presentation of choice alternatives that make the desired choice the easy, automatic or default choice.	Requires autonomy: freedom of choice, a sense of awareness, and the healthy choice being default: easy and attractive.

The next section will focus on another framework (i.e. the Table of Gamification Elements), which serves as an instrument to translate selected change methods into practical applications.

4.3.3 Theoretical guidelines for practical application: the Table of Gamification Elements

Gamification is about the **application of game-specific design elements**, mechanisms and features outside the context of entertainment and play, i.e. **in a non-gaming context** (Deterding, et al., 2011; Rigby and Ryan, 2011; Burke, 2014). The main purpose of gamification is to trigger the motivation to reinforce, change or shape a desired behaviour, and to sustain this effect over time by developing so-called intrinsic motivation. According to Oinas-Kukkonen & Harjumaa (2008), gamification is a very suitable approach to turn technology (e.g. interactive information technology like the Web, Internet, mobile- and other ambient technologies, but in-vehicle devices for driver assistance as well) into a persuasive system. In other words, **gamification allows abstractly formulated methods for changing behaviour and its underlying determinants, to 'materialize' into concrete and specific practical applications**.

Relevant for the i-DREAMS interventions is that gamification has **already received attention both in the context of real-time interventions and post-trip interventions**, with applications to road safety and eco-driving (e.g. Rakotonirainy et al., 2014; Vaezipour et al., 2015). In the field of eco-driving, the interest in gamification for the design of real-time interventions came from evidence found in the literature that fuel efficiency can be achieved via positive interactions between vehicle operators and in-vehicle systems (e.g. Barth & Boriboonsomsin, 2009; Strömberg & Karlson, 2013; Larue et al., 2014). Within the automotive domain, this raised the interest in gameful design (e.g. Diewald et al., 2013), resulting in a first series of studies empirically exploring acceptance and efficacy of **persuasive or 'gamified' in-car interfaces** (e.g. Huang et al., 2005; Pace et al., 2007; Meschtscherjakov et al., 2009; Bellotti et al., 2014; McIlroy et al., 2014; Vaezipour et al., 2017, 2018, 2019). The use of **gamification principles in mobile applications and online dashboards meant to coach drivers in a post-trip setting** has also attracted much interest over the last decade. In **Deliverable 2.2 (see section 4.2)**, more than thirty of such **commercialized applications** were identified and reviewed. Typically, such telematic recording web-based platforms use **big data and machine learning algorithms** to reliably quantify the risk associated with a specific driving behaviour (e.g. speeding, number and severity of harsh events (braking and acceleration), harsh cornerings, or driving aggressiveness), and offer **personal and contextualized feedback in combination with gamification mechanics** (like competitions, leaderboards, badges, rewards, et cetera) to keep drivers motivated and support them to work on an improvement of their driving style.

As described already in Deliverable 2.2 (section 2.7), various gamification mechanisms and features have been described over the years with different classification systems as an intent to keep the overview (see for instance the GamECAR-project: www.gamecar.eu). Without the intention to be exhaustive, the work of Andrzej Marczewski (see www.gamified.uk) can be seen as a sort of meta-synthesis. In his **Gamification Design Framework**, he proposed a summary overview of different player types, the basic gamification dynamics that drive these player types, and for each of these, the most frequently used gamification mechanisms. Marczewski distinguishes between six player types (i.e. achievers, socializers, philanthropists, free spiritists, players, and disruptors), and six dynamics that drive game players, and keep them engaged, depending on what player type is being considered (i.e. mastery, autonomy, purpose, relatedness, reward, and change). **Achievers** are motivated primarily by **mastery**: they are looking to learn new things, to overcome challenges, and to improve themselves. **Socializers** are driven by relatedness: they want to **interact with others** and create social connections. **Philanthropists** are motivated by purpose and meaning: they **are altruistic**, want to give to other people and enrich others without expectation of reward. **Free spiritists** are motivated by **autonomy and self-expression**: they want to create and explore. **Players** are **driven by rewards**: they will do what is required to collect rewards and they are primarily self-oriented. **Disruptors** are **motivated by change**: overall, they want to disrupt the system, either directly or through other users to force positive or negative change.

In his **Periodic Table of Gamification Elements** (see Figure 10), Marczewski shows which gamification mechanics can be used to satisfy the dynamics that drive the six player types mentioned above.

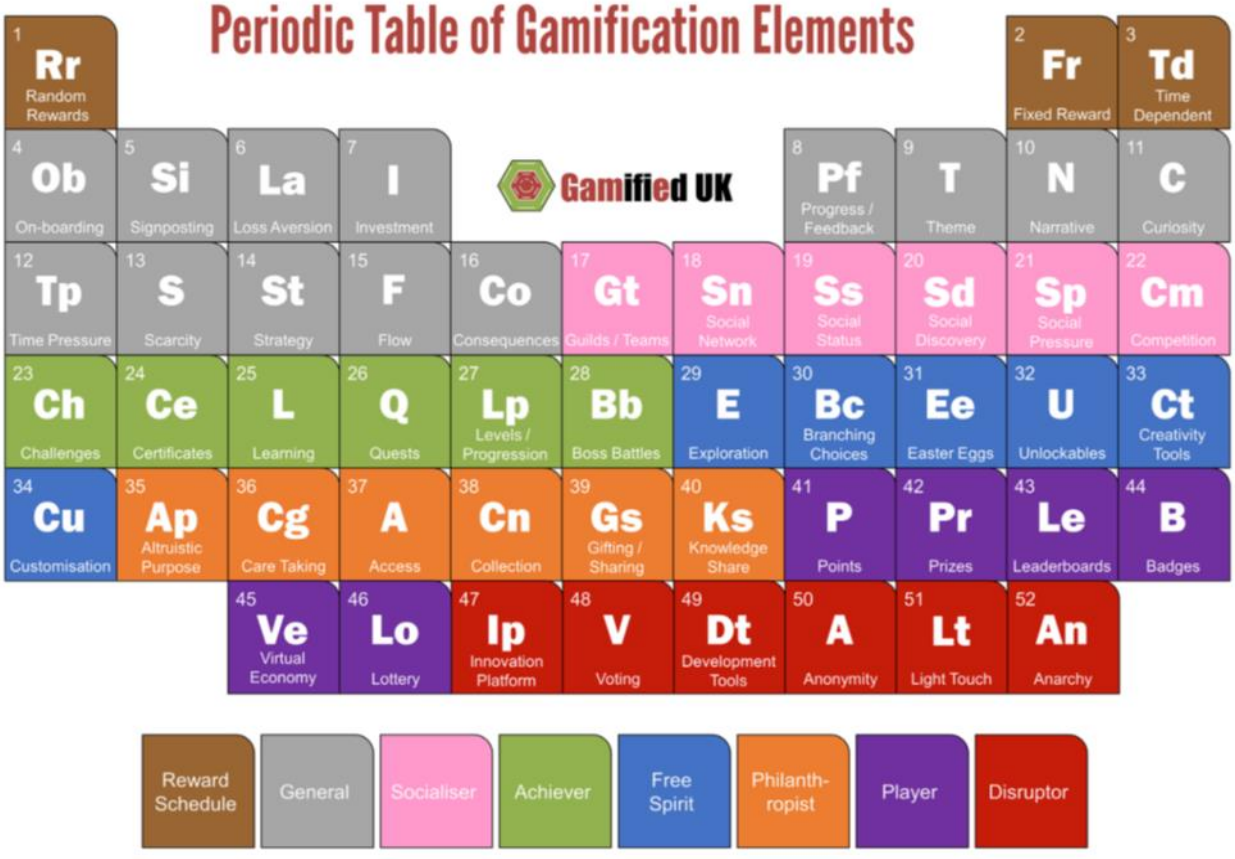


Figure 10: The Periodic Table of Gamification Elements by Andrej Marczewski. Source: www.gamified.uk

Formal definitions of the different gamification mechanisms appearing in the Periodic Table can be found in Table 15 under Annex 2. Several of the gamification mechanisms appearing in the Periodic Table of Gamification Elements have already been explored and empirically investigated for their effectiveness in the literature on safety and eco-efficiency (see Table 8 for an overview).

Table 8: Sample of studies where gamification mechanisms have been empirically studied.

Gamification elements studied	Sources	Findings
Scores	Toledo & Lotan (2006); Toledo et al. (2008)	Exposing drivers to safety-relate scores calculated based on in-vehicle monitoring and provided via personal web pages had a significant positive impact on driver performance.
Feedback + financial incentives	Dijksterhuis et al. (2015)	Results indicated clear driving behavior improvements for two different Pay-As-You-Drive (PAYD) groups as compared to baseline rides and an equal sized control group.
Financial incentives + gain/loss asymmetry	Mortimer et al. (2018)	Results suggested that (i) penalties may be more effective than rewards of equal value, (ii) even low-value incentives can deliver net reductions in risky driving behaviours, and (iii) increasing the monetary value of incentives may not increase their effectiveness.
Scores + feedback + group incentives	Musicant & Lotan (2016)	Despite the more challenging scheme needed to gain rewards, results indicated that all eligible participants downloaded the app and used it to win rewards for the group. Also, friends were recruited by participants without any personal rewards for themselves. Yet, once all pre-specified rewards were achieved within the allotted time period, young drivers stopped using the app.
Monetary & non-monetary rewards	Schall & Mohnen (2017)	Results showed a reduction of fuel consumption of 5% due to a tangible non-monetary reward and suggested only a small reduction of the average fuel consumption in the equivalent monetary reward treatment.

Gamification elements studied	Sources	Findings
Penalties	Corsi & Barnard (2003); Knipling et al. (2003); Hickman et al. (2007); Knipling (2009)	Managers consider punishments as an effective strategy to eliminate specific unwanted behaviours. It is important that penalties are applied uniformly for specific, announced behaviours (e.g. exceeding speed limits) or non-behaviours (e.g. not wearing the seat belt). Moreover, punishments need to be timely and certain, but they do not necessarily have to be severe in order to be effective.
Social feedback	McGehee et al. (2007); Farah et al. (2013)	The combination of in-vehicle monitoring and parental feedback and guidance can be a successful strategy to reduce risk-taking behaviours, even though it depends on several implementation-related aspects, such as tone of voice, coaching style adopted, et cetera.
Feedback + competition + extrinsic & intrinsic incentives	Vaezipour et al. (2019)	Findings revealed a 4.7% reduction in fuel consumption with an addition of incentive and competition with other drivers. Moreover, there was some evidence to suggest that a range of extrinsic and intrinsic incentives may be beneficial for increasing intentions to use an in-vehicle Human-Machine Interface (HMI) for the promotion of eco-efficiency.
Personalization + (historical) progress + learning	Brouwer et al. (2015)	Use of historical feedback that incorporates learning elements suggested a non-verifiable increase in terms of acceptance of an in-car display to promote eco-driving. However, the authors argued that maybe, historical feedback and learning elements are less effective for performance oriented drivers who may need comparative feedback and game elements to improve energy conserving driving behaviour.

Gamification elements studied	Sources	Findings
Adaptive learning	Pozueco et al. (2017)	The authors developed a complete methodology to evaluate driving efficiency of professional fleet drivers. The methodology includes an early-classification component that allows to establish the initial efficiency level of the individual driver, which permits an adaptation of the learning process from the beginning.
Tips & recommendations	Sureth et al. (2019)	The authors found that tips were evaluated as largely positive, and that participants receiving eco-driving tips that focused on implementation intentions and technical explanations, significantly reduced their fuel consumption by 4% on average over time.
Self-interest (financial, health, kin)	Van de Vyver et al. (2018)	Drivers were shown one of three self-interest appeals (financial, health, kin) while waiting at a congested level-crossing site in the UK. Results showed that all three self-interest appeals increased the chances of drivers turning off their engines compared to the control condition.
Scores + ranking + tips	Magaña & Organero (2015)	Results show that the gamification tools and techniques implemented in an eco-driving assistant system helps drivers not to lose interest for fuel saving and helps them not to return back to their previous bad driving habits.

The Periodic Table of Gamification Elements will serve as a supportive tool to come to well-informed decisions in step 4 of IM (see section 6.3.3) where the focus will be on how to practically implement the methods for behavioural change selected in step 3. The next section will be dedicated to three theoretical frameworks that are relevant for designing the post-trip interventions.

4.4 Post-trip interventions

In this section, three theoretical frameworks will be presented that are relevant for the design of the post-trip interventions. More particularly, from each of these three models, an important critical design parameter can be inferred. For instance, according to the **Transtheoretical Model of Change** (see section 4.4.1), people are different in terms of how open they are to the idea of changing their behaviour. This in turn, means that the selected

methods for behavioural change should be tailored to where in the process of behavioural change an individual is situated. **Self-Determination Theory** (see section 4.4.2) adds to this, the idea that people are motivated differently depending on where they are in the process of behavioural change. These differences in the type of motivation that drive people in their daily-life activities, have important implications for the selection of methods, meant to influence a person's motivation to change behaviour. Finally, according to the **Goals for Driving Education (GDE) Matrix** (see section 4.4.3), behavioural change understood as an intent to change a person's driving style, actually implies not only an improvement of the vehicle operator's driving performance, but of the vehicle operator's deeper-situated and more stable safety-related dispositions as well (e.g., attitudes, norms, values, life-goals, et cetera). Depending on a person's current performance (e.g. novice vs experienced) and overall safety-related disposition (more safety concerned vs less safety concerned), he or she can be situated in a hierarchically structured learning process that moves from simpler 'lower order skills' to more complex 'higher order skills'.

4.4.1 The Transtheoretical Model of Behaviour Change

The Transtheoretical Model of Behaviour Change is an integrative theory of therapy (i.e. it is based on analysis and use of different theories of psychotherapy) that assess a person's **readiness to act** on a new (healthier or safer) behaviour, and provides strategies or '**processes of change'** to guide the individual (Prochaska & DiClemente, 2005). The theory is visualized in Figure 11.

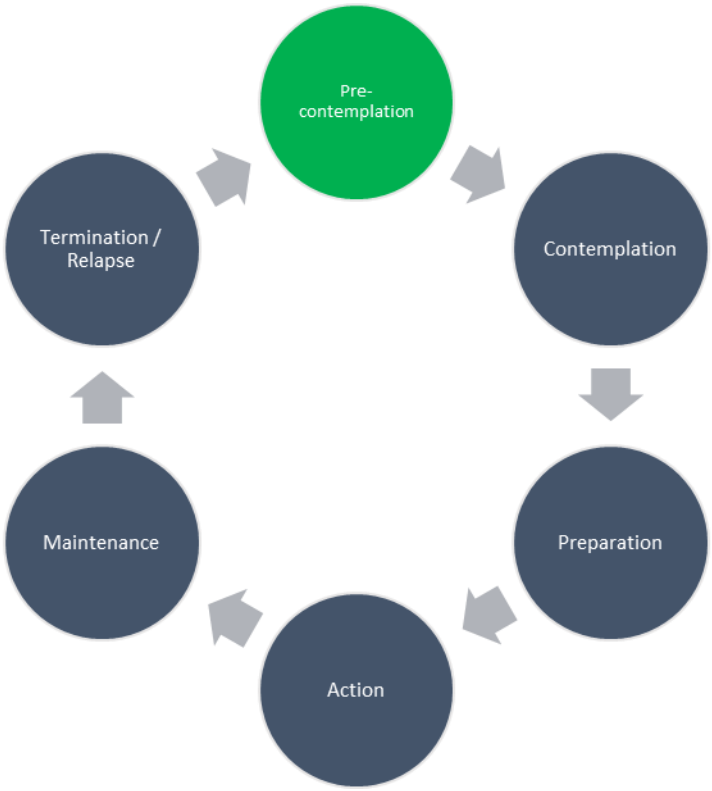


Figure 11: The Transtheoretical Model of Behaviour Change

The theory proposes that **behaviour change is a multi-step process occurring in five sequential stages,** i.e. precontemplation (this is the starting point, therefore coloured in

green), contemplation, preparation, action, and maintenance (Prochaska & DiClemente, 1982). More recently, two additional concepts have been added, i.e. termination and relapse (e.g. Prochaska et al., 2015; Biehl et al., 2018). Neither of the two however, are considered as 'stages'. Prochaska & Velicer (1997) for example, conceptualized relapse rather as a dynamic where a person returns from action or maintenance to an earlier stage. Due to the fact that people can regress, movement through the process of behavioural change is thus **not necessarily a linear, but potentially a spiral pattern**. The importance of distinguishing between these different stages of change for intervention design, is that they can be expected to be **more effective in case they are 'stage-matched'** (i.e. tailored to each individual's stage of change), both in terms of the determinants for behavioural change that are being targeted, and in terms of the methods used to realize that change (e.g. Prochaska et al. 1992). As for the last point, ten different '**processes of change**' have been proposed by the authors who developed the theory, to explain how people move from one stage to another (Prochaska & DiClemente, 1983). The term 'change process', formally defined as "covert and overt activities that people use to progress through the stages" can thus be considered as an equivalent of what has been referred to before as methods for behavioural change. Table 9 gives an overview of the five main stages inside the Transtheoretical Model of Behaviour Change, together with a formal definition, and some key-characteristics. Moreover, for the first four stages, the change processes to move forward to the next stage are mentioned and briefly described.

Table 9: The stages of change and associated change processes

Stage of change	Definition	Description	Change process	Description
Precontemplation	'not ready': people are not intending to take action in the foreseeable future, and can be unaware that their behaviour is problematic.	Precontemplators typically underestimate the pros of changing, overestimate the cons, and often are not aware of making such mistakes.	Consciousness raising	Get the facts: increasing awareness via information, education, and personal feedback about the safe behaviour.
			Dramatic relief	Pay attention to feelings: feeling fear, anxiety, or worry because of the unsafe behaviour or feeling inspiration and hope when hearing about how people are able to change to safe behaviours.
			Environmental re-evaluation	Notice your effect on others: realizing how one's unsafe behaviour affects others and how others could have more positive effects by changing.

			Social liberation	Notice public support: realizing that society is more supportive of safe behaviour.
Contemplation	'getting ready': people are beginning to recognize that their behaviour is problematic, and start to look at the pros and cons of their continued actions.	Contemplators are usually more aware now of the pros of changing, but, their cons are about equal to their pros. This ambivalence about changing can cause them to keep putting off taking action.	Self- re-evaluation	Create a new self-image: realizing that the healthy behaviour is an important part of who one is and wants to be.
Preparation	'ready': People are intending to take action in the immediate future, and may begin taking small steps towards behaviour change.	Preparators take small steps that they believe can help them make safe behaviour part of their lives. Their number one concern is whether they will fail when they act. They learn that the better prepared they are, the more likely they are to keep progressing.	Self-liberation	Make a commitment: believing in one's ability to change and making commitments and re-commitments to act on that belief.
Action	'current action': People have made specific overt modifications in modifying their problem behaviour or in acquiring new safe behaviours.	Actioners need to learn how to strengthen their commitments to change and to fight urges to slip back.	Helping relationships	Get support: finding people who are supportive of change.
			Counter-conditioning	Use substitutes: substituting safe ways of acting and thinking for unsafe ways.
			Reinforcement management	Use rewards: increasing the rewards that come from positive behaviour and reducing those that come from negative behaviour.
			Stimulus control	Manage your environment: using reminders and cues that encourage safe behaviour as substitutes for those

				that encourage unsafe behaviour.
Maintenance	'monitoring': People have been able to sustain action for at least a considerable amount of time (e.g. six months) and are working to prevent relapse	For maintainers it is important to be aware of situations that may tempt them to slip back doing the unsafe behaviour, particularly stressful situations.	It is recommended that people in this stage seek support from and talk with people who behave in safe ways, and remember to engage in safe activities, to cope with stress instead of relying on unsafe behaviour.	
Termination	People have zero temptation and are sure they will not return to their old unsafe habit as a way of coping.			
Relapse	People that regress from action or maintenance to an earlier stage.			

Even though there is debate about the validity of the Transtheorteical Model of Behaviour Change, and more particularly about the exact number of change stages (e.g. Brug et al., 2005 for instance suggest distinguishing between only two main stages, namely, motivation, and volition), the model has been applied in its orginial format in the field of transportation and road safety before (e.g. Biehl et al., 2018; Kidd et al., 2003; Kowalski et al., 2014). Moreover, the essential point being made by the theory, is that behavioural change is to be seen as a process.

In sum, according to the Transtheoretical Model of Behaviour Change, people are different in terms of how open they are to the idea of changing their behaviour. This in turn, means that the selected methods for behavioural change (or change processes) should be tailored to where in the process of behavioural change an individual is situated.

The next section will discuss a framework (i.e. Self-Determination Theory) that is complementary to the Transtheoretical Model in a sense that it adds the idea that people are motivated differently depending on where they are in the process of behavioural change. These differences in turn, have important implications for the selection of methods, meant to influence a person's motivation to change behaviour.

4.4.2 Self-Determination Theory

As discussed by Michie et al. (2014: p. 321-328), Self-Determination is a meta-theory comprising five mini-theories (i.e. Cognitive Evaluation Theory, Organismic Integration Theory, Causality Orientations Theory, Basic Psychological Needs Theory, and Goal Contents Theory), with the aim of providing a broad framework for the study of motivation, personality, and behaviour. Central to the theory's explanation of behaviour is the distinction

between intrinsic motivation vs extrinsic motivation, and people's basic need for autonomy, competence and relatedness (Deci & Ryan, 1985).

According to the theory, all humans have three basic needs: **competence** (i.e. the need to feel competent), **autonomy** (i.e. the need to feel volition an choice), and **relatedness** (i.e. the need to feel related to others) (Ryan & Deci, 2000). Depending on how well these basic needs are satisfied, three different types of motivation can be distinguished (e.g. Howard et al., 2017). (Social) Contexts that satisfy these needs promote **intrinsic motivation** to engage in a certain behaviour (i.e. motivation that comes from the individual's inherent interest or enjoyment). Conversely, (social) contexts that undermine the satisfaction of these needs lead to another form of motivation, namely **extrinsic motivation** (i.e. motivation that is regulated by external factors or controls). People can even be **amovitated**, meaning there simply is a lack of intention to engage in a particular behaviour. Depending on how autonomous or self-determined a person is when engaging in a certain behaviour, six different so-called 'regulation' mechanisms can be distinguished (see Figure 12).

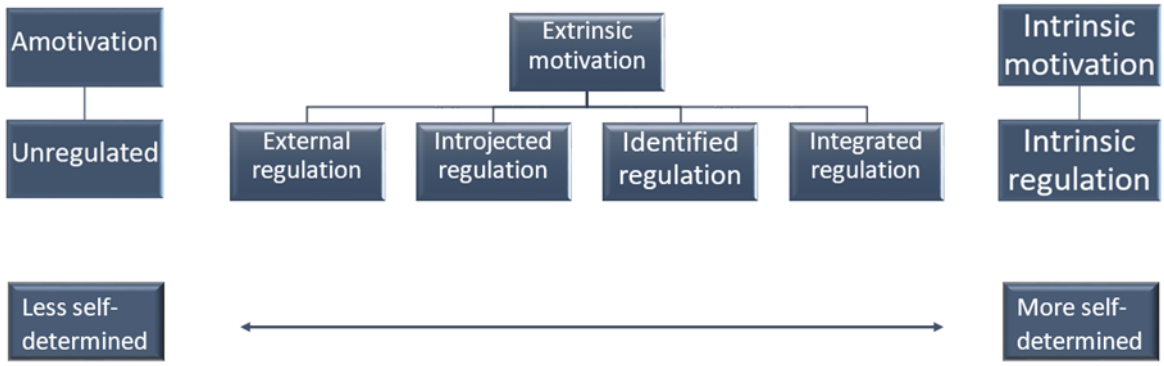


Figure 12: Types of motivation and related regulation mechanisms. Source: Michie et al. (2014: p. 328)

As can be seen, four regulation mechanisms can be associated with the concept of extrinsic motivation. **External regulation** refers to situations where behaviour is motivated by controlling personally unrelated consequences (e.g. getting a reward or avoiding a punishment). **Introjected regulation** is when behaviour is motivated via regulation of internal representations of external consequences (e.g. looking for positive feelings like approval, or avoiding negative feelings like guilt). **Identified regulation** refers to cases where motivation occurs because the outcome of the behaviour is important to the person (e.g. engaging in physical activity because it is important to the person). **Integrated regulation** refers to behaviour that is motivated because the behaviour is considered as part of one's own identity (e.g. 'I run because I am a runner').

The relevance of Self-Determination Theory for the post-trip interventions in the i-DREAMS platform, is that research indicates that more externally controlled forms of motivation are suitable to initiate and realize behavioural change in the short term, while **sustainable behavioural change actually requires more internally controlled forms of motivation, and preferably, intrinsic motivation** (e.g. Ingledew & Markland, 2008). Put differently, it is not primarily the 'quantity' but the 'quality' of motivation that counts when trying to change behaviour. Furthermore, studies have shown that **moving forward through the process of behavioural change** (see section 4.4.1) **correlates with a shift in the type of motivation**

that drives behaviour. More in detail, extrinsic motivation seems to be more prominent in the early stages of change, while internally controlled types of motivation become more important in the later stages of change, possibly culminating in intrinsic motivation and termination of the change process (e.g. Ceccarini et al., 2015; Kushnir et al., 2016). This in turn, has important implications, for instance, in terms of how gamification mechanics will be used in the post-trip interventions. These **gamification mechanics actually need to be tailored to the type of motivation, which will be different across the various stages of the change process** (e.g. Weiser, 2015; Mekler et al., 2017; Feng et al., 2018). This is illustrated for example, in the work of Sailer et al. (2017) where guidelines have been proposed on how to effectively implement gamification mechanics and features in function of the more specific motivation-related needs that are to be satisfied (see Table 10).

Table 10: Overview of psychological needs with matching game design elements. Source: Sailer et al. (2017)

Psychological need	Gamification mechanism	Game design element
Need for competence	Granular feedback	Points
	Sustained feedback	Performance graphs
	Cumulative feedback	Badges
	Cumulative feedback	Leaderboards
Need for autonomy (decision freedom)	Choices	Avatars
Need for autonomy (task meaningfulness)	Volitional engagement	Meaningful stories
Need for social relatedness	Sense of relevance	Teammates
	Shared goal	Meaningful stories

Tailored use of gamification mechanics, taking into account what the type of motivation is that drives people, is also recommended by gamification experts like Michael Wu (current Chief AI Strategist at PROS). In his Gamification Spectrum (see Figure 13) he illustrates how different gamification features can be used most optimally, considering the idea that motivation regulation is actually a continuum (from extrinsic to intrinsic). The use of points for instance is typically a way to extrinsically motivate people, while at the other side of the spectrum, team reputation is a more appropriate way to keep engaged people that are intrinsically motivated. As can be seen, gamification features to stimulate extrinsic motivation are more oriented towards the individual, easier to implement, but not suitable for sustainable behavioural change. The latter actually requires people to become intrinsically motivated, which is a more time consuming process with the focus moving more from the individual to the group. Michael Wu summarizes the underlying idea quite nicely, stating that essentially, people come for the game, but stay for the community.

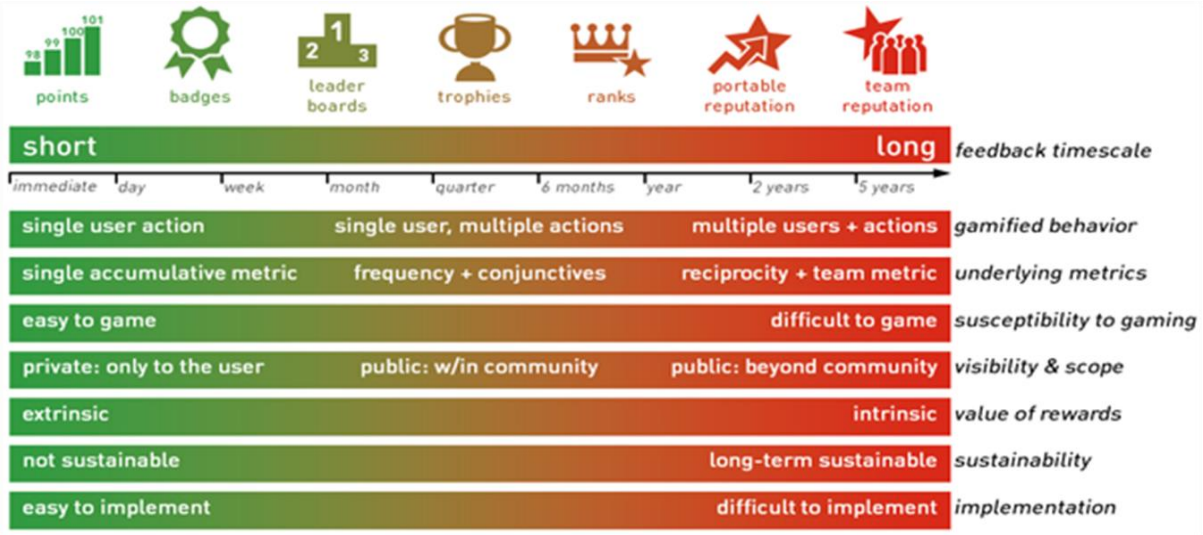


Figure 13: The Gamification Spectrum. Source: Personal blog by Michael Wu, see www.community.khoros.com

To summarize, according to Self-Determination Theory, people are motivated differently depending on where they are in the process of behavioural change. These differences in the type of motivation that drive people in their daily-life activities, have important implications for the selection of methods, meant to influence a person's motivation to change behaviour. The use of gamification elements in the post-trip interventions is best tailored to the specific motivation-related needs that are to be satisfied. The next section will be dedicated to the Goals for Driving Education Matrix.

4.4.3 The Goals for Driving Education Matrix

The **Goals for Driving Education (GDE) Matrix** (Christ et al., 1999) is relevant for the design of the post-trip interventions, since one of the key-objectives of these interventions is to influence a vehicle operator's driving *style*. According to the GDE, **changing driving *style* implies not only an improvement of the vehicle operator's driving performance, but of the vehicle operator's deeper-situated and more stable safety-related dispositions as well (e.g., attitudes, norms, values, life-goals, et cetera)**. In other words, acquiring a safe driving style is not only a matter of mastering a series of practical skills, but of adopting a safety-supportive orientation as well (Hatakka et al., 2002).

This idea was an important addition to earlier conceptual frameworks that tried to describe the driving task. Most of these models adopted a hierarchical perspective, and modelled the driving task as a structured set of practical skills, organized in different levels going from **vehicle control skills** like pedal use, gear shifting, tyre grip et cetera (i.e. first and lowest level), to **skills for mastering traffic situations like hazard avoidance skills**, driving path monitoring, road user interaction (i.e. second level), and **skills related to trip planning and coping with context-factors** like how to deal with time pressure or sources of distraction (i.e. the third level) (e.g. Michon, 1985). Addition of a fourth level (i.e. **goals for life and skills for living**) was meant to complement the exclusively skills-oriented conceptions of the driving task (Keskinen, 1996).

In its most recent version, the GDE-matrix has even received an additional fifth layer (i.e. **social environment**), emphasizing the importance of the wider socio-cultural environment and the impact it can have on an individual's driving style (Keskinen et al., 2010; Weiße et

al., 2015). The most popular representation of the GDE-matrix as a four-level hierarchy is visualized in Figure 14.

	Knowledge and Skill	Risk Increasing Aspects	Self-Assessment
Goals for Life and Skills for Living	Understanding the importance of lifestyle, age group, culture, social circumstances, etc.	Understanding the importance of sensation-seeking, risk acceptance, group norms, peer pressure, etc.	Understanding the importance of introspection, competence, personal preconditions for safe driving, impulse control, etc.
Goals for, and Context of Driving	Understanding the importance of modal choice, time-of-day, motives for driving, route planning, etc.	Understanding the impact of alcohol, fatigue, low friction, rush hour traffic, peer-age passengers, etc.	Understanding the importance of personal motives, self-critical thinking, etc.
Driving in Traffic	Mastering traffic rules, hazard perception, etc. Automating elements of the driving process. Co-operating with other drivers, etc.	Understanding the risks associated with disobeying rules, close-following, low friction, vulnerable road users, etc.	Calibration of driving skills, developing a personal driving style, etc.
Vehicle Control	Mastering vehicle functioning, protective systems, vehicle control, etc. Understanding the impact of physical laws.	Understanding risks associated with non-use of seat belts, breakdown of vehicle systems, worn out tires, etc.	Calibration of car control skills

Figure 14: The Goals for Driving Education (GDE) Matrix. Source: OECD (2006)

Without going into all the details, the Matrix rests on **three important assumptions**. Firstly, the idea that lower levels of the driving task affect higher levels, and vice versa. In other words, there is **a continuous top-down and bottom-up interaction between the different levels of the hierarchy**. Secondly, even though the matrix intuitively suggests there is a kind of 'exemplar' trajectory to follow when learning how to drive safely (i.e. a gradual progress from lower-order skills to higher-order skills), from a pedagogical point of view, it is **the combination of the person's current performance (e.g. novice vs experienced) and overall safety-related disposition (more safety concerned vs less safety concerned), that determines the focus of interventions aimed at influencing an individual's driving style**. Finally, the columns in the Matrix indicate that adoption of a safe driving style comprises **a variety of competences**, such as **awareness and knowledge** of **risk-increasing factors** and procedures on how to safely cope with these, the **skills** to implement such risk coping procedures while driving, causal attribution strategies, accurate **self-evaluation**, et cetera. Importantly, these competences are relevant at each of the levels within the hierarchy, thus, not only within the specific trip- or traffic context (i.e. levels one to three), but also in regard to more stable and person-bound aspects that (in)directly affect a vehicle operator's driving performance in a specific traffic situation or trip (e.g. goals for life and skills for living, the social environment).

For the EU Member States, the competences appearing in the GDE-matrix serve as a kind of blueprint for setting the minimum requirements for driving tests to obtain a **private car driver licence** (i.e. category B). Actually, these minimum requirements have been formally stipulated in **Directive 2006/126/EC (Annex II)** on driving licences (for a detailed overview: see Deliverable 2.2, Annex A). The same counts for **professional drivers of buses, coaches and trucks** where since **Directive 2003/59/EC (Annex I)**, amended more recently by **Directive 2018/645**, basic requirements for **initial qualification and periodic training**

('code 95') have been proposed, together with the legal obligation of holding a valid **Certificate of Professional Competence** (CPC) (for a detailed overview: see Deliverable 2.2, Annex A). These basic requirements for professional drivers are also substantially based on competences in the GDE-matrix. Whatever post-trip intervention would be proposed, it is of strategic importance for its successful adoption, to **use the GDE-matrix as a guiding instrument to determine and structure the competences to be targeted**, as the GDE-matrix gave direction to the requirements proposed in the three EU Directives mentioned above.

In sum, behavioural change understood as an intent to modify a person's driving style, implies an improvement of the vehicle operator's driving performance *and* of the vehicle operator's deeper-situated and more stable safety-related dispositions (e.g., attitudes, norms, values, life-goals, et cetera). Depending on a person's current performance (e.g. novice vs experienced) and overall safety-related disposition (more safety concerned vs less safety concerned), he or she can be situated in a hierarchically structured learning process that moves from simpler 'lower order competences' to more complex 'higher order competences'. These competences cover various areas of learning, i.e. awareness and knowledge of risk increasing aspects, skills on how to cope with these, and accurate self-assessment, and apply not only to the specific context of a trip or a traffic situation, but to more stable person-related dispositions (and even the supra-personal socio-cultural context) that might affect driving as well.

The next section of this Deliverable is devoted to preliminary considerations that apply to the different modes that are being addressed in the i-DREAMS project (i.e. car, bus, truck, tram, and train). More in detail, these considerations relate to the implementation of the real-time and post-trip interventions. Even though intervention implementation is not the key-focus of this Deliverable (intervention implementation is more elaborately discussed in Deliverable 3.4: Design of the experimental protocol), the two cross-modal considerations that will be addressed here (i.e. user acceptance and private vs occupational safety setting) in some way also affect the way in which the interventions will be designed.

5 Preliminary cross-modal considerations

This section first addresses **user acceptance** (see section 5.1) as a key-issue to be taken into account already in the stage of designing the i-DREAMS interventions. Since there is considerable theoretical and empirical literature available on the topic, user acceptance can already be taken into account in the stage where we develop and technically implement the real-time and the post-trip interventions. Doing so will minimize the risk of having to remedy certain components of the interventions later on in the process, i.e. once they will be pre-tested and field trialled, and will increase the probability for intervention efficacy and effectiveness.

Besides user acceptance, the **distinction between a private vehicle operator context on the one hand, and a professional vehicle operator context on the other hand** (see section 5.2), is a key-issue to be taken into account when designing interventions aimed to promote road safety. Especially in an occupational context, individual behaviour is strongly embedded in a workplace context. Company-specific habits, procedures, protocols, and rules give guidance to how individual employees are expected to function, also when operating a vehicle. Management commitment, fleet safety management, and communication regarding fleet safety have been identified as strategically important actions that can positively contribute to a prosperous safety culture and climate. As a consequence, to maximize intervention effectiveness, actual involvement of other agents within the workplace setting (besides the targeted end-users), is of essential importance.

5.1 User acceptance

In **Deliverable 2.2 (see section 2.9)**, the point has been clearly made that the adoption and effectiveness of technology-mediated interventions (like the ones that are being planned in the i-DREAMS project) are critically dependent upon whether users have the intention to use and are open for a new system (i.e. so-called acceptability), and how they experience the actual use of a new system (i.e. so-called acceptance). A detailed overview has been presented of a variety of theoretical models and studies that have conceptually defined and empirically investigated user acceptability and acceptance of new technology systems.

The **Unified Model of Driver Acceptance** (UMDA) (see Figure 15) proposed by Rahman et al. (2018) can be seen as a kind of meta-synthesis of the literature on the topic and integrates concepts from several individual theories, such as the Technology Acceptance Model, the Theory of Planned Behaviour, and the Unified Theory of Acceptance and Use of Technology. The most important additions to the model in comparison to the aforementioned models, are trust, endorsement, compatibility, and affordability. **Attitude** stands for an individual's positive or negative assessment about performing a certain behaviour, in this case, using a new technology system in a real-time or post-trip setting. **Perceived usefulness** refers to the degree to which a person believes that using a particular system would enhance his or her performance, in this case, how safely he or she operates a vehicle. **Perceived ease of use** is the degree to which a person believes that using a particular system would be free of effort. **Subjective norm** relates to a person's perception that most people who are important to him or her think he or she should or should not perform a particular behaviour, in this case, using a new system in a real-time or a post-trip setting. **Perceived behavioural control** refers to the perceived ease or difficulty of performing a certain behaviour, i.e. using a new system in a real-time or post-trip setting. **Compatibility** is the degree to which an innovative system is perceived as being consistent with the existing

values, needs, and past experiences of potential adopters. **Trust** is the belief of users that the system would perform its intended task(s) with high effectiveness. **Endorsement** stands for the willingness to approve or recommend the purchase and/or the use of a new technology system. **Affordability** refers to the monetary amount people are willing to pay to purchase, install, and maintain the system. This set of factors is assumed to predict overall **acceptance** of new technology, with acceptance considered as the combination of the intention for future use as well as the actual use experience. Potential moderators of the relationship between user acceptance on the one hand, and its predictors on the other hand, are **age**, **gender**, **user experience**, and **personal innovativeness**. Personal innovativeness is defined as the willingness to adopt technological innovations earlier than others.

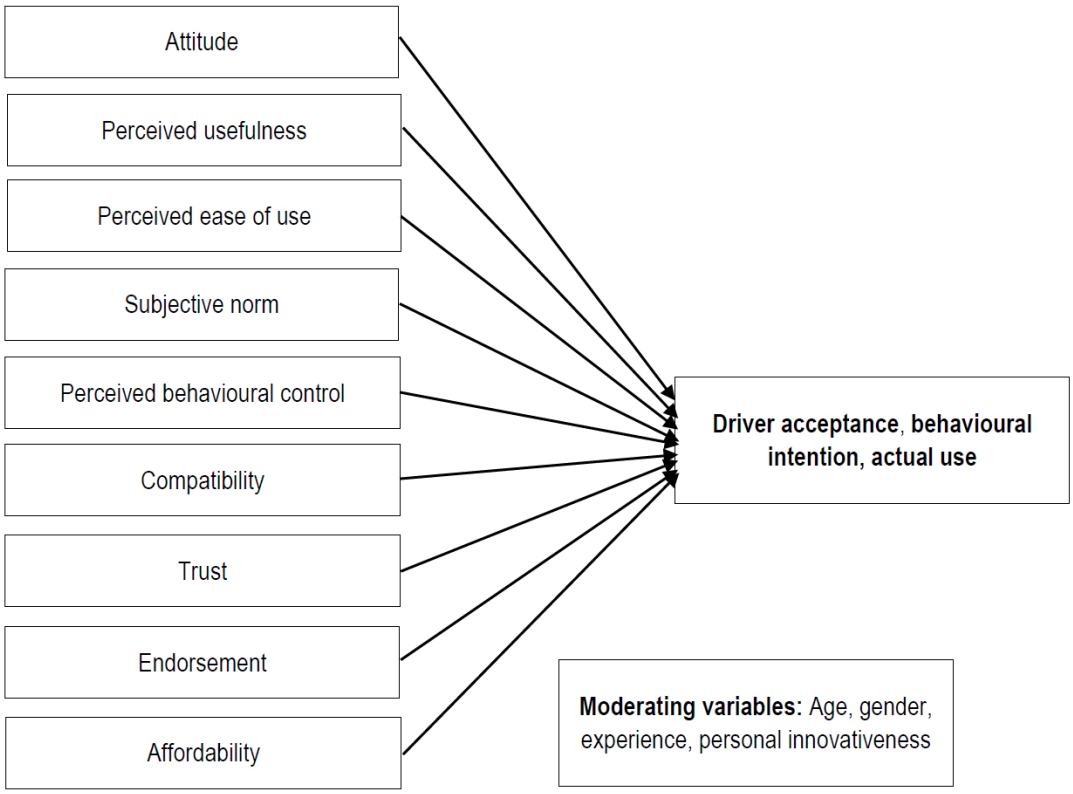


Figure 15: The Unified Model of Driver Acceptance

As already mentioned, it is advisable to take the different determinants of user acceptance into account, already in the stage of operational design and technical implementation of the interventions in order to avoid users would not be willing to adopt the i-DREAMS interventions, or not make use of these as originally intended.

User acceptance of course not only applies to the real-time interventions, but to the post-trip interventions as well, as these will be supported by technology (i.e. app + web-based coaching platform) to a substantial extent. Detailed guidelines have been published for user-friendly design of web applications, among which the well-known ***Research-Based Web Design & Usability Guidelines*** by the U.S. Department of Health and Human Services and the U.S. General Services Administration (HHS & GSA, 2006). Without going into the finest details, Table 16 (see Annex 3) gives a summary overview of the most important guidelines to be kept in mind. The next section will discuss the importance for intervention design of a

clear distinction between a private driving context on the one hand, and an occupational context on the other hand.

5.2 Private vs. Occupational context

In **Deliverable 2.2 (see section 2.3)** it was discussed already that one of the crucial and consistent findings in the field of **Occupational Health and Safety** (OHS), is that building and sustaining employee health and safety is to a large extent dependent on how the workplace environment is oriented towards health and safety. This of course, is a crucial difference with a private driver context, where individual behaviour is less bound to rules, guidelines or protocols that regulate personal conduct. Organizations can differ greatly in terms of how strong (or weak) their safety culture and safety climate is developed. Research shows that **management commitment**, **fleet safety management**, and **communication regarding fleet safety** are strategically important actions that can positively contribute to a prosperous safety culture and climate. This was confirmed in an extensive literature review study by Naevestad et al. (2018). More in detail, the authors of that study identified eight factors that appear to influence the quality of workplace safety culture across different transportation domains (i.e. road, rail, maritime and aviation).

1. **Top management commitment during the entire intervention period.**
   Manager commitment was identified as an important factor in several studies and was relevant across all modes. Specific for rail transport, studies indicated the importance of strong leadership, sufficient management commitment, and absence of role confusion that decreases commitment visibility.

2. **Engagement and support of employees.**
   Employee engagement in the process of change and interventions measure(s) is key to safety culture change. Several studies also indicated that union cooperation can likely encourage the engagement of employees. Finally, according to a study in road transport (including cars and trucks), the effectiveness of group discussions for improving safety could be caused by employee engagement in risk analysis and subsequent execution of action plans.

3. **Manager and employee relationship.**
   Two studies in rail transport indicated the importance of the manager-employee relationship. Several impeding factors were mentioned, i.e. trust, resistance in experienced employees, and an unjust culture.

4. **Motivation for the intervention.**
   A strong motivation, or high need, is important for successful safety interventions (e.g. a lot of dangerous incidents, poor safety culture). In this regard, effects should be communicated in line of the reasons behind the intervention. Specific for car drivers, intervention motivations can differ in case of business drives, for which motivations often relate to benefits of increased productivity.

5. **Focus of regulatory authorities on safety (culture) and company support.**
   Some promising studies indicated the importance of a regulatory focus on (safety) culture as a motivating factor for interventions. However, in one study, standalone regulatory focus was insufficient. Moreover, some other interventions were not motivated by such a regulatory focus.

6. **A clear and congruent intervention implementation.**
   The necessity for a clear and congruent intervention was derived from cases targeting different modes that indicated the importance of clear implementation (rail), avoiding complicated procedures (maritime), and interventions that are, besides being coherent and structured, congruent with existing systems (road).

7. **Attention taken away from the intervention by reorganization or other processes.**
   Reorganizations were found to negatively affect the intervention in some studies. For instance, when managers related to the intervention implementation were replaced.

8. **Intervention content.**
   The content of the intervention, e.g. activities and goals, is a very important factor that influences the motivation of employees to participate. As already mentioned, for a successful adoption of the i-DREAMS interventions, it would be of strategic importance to take the minimum requirements stipulated in Directive 2006/126/EC (for obtaining a private car driver licence) and in Directive 2018/645 (amending Directive 2003/59/EC and Directive 206/126.EC) (for initial qualification and periodic training of professional drivers of buses, coaches, and trucks) as a guideline for determining the competences to be targeted. The GDE-matrix which was a major source of inspiration for these EU Directives, can be useful to organize and structure these different competences in a more formally structured learning curriculum.

From this overview, it becomes clear that **actual involvement of other agents within the workplace setting (besides the targeted end-users), is of essential importance for the success of the i-DREAMS interventions**, most particularly, for those modes that are operational in a professional context (i.e. bus, truck, tram, and train). Especially in the case of the post-trip interventions where a coaching approach will be adopted as a basic strategy for behavioural change, the proposed i-DREAMS platform (i.e. app + web-based dashboard) will not operate as a stand-alone solution or a full replacement of human interaction. Rather, the **i-DREAMS platform will function as kind of automated expert system, meant to provide support to the different key-stakeholders that are actively involved in the process of coaching professional vehicle operators to improve their driving style**. In section 6.3.2.2 of this Deliverable, it will be indicated which stakeholders besides the end-users will be actively involved in the i-DREAMS post-trip interventions in the role of adopter or implementer respectively.

Now that some basic principles of behavioural change have been discussed, and two important cross-modal considerations for intervention design and implementation have been addressed, the next section of this Deliverable will be dedicated to the operationalization itself (i.e. the ‘toolbox’) of the i-DREAMS interventions.

6 Toolbox for i-DREAMS interventions

In this section of the Deliverable, we will come to the operationalization itself of the i-DREAMS interventions. As already mentioned, IM will be used as a structured guideline to operationalize the i-DREAMS interventions. This Deliverable covers **the four first steps of IM** (i.e. logic model of the problem, logic model of change, intervention design, and intervention production). Step five (i.e. intervention implementation) and step six (i.e. intervention evaluation) fall outside the scope of this Deliverable and will be dealt with elsewhere (see Deliverable 3.4 and Work Package 5). The result of this exercise will be **an 'operational toolbox'** that contains what is needed for the technical project partners to build the real-time and post-trip interventions. More specifically, that will be a selection of methods for behavioural change, together with a selection of gamification mechanics to put these methods into practice, and first drafts of material designs that demonstrate what the end-users will receive at the front-end. Moreover, a selection of objectives targeted by the i-DREAMS interventions that are based on a logic model of the problem addressed, will be included in the toolbox. That information will be relevant for the project partners involved in the evaluation of the i-DREAMS interventions.

Figure 16 gives an overview of **the different compartments inside the toolbox** and how they structurally relate to each other.

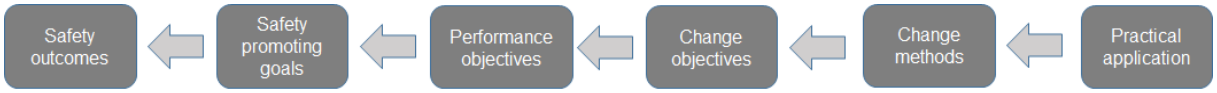


Figure 16: Structural overview of the compartments inside the operational toolbox for the i-DREAMS interventions

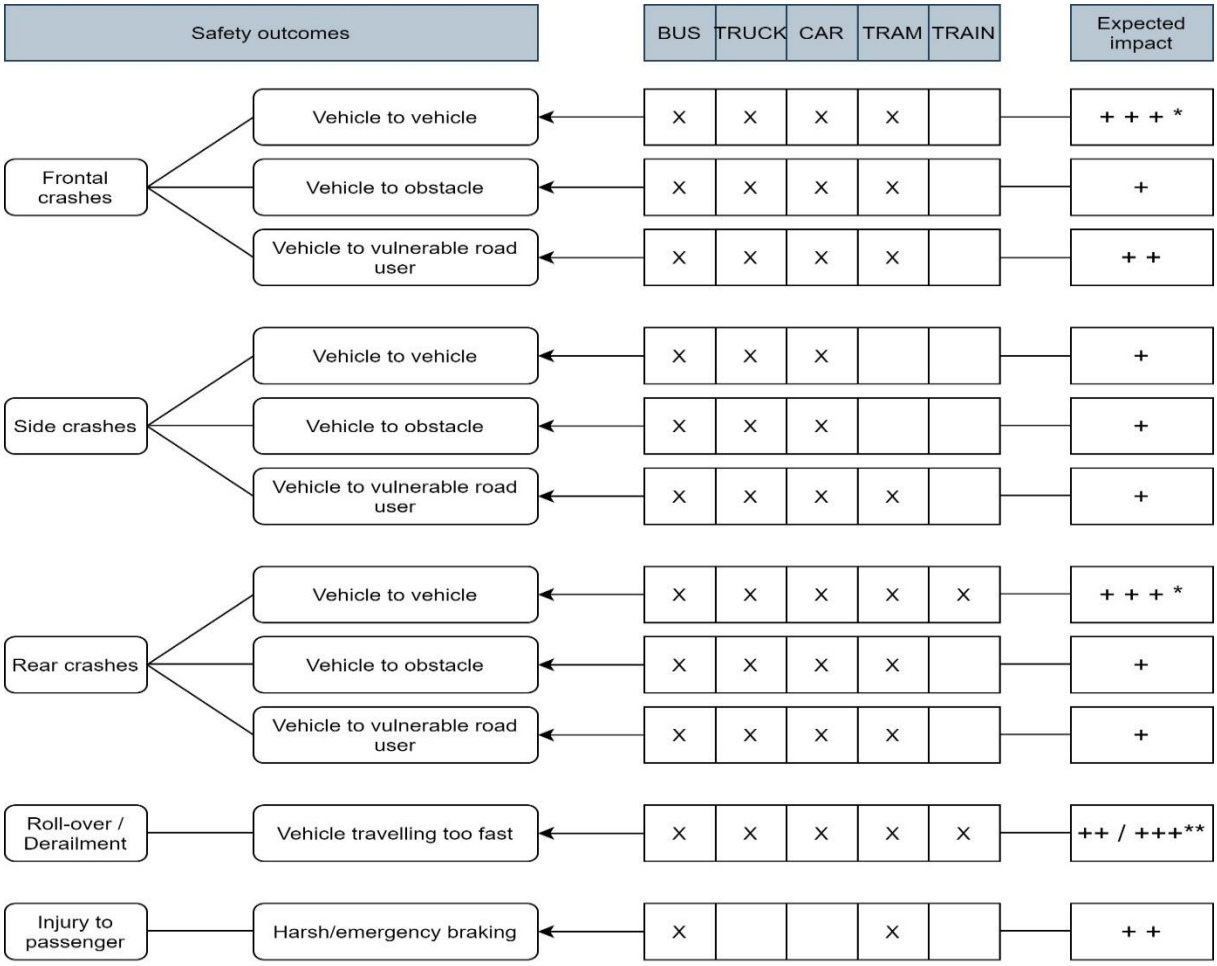
As can be seen, the toolbox will consist of six compartments. From left to right, the first compartment is where the **safety outcomes** can be found. As already explained in section 3.1, safety outcomes represent the highest level of impact targeted by the i-DREAMS interventions. The second compartment contains the **safety promoting goals**. These represent the behaviours that need to change in order for the safety outcomes to be realized. The third compartment is dedicated to the **performance objectives**, i.e. the more specific actions or behavioural parameters that need to change in order for the safety promoting goals to be achievable. The fourth compartment includes the **change objectives**. These apply to the underlying behavioural determinants that need to change for the performance objectives to become realizable. The safety outcomes, and safety promoting goals as well as the specific behavioural parameters and their underlying determinants are typically identified and determined in step one of IM (see section 6.1). Formulation of the performance objectives and the change objectives in such a manner that their causal connection is kept intact so that a logic model of change can be constructed, is done in step two of IM (see section 6.2). The fifth compartment contains the **change methods** that will be selected for application in the i-DREAMS interventions. As explained in section 4.3.2, change methods are abstractly defined principles for behavioural change. Compartment six includes the **practical applications**, i.e. the translation of the selected change methods into practically applicable formats. As discussed in section 4.3.3, gamification mechanics will be used for that purpose. Change methods, and their respective practical applications are selected and determined in step three of IM (see section 6.3). Also part of this Deliverable, will be first drafts or **mock-ups** of what users of the i-DREAMS interventions will receive at the **front-end** (see section 1.1).

6.1 Step 1: Logic model of the problem

Stated in general terms, the health problem addressed in the i-DREAMS project, is road safety, and in more specific terms, the occurrence of road crashes with involvement of private car drivers or professional vehicle operators (i.e. bus, truck, tram and train). In this section, this **problem will be logically analysed**, resulting in the identification of the to-be-targeted safety outcomes (see section 6.1.1), the related behaviours (i.e. safety promoting goals: see section 6.1.2), the specific parameters linked to those behaviours (see section 6.1.2), and the respective underlying determinants of those parameters (see section 6.1.3).

6.1.1 Safety outcomes

Both the real-time interventions and the post-trip interventions share the same set of safety outcomes. These are visualized in Figure 17.



+ + +	High impact
+ +	Medium impact
+	Low impact
*	For trains this is achieved through prevention of signal passed at danger (SPAD) events
**	For road the expected impact is + +, for rail + + +

Figure 17: Safety outcomes

At the highest (i.e. epidemiologic) level of impact, **the real-time and post-trip interventions provided by the i-DREAMS platform are expected to reduce the likelihood of crash**

occurrence. This of course, is a long-term outcome, and will require a longitudinal research design in terms of evaluation. Conform to the **ISO 6813:1998** which defines terms related to the classification of road vehicle collisions, crashes are categorized in function of the impact type as **frontal collisions** (i.e. the operator's vehicle hitting another collision subject or object in the front side), **side collisions** (i.e. the operator's vehicle hitting another collision subject or object in the side), and **rear collisions** (i.e. the operator's vehicle hitting another collision subject or object in the rear side). Within each of these three crash categories, a distinction is made in terms of whether the subject or object colliding with is a vehicle, an obstacle or a vulnerable road user. The categories 'roll-over/derailment' and 'injury to passenger' are more typical for the rail modes in i-DREAMS. Formally worded, but without any quantification or operational measure yet (see Deliverable 7.1: Methodology for the evaluation of interventions), these would be the five Safety Outcomes (SO) targeted by the i-DREAMS interventions:

- **SO1**: The likelihood of cars, buses, trucks, or trams equipped with and exposed to the i-DREAMS interventions to be involved in a **frontal crash** will significantly reduce.
- **SO2**: The likelihood of cars, buses, trucks, or trams equipped with and exposed to the i-DREAMS interventions to be involved in a **side crash** will significantly reduce.
- **SO3**: The likelihood of cars, buses, trucks, trams or trains equipped with and exposed to the i-DREAMS interventions to be involved in a **rear crash** will significantly reduce.
- **SO4**: The likelihood of trams and trains equipped with and exposed to the i-DREAMS interventions to be involved in a **roll-over/derailment crash** will significantly reduce.
- **SO5**: The likelihood of trams equipped with and exposed to the i-DREAMS interventions to be involved in a **crash with injury for passengers** will significantly reduce.

As can be seen in Figure 17, the real-time and post-trip interventions provided by the i-DREAMS platform are believed to have the potential to have impact on each of the nine collision types identified within the ISO classification system, although **the expected impact is believed to be different across different collision types**. For both frontal crashes and rear crashes, the expected impact is overall higher. This is mainly due to the fact that for the real-time interventions, one of the key-sensors (i.e. the Mobileye®) inside the monitoring pillar of the i-DREAMS platform is meant to monitor and warn for headway timing, forward collision risk, and lane departures, besides additional (optional) functionalities, like for instance, traffic sign recognition. As one of the key-features of the Mobileye® is to detect lead vehicles inside the driving lane, and to continuously provide evaluative feedback on a vehicle operator's headway time towards that lead vehicle, the potential impact of the i-DREAMS interventions on vehicle-to-vehicle rear crashes is expected to be high. Mobileye® is also able to detect vulnerable road users (i.e. pedestrians and cyclists) crossing in front of the vehicle's path, but is not monitoring and warning the specific headway time as in the case of having a lead vehicle in front of the driving lane. This is why the effect on vehicle-to-vulnerable road user crashes is expected to be of mediate size for frontal crashes, and of small size for side- and rear crashes, as Mobileye® has no sensors to detect vulnerable road users alongside the vehicle. Since fixed obstacle detection is not a functionality targeted by the Mobileye®, the impact of the i-DREAMS interventions on vehicle-to-obstacle crashes in general (i.e. whether rear-, side-, or front impact), is expected to be rather low. Given that Mobileye® detects lane changes, the impact of vehicle-to-vehicle frontal crashes is also expected to be high. Different from that, the impact on vehicle-to-vehicle side crashes is expected to be rather low, since Mobileye® is primarily monitoring what happens inside the

driving lane, rather than being focused on vehicles that cross the driving path transversally. Finally, from Figure 17 it can be seen that the nine different collision types apply as safety outcomes to each of the three road transport modes (i.e. car, bus, and truck), while they do not apply necessarily to the rail modes, especially to train. Even though both tram and train can be equipped with a Mobileye® system, some collision types simply do not apply because they do not align with what is the typical trip context of a tram or a train. Crashes with injury to passengers due to harsh or emergency braking are specifically important for trams, while roll-over crashes or derailment due to excessive speed are relevant for trains.

6.1.2 Safety promoting goals & related parameters

As can be derived from Figure 18, the safety outcomes (defined in terms of crashes: see previous section for a more detailed typology) are causally dependent upon an underlying set of safety promoting goals. These safety promoting goals refer to behaviours that can be logically linked to the safety outcomes, based on existing empirical evidence (for an overview of mode-specific crash types, risk scenarios and behaviours: see **Deliverable 3.4**). As was elaborately discussed in **Deliverable 2.2 (see sections 3 and 4)**, behaviours that are typically monitored in the context of safety promoting interventions relate (but are not necessarily limited) to one of the five behaviours that appear as safety promoting goals in Figure 18, i.e. vehicle control, sharing the road with others, speed management, driving fitness, and use of safety devices. These safety promoting goals have been hierarchically structured, to represent where in the GDE matrix they have to be situated. As such, **vehicle control** appears at the bottom (i.e. the lowest level of the GDE-matrix), because it refers to how a human operator masters his or her vehicle. **Sharing the road** refers to interaction with other road users. Together with **speed management**, these are two safety promoting goals to be situated at the second level in the GDE-matrix, i.e. driving in traffic. **Driving under conditions where one is physically and mentally 'fit' enough to do so**, and the **use of safety devices** while driving, correspond to the third level of the GDE-matrix, i.e. the level that is dedicated to how people take trip-related decisions (e.g. 'Am I fit enough to drive?'), and to how people respond to context factors while driving, such as possible sources of distraction, or feedback from in-vehicle safety devices. In the context of the i-DREAMS project, both the real-time and the post-trip interventions target the same set of behaviours.

These behaviours are thus the goals that need to be promoted. In a more formal way, but without any quantification, the five Safety Promoting Goals (SPG) targeted by the i-DREAMS interventions can be formulated as follows:

- **SPG1**: Performance in terms of **vehicle control** (expressed as a numerical score) will significantly improve for cars, bus, trucks, trams and trains equipped with and exposed to the i-DREAMS interventions.
- **SPG2**: Performance in terms of **sharing the road with others** (expressed as a numerical score) will significantly improve for cars, bus, trucks, and trams equipped with and exposed to the i-DREAMS interventions.
- **SPG3**: Performance in terms of **speed management** (expressed as a numerical score) will significantly improve for cars, bus, trucks, trams and trains equipped with and exposed to the i-DREAMS interventions.
- **SPG4**: Performance in terms of **driving under conditions where one is fit enough** (expressed as a numerical score) will significantly improve for cars, bus, trucks, trams and trains equipped with and exposed to the i-DREAMS interventions.

- **SPG5**: Performance in terms of **using safety devices** (expressed as a numerical score) will significantly improve for cars, bus, trucks, trams and trains equipped with and exposed to the i-DREAMS interventions.

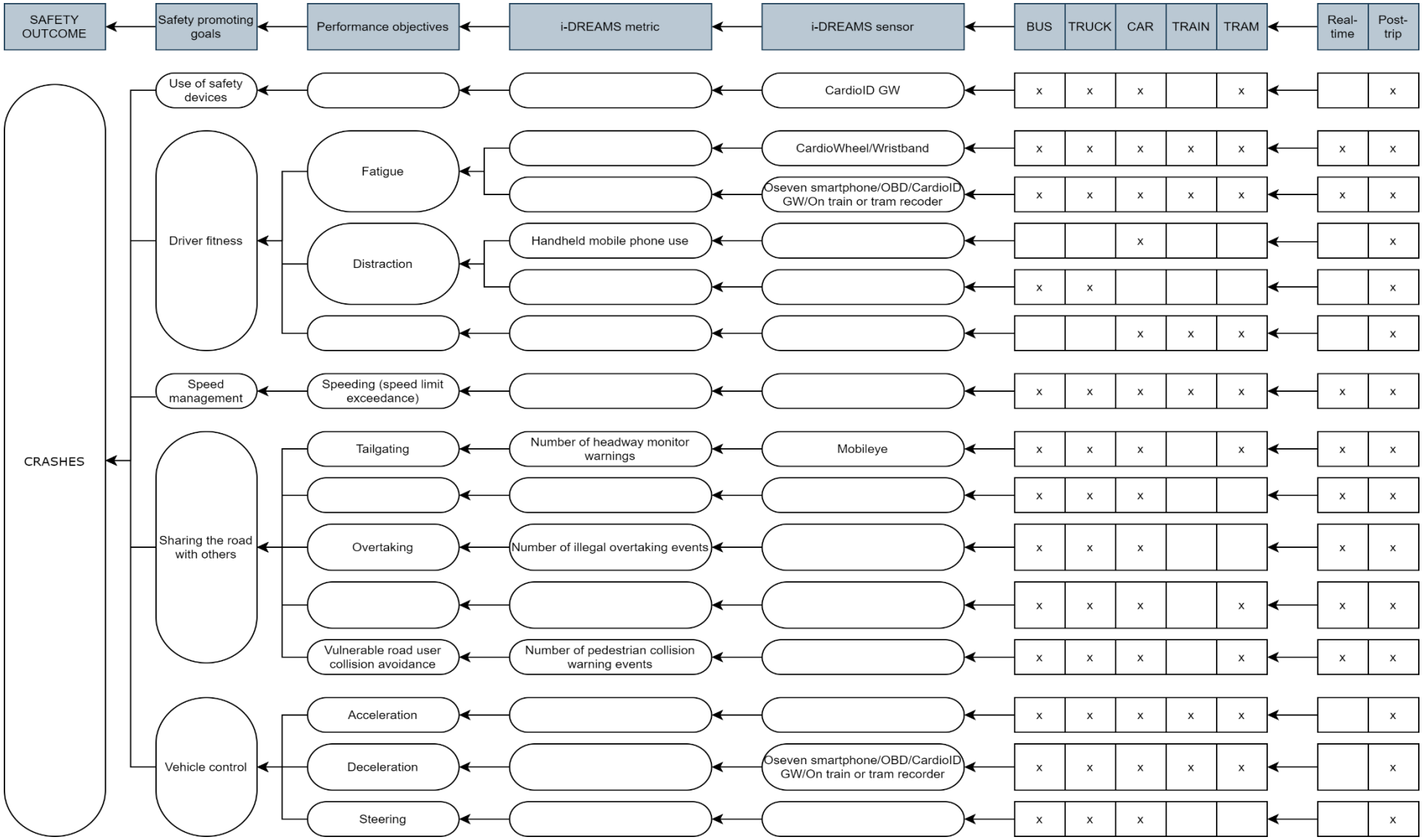


Figure 18: Safety promoting goals and related parameters

Figure 18 further continuous the logical analysis with an indication of the more specific behavioural parameters that co-determine a vehicle operator's performance on the different safety promoting goals. A subset of the 14 behavioural parameters selected for the i-DREAMS project appears in the overview, and the connection with their respective safety promoting goals, is again based on a detailed review of the literature reported in Deliverable 2.2. These parameters will later on be used to define the performance objectives targeted by the i-DREAMS interventions (see section 6.2). For instance, the safety promoting goal 'driving while fit to do so' is dependent on three specific parameters, e.g. the extent to which one is (not) driving while task fatigued, or the extent to which one is (not) driving while distracted.

Regarding the more specific behavioural parameters, four additional elements are shown in Figure 18. Firstly, under the column header 'i-DREAMS metric', it is mentioned what the formal indicators are that will be used to measure the behavioural parameters, and to determine a vehicle operator's performance (expressed as a numerical score) on those parameters. For example, to measure performance on the parameter (not) driving while distracted, the i-DREAMS monitoring platform will use a combination of two different metrics, one of these being 'handheld mobile phone use'. Secondly, under the column header 'i-DREAMS sensor', it can be found which sensor or technology will be used to capture the required metrics (for more detailed technical specifications on the i-DREAMS sensors and metrics: see Deliverable 3.2). For example, the metric for 'tailgating' is 'number of headway monitor warnings', which is captured by the Mobileye® system. Thirdly, for each of the modes in the i-DREAMS project, it is indicated whether (or not) a metric will be captured. As can be seen, not all metrics will be monitored for each of the modes. For instance, the metric 'number of illegal overtaking events' will not be registered for tram and train, because for these modes, that specific metric is not relevant. Finally, it is shown for each of the behavioural parameters whether (or not) they will be part of and targeted by the real-time and/or the post-trip interventions. To illustrate, fatigue could be warned for while driving, and could lend itself to sensibilisation via the post-trip interventions. Here as well, the review of available intervention strategies in Deliverable 2.2 was taken as a guideline to decide which parameters to include or exclude for the real-time and the post-trip interventions.

Figure 18, however, is not the endpoint of the logical problem analysis. As already reported in section 4.3.1, changing behaviour, requires the underlying determinants of the targeted behaviour to be identified. Without impact on those determinants, the effectiveness of interventions might be seriously jeopardized. The next section is dedicated to the identification of the determinants that will be targeted by the i-DREAMS interventions.

6.1.3 Determinants

For the identification of relevant determinants to be targeted by the real-time and the post-trip interventions, the search strategy proposed by Buunk & Van Vugt (2008) was followed. More in detail, they developed **a three-staged search strategy** where first, the reviewer's focus is on a so-called 'issue-based' scanning and reading of the literature.

An **issue-based review** is where the researcher limits his/her focus on references that directly address the specific topic of interest. That can be for instance, studies specifically addressing the topic of speeding, distraction, tailgating, et cetera. From those studies, a first set of determinants explaining the occurrence of those behaviours, can be derived. For instance, studies on speeding where socio-cognitive models (like the Theory of Planned Behaviour) have been used to uncover the determinants of that behaviour, have identified

attitude, subjective norm and perceived behavioural control as significant predictors of speeding (e.g. Warner & Åberg, 2006; De Pelsmacker & Janssens, 2007). Next, the reviewer's focus goes to a so-called 'concept-based' scanning and reading of the literature. A **concept-based review** is where the researcher turns to references that discuss psychological concepts that do not necessarily appear in issue-specific references, but nevertheless might be relevant to develop a more complete understanding of the issue under study. For example, the concept 'implementation intention' (i.e. a self-regulatory strategy in the form of an 'if-then' plan) is seldomly included in studies where socio-cognitive theories are used to learn more about the determinants of specific risky behaviours like dangerous overtaking, or driving while fatigued, although it is well-known that an implementation intention can increase the likelihood of translating good intentions into behaviour (e.g. Gollwitzer & Bargh, 1996). From a conceptual point of view, implementation intention might thus be an additionally relevant determinant. The final step in the review process, is where the focus turns to scanning and reading general theories on behaviour formation and change. A **general theories-based review** is where the researcher consults theoretical frameworks on behaviour formation and change not yet applied to the topic under investigation, to further complement the available list of determinants with additionally relevant variables. For example, according to Goal Directed Theory (Bagozzi, 1992), to guarantee that people act on their intentions, and in order to be able to develop an action plan or implementation intention, goals need to be set. Thus, from Goal Directed Theory, the concept 'goal' can be added to the list of already identified determinants.

The following two sections summarize the results of this three-staged literature review and show which determinants have been selected for inclusion in the real-time and the post-trip interventions respectively.

6.1.3.1 Real-time interventions

Figure 19 shows which components from the COM-B Model were identified as relevant for inclusion in the real-time interventions, i.e. psychological capability, automatic motivation, and physical opportunity. These three components and the more specific determinants that relate (i.e. detailed below) to them are to be understood as causally linked to each of the behavioural parameters already mentioned (see Figure 18).

The decision to select these COM-B Model components, relates to the fact that they align best with the idea of nudging, which is how the real-time interventions inside the i-DREAMS platform have been categorized (see section 2.4.1). **Physical opportunity** refers to factors situated in the cockpit environment that steer the vehicle operator's decision-making while driving, thereby facilitating safe behaviour. **Automatic motivation** is more relevant than reflective motivation in the context of real-time interventions, due to the simple fact that the window of opportunity for decision-making is often limited to (milli)seconds. **Psychological capability** is by definition relevant in the context of real-time interventions, as vehicle operators should be mentally ready to act when necessary, and knowledgeable of how to appropriately adapt their behaviour.

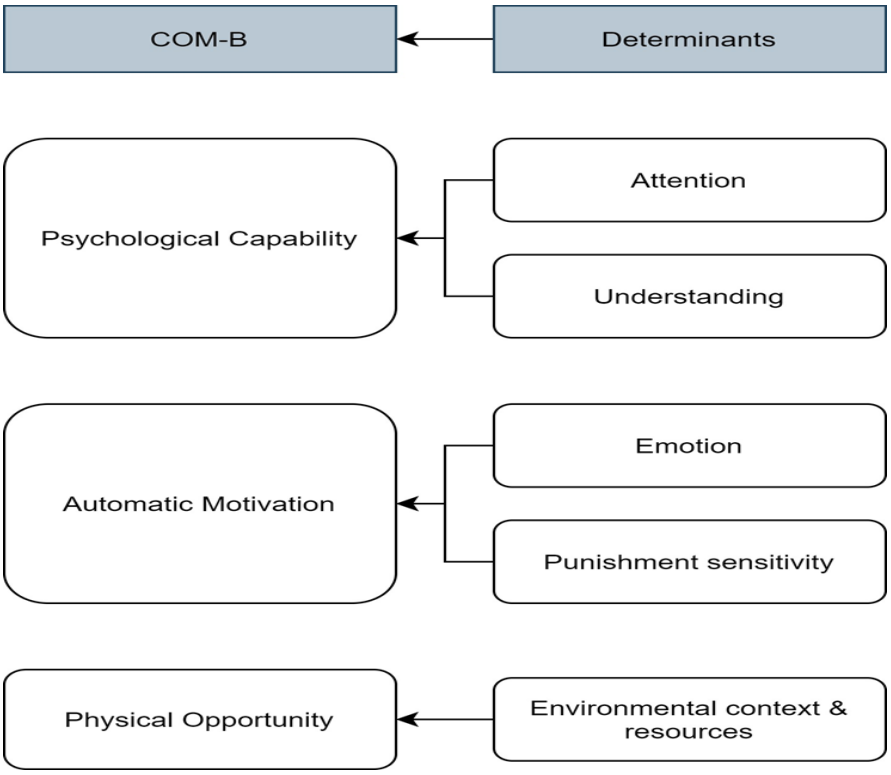


Figure 19: Determinants for real-time interventions

As for the component 'physical opportunity', the determinant selected for inclusion, is labelled '**environmental context and resources**', i.e. any circumstance of a person's situation or environment that discourages undesirable behaviour or encourages the desired (adaptive) behaviour (Michie et al., 2014). Environmental context and resources refers to any kind of technological device inside the cockpit that is meant to discourage risky behaviours and/or encourage safe behaviours while driving. As can be seen from Deliverable 2.2 (see section 3.2), that can be anything from dashboards, head-up displays, augmented reality, or centre console displays, to haptic, visual or auditory nomadic devices.

As already explained, the component 'automatic motivation' refers to impulses and reflex responses, rather than motivation as the outcome of conscious reasoning. As discussed in Deliverable 2.1 (see Section 5.3) triggering **emotion** (e.g. fear) can be a very powerful leverage to initiate immediate action whenever required, even though it needs to be implemented with care. The importance of emotions for the modelling of human decision making and behaviour, has become standard in modern theories in cognitive psychology and neuroscience (e.g. Slovic et al. 2004). The relevance of emotions for instance, has been explicitly recognized in the work by Summala (2007) and Vaa (2007). Vaa (2014) even incorporated it as a key-element (i.e. the 'somatic marker') in his Risk Monitor Model. It has also been picked up in the field of modelling driver behaviour in automotive environments (e.g. Cacciabue, 2007).

Especially in case of imminent danger, **punishment sensitivity** (i.e. the degree to which an individual's behaviour is inhibited by punishment-relevant stimuli: see Carver & White, 1994) is another potentially relevant determinant that can facilitate motivating the vehicle operators to adapt their behaviour. In the field of transportation, punishment sensitivity has already

been examined in relation to the commission of traffic violations (e.g. Castellà & Pérez, 2004). In the context of the i-DREAMS project, the punishment-relevant stimulus would be the acute risk of colliding, and a way to sensitize vehicle operators for that potential punishment would be to make that collision risk explicitly salient.

Finally, for the component 'psychological capability', two determinants have been selected, i.e. attention and understanding. As discussed in Deliverable 2.1 (see section 5.1.3), vehicle operators have to cope with various attention-demanding tasks while driving. To keep vehicle operators sufficiently situation aware (e.g. Wickens, 2008), **attention regulation** is a key-determinant for real-time interventions (e.g. Terry et al., 2008; Charlton & Starkey, 2011; Engström, 2011; Masala & Grosso, 2014; Charlton & Starkey, 2018). Next to being attentive while driving, it is also important that vehicle operators are knowledgeable of how to appropriately adapt their behaviour, in case necessary. Without clear and precise enough **understanding** of what particular aspect(s) of current driving need(s) correction, it remains difficult for vehicle operators to make accurate decisions, and take appropriate action, especially under challenging conditions and without much time. The relevance of timely available understanding of what to do as a vehicle operator is recently receiving much attention in the literature on monitoring- and control transitions in automated driving (e.g. Lu et al., 2019).

The above mentioned five determinants will constitute the conceptual basis of what later on (see section 6.2) will become the change objectives to be targeted by the real-time interventions. The following section continues with the COM-B components and the respective determinants that will be targeted by the post-trip interventions.

6.1.3.2 Post-trip interventions

Figure 20 shows which components from the COM-B Model were identified as relevant for inclusion in the post-trip interventions, i.e. psychological capability, physical capability, reflective motivation, automatic motivation, and social opportunity. These five components and the more specific determinants associated with them, are thus also to be seen as causally linked with the behavioural parameters previously mentioned (see Figure 18).

As already discussed, the post-trip interventions are primarily aimed at coaching vehicle operators to become (more) safe drivers (see section 2.4.2). Building the **psychological capability** to do that, is a first objective targeted by the post-trip interventions. More in particular, two determinants fall under this component, i.e. knowledge and implementation intention. As for **knowledge**, it is also one of the basic learning competences targeted by the GDE-matrix (Hatakka et al., 2002; Keskinen et al., 2010). Different from the real-time interventions where understanding is to be interpreted as an ephemeral and momentarily triggered conscious recognition of the need to adapt behaviour, for the post-trip interventions, knowledge refers to more stable and elaborate mental schemes referring to factual information. For instance, concerning the advantages and disadvantages of safe and unsafe behaviour respectively, to codes and rules that apply to traffic, or to procedures on how to cope with challenging driving conditions. **Implementation intention** relates to volition and has already been explained as a self-regulatory strategy in the form of an 'if-then' plan that increases the likelihood for an individual to act upon motivation. It is in other words, that aspect of psychological capability that refers to an individual's capacity to turn good intentions into behaviour. The relevance of implementation intentions has been empirically demonstrated, for instance in a study on the effectiveness of an intervention aimed at

reducing the intentions to speed by Brewster et al. (2015). Due to the fact that the post-trip interventions have a wider window of opportunity, creating the required knowledge and forming the necessary implementation intentions are an achievable objective.

The determinant associated with the COM-B component '**physical capability**', is skill. **Skills** (i.e. an ability or proficiency acquired through practice, see Michie et al., 2014) are another learning key-competence according to the GDE-matrix (Hatakka et al., 2002; Keskinen et al., 2010), and various so-called 'integrative models' in health psychology consider skills to be a crucial direct predictor of behaviour, e.g. the Integrated Theory of Health Behaviour Change (Ryan, 2009), or the Integrative Model of Behavioural Prediction (Fishbein, 2000). Due to the fact that the post-trip interventions run over wider time episodes, they lend themselves much better to building up the skills needed to master the behavioural parameters that are causally linked to the safety promoting goals targeted by the i-DREAMS interventions.

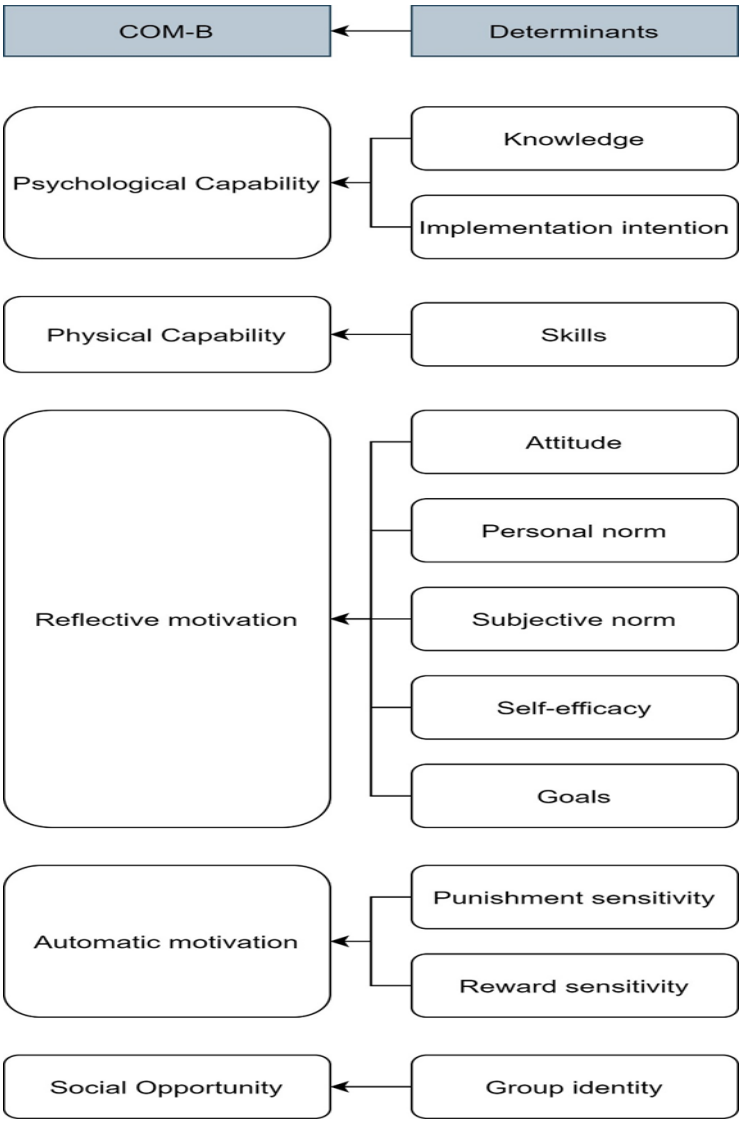


Figure 20: Determinants for post-trip interventions

Reflective motivation is also a more suitable target for post-trip interventions, as they are not bound to a (milli)second time window. As already explained, reflective motivation is to be

understood as motivation that results from conscious thought processes. These thought processes can be of various kinds, as can be derived from the variety of determinants falling under this COM-B component.

In the case of **attitude**, the thought process behind motivation, is mainly focused on outcome expectancies (i.e. beliefs about what will be the consequences of performing a certain behaviour), and their affective evaluation (i.e. whether one appraises the expected consequences as positive or negative) (e.g. Eagly & Chaiken, 1993; Albarracín et al., 2005). **Personal norm** is when the motivation to perform a certain behaviour (or not) is dependent upon one's own personal value system. As Parker et al. (1995) explain, the underlying idea is that before engaging in a particular behaviour, an individual will consider the potential consequences for his or her self-image. In case there is a perceived conflict with a set of deeply engrained moral values, anticipated regret will refrain a person from carrying out the behaviour. Different from that, in the case of **subjective norm** as the underlying determinant, motivation is believed to be dependent on the extent to which a person complies (or not) with the opinion of important social referents (e.g. colleagues, friends, partner, et cetera) about performing a particular behaviour (Ajzen & Fishbein, 1980). **Self-efficacy** was proposed by Bandura (1986) as part of his Social Cognitive Theory, and is to be understood as a person's judgment of his or her ability to cope effectively in different circumstances. Finally, **goals** direct people's attention, evaluations, consideration of actions/alternative actions, and the cognitive accessibility of knowledge and attitudes (Lindenberg & Steg, 2007). As put by Michie et al. (2014), goals are mental representations of outcomes or end states that an individual wants to achieve. Goals are thus to be seen as important behavioural regulators.

The relevance of attitude, subjective norm, and self-efficacy as key-determinants of road user motivation and behaviour can be derived from a vast amount of studies where the Theory of Planned Behaviour (Ajzen, 1991) was used as a theoretical framework to develop and empirically test hypotheses on which variables explain how road users behave in traffic. The theory has been applied to a wide variety of road user groups and numerous safety- and risk-related behaviours, such as speed management (e.g., Conner et al., 2007; Paris & Van den Broucke, 2008; Bordarie, 2019), distracted driving (e.g., Marulanda et al., 2015; Sullman et al., 2018), alcohol impaired driving (e.g. Potard et al., 2018), the use of self-protective safety measures (e.g. Brijs et al., 2011; Brijs et al., 2014), the commission of violations (e.g. Desrichard et al., 2007; Forward, 2009), and regulation compliance (e.g. Poulter et al., 2008). Personal norm has also been identified as a relevant predictor of road user motivation and behaviour, for instance, in a study by Manstead and Parker (1995), where it was reported that 10-15% of traffic behaviour can be explained by the variable personal norm. In addition, De Pelsmacker and Janssens (2007) found personal norm to be a significant predictor of self-reported speeding behaviour. Moreover, Elliott and Thomson (2010) found the two basic components of personal norm (i.e. moral norm and anticipated regret) to contribute to the explanation of intentions to speed. The relevance of goals for the activation of the required self-regulatory processes in the context of interventions for behavioural change, was advocated in a study by Hickman & Hanowski (2011) where a video monitoring approach was used to reduce at-risk driving behaviours in commercial vehicle operations.

Post-trip interventions often also rely on other mechanisms than conscious thought to motivate people to change their behaviour. The principles of operant conditioning (i.e. positive and/or negative reinforcement), for example, are a frequently used approach to promote desirable behaviours, and extinguish undesirable habits (e.g. Mazur, 2017). Operant conditioning is based on the formation of associations between a particular behaviour, and

the consequences of that behaviour (i.e. more typical for automatic motivation) (see Murphy & Lupfer, 2014), rather than on in-depth logical reasoning creating deeper insight into the cause-effect mechanisms linked to a particular behaviour (i.e. more typical for reflective motivation). Rewarding desirable behaviour and penalizing undesirable behaviour are popular methods, for instance in the field of fleet safety management where so-called Compliance, Safety and Accountability programs are considered as an effective approach (e.g. Corsi & Barnard, 2003; Knipling et al., 2003; Hickman et al., 2007). **Automatic motivation** is therefore included as a fourth COM-B component to be targeted by the post-trip interventions. Two determinants are associated with this component. **Punishment sensitivity** was already defined in the context of the real-time interventions (see section 6.1.3.1). Since post-trip interventions also frequently work with reward strategies to motivate people to show the desired behaviour, **reward sensitivity** is included here as well. Reward sensitivity can be defined as the tendency to detect, pursue, learn from, and derive pleasure from positive stimuli (Goodnight, 2018). Reward sensitivity has been identified as a potentially important precursor of the motivation to engage in risky behaviours in the literature on young novice drivers (e.g. Jongen et al., 2011; Scott-Parker et al., 2013; Harbeck et al., 2017; Scott-Parker & Weston, 2017). However, sensitivity to rewards has not only been related to the propensity to take risks, but to the motivation to drive safely or eco-efficiently as well (e.g. Dijksterhuis et al., 2015; Musicant & Lotan, 2016; Schall & Mohnen, 2017; Mortimer et al., 2018; Vaezipour et al., 2019).

Social opportunity is the final COM-B component selected for inclusion in the i-DREAMS post-trip interventions. Social opportunity refers to agents in the individual's social environment that can facilitate the desired behaviour. As already indicated, a post-trip intervention setting is very well suited to positively exploit human's craving for social connectedness (Pratkanis, 2014). Important social referents can be a powerful leverage for individuals to modify their behaviour, in the case it does not conform to the group norm (see Social Identity Theory as proposed by Tajfel & Turner, 1986). **Group identity**, defined as the portion of an individual's self-concept derived from perceived membership in a relevant group (Turner & Oakes, 1986), is a crucial determinant within this COM-B component. The importance of group identity for the promotion of road safety has been demonstrated both in the literature on private drivers as in the literature on professional drivers. For private drivers, the importance of group membership or social affiliation has been demonstrated, for instance in studies on the impact of parenting (e.g. Simons-Morton et al., 2002; Taubman-Ben - Ari et al., 2005; McGehee et al., 2007; Prato et al., 2010; Farah et al., 2014; Shimshoni et al., 2015), and family climate (e.g. Taubman-Ben – Ari & Katz-Ben – Ami, 2012, 2013; Carpentier et al., 2014) on young novice drivers' tendency to behave (un)safely. For professional drivers, there is extensive evidence available indicating that corporate safety culture and climate can guide individual driving behaviour (e.g. Zohar, 2008; Nævestad, 2010; Zohar, 2010; Huang et al., 2018).

The next section will be dedicated to the translation of the behavioural parameters in Figure 18 into performance objectives, and the determinants discussed into change objectives.

6.2 Step 2: Logic model of change

Now that the behavioural parameters that causally link to the safety promoting goals have been identified, together with their underlying determinants, it is time to formally propose **the logic model of change** that will be applied in the real-time and post-trip interventions. As explained by Bartholomew Eldredge et al. (2016), it is important that the proposed logic

model for change keeps the idea intact that the selected determinants are causally linked to the selected behavioural parameters, and that these in turn are also causally linked to the selected safety promoting goals. In order to do so, the authors have developed a so-called **'matrix' technique** where safety promoting goals are coupled to **Performance Objectives** (PO: i.e. objectives that apply to behavioural parameters), and where performance objectives are crossed with their related determinants. The **Change Objectives** (CO: i.e. objectives that apply to determinants) are formulated in the cells where horizontal rows containing the performance objectives cross with the vertical columns containing the determinants. As such, the causal link between change objectives, performance objectives, and safety promoting goals is kept intact.

In the following two sections, two change matrices will be constructed, one for the real-time interventions, and one for the post-trip interventions, to illustrate the matrix technique just described. Due to the large number of safety promoting goals, behavioural parameters, and underlying determinants, only one change matrix focussing on one specific safety promoting goal will be proposed. Strictly taken, for both the real-time and the post-trip interventions, five change matrices (i.e. one per safety promoting goal) could be developed, but to avoid a lengthy list of matrix tables, the full set of change matrices will not be included.

6.2.1 Sample matrix for the real-time interventions

For the real-time interventions, the change matrix proposed will focus on the safety promoting goal referring to sharing the road with others. As can be derived from Figure 18, this matrix consists of five rows (five behavioural parameters for which a performance objective is formulated, can be linked to sharing the road with others), to be crossed with five columns (five determinants can be linked with each of the five behavioural parameters). This means that the safety promoting goal for 'sharing the road with others' is causally dependent upon five performance objectives, and a total of 25 change objectives (five change objectives per performance objective). The sample matrix is shown in Figure 21.

Safety Promoting Goal: Vehicle operators improve the way they share the road with others					
Determinants					
Performance objective	Attention	Understanding	Emotion	Punishment sensitivity	Environmental context & resources
PO1: vehicle operators reduce risky tailgating events	A1: identify headway time	U1: recognize the need to adjust headway time in case a risky tailgating event is imminent	E1: demonstrate worry when receiving a headway time warning	PS1: adjust headway time when receiving a headway time warning	ECR1: have a nomadic device inside the cockpit providing continuous feedback on headway time
PO2: vehicle operators reduce risky lane discipline events	A2: identify unintended lane departures or intended lane departures without use of the indicator	U2: recognize the need to move back into the lane or use the indicator in case they want to change lane when receiving a lane departure warning	E2: demonstrate worry when receiving a lane departure time warning	PS2: move back into the lane in case of an unintended lane departure or activate the indicator in case of an intended lane departure when receiving a lane departure warning	ECR2: have a nomadic device inside the cockpit providing continuous feedback on lane departures
PO3: vehicle operators reduce risky overtaking events	A3: identify whether it is legally allowed to overtake	U3: recognize they cannot overtake when legally not allowed to	E3: demonstrate determination when it is legally not allowed to overtake	PS3: do not overtake when legally not allowed to	ECR3: have a nomadic device inside the cockpit providing continuous feedback on whether it is legally allowed (or not) to overtake
PO4: vehicle operators reduce forward collision events	A4: identify headway time	U4: recognize the need to adjust headway time in case a forward collision event is imminent	E4: demonstrate worry when receiving a forward collision warning	PS4: adjust headway time when receiving a forward collision warning	ECR4: have a nomadic device inside the cockpit providing continuous feedback on forward collision risk
PO5: vehicle operators reduce vulnerable road user collision events	A6: identify vulnerable road users crossing their path	U6: recognize the need to adjust their headway time when a vulnerable road user collision event is imminent	E6: demonstrate worry when receiving a vulnerable road user collision warning	PS6: adjust the headway time when receiving a vulnerable road user collision warning	ECR6: have a nomadic device inside the cockpit providing continuous feedback on the presence of vulnerable road users crossing their path

Figure 21: Sample matrix for real-time interventions

6.2.2 Sample matrix for the post-trip interventions

For the post-trip interventions, the change matrix proposed will focus on the safety promoting goal referring to vehicle control. As can be derived from Figure 18, this matrix will consist of three rows (three behavioural parameters for which a performance objective is formulated, can be linked to vehicle control), to be crossed with 11 columns (11 determinants can be linked with each of the three behavioural parameters). This means that the safety promoting goal for 'vehicle control' is causally dependent upon three performance objectives, and a total of 33 change objectives (11 change objectives per performance objective). The sample matrix is shown in Figure 22.

Safety Promoting Goal: Vehicle operators improve their vehicle control											
Determinants											
Performance Objectives	Knowledge	Implementa-tion intention	Skills	Attitude	Personal norm	Subjective norm	Self-efficacy	Goals	Punishment sensitivity	Reward sensitivity	Group identity
PO1: vehicle operators reduce the amount and aggressiveness level of harsh acceleration events	K1: state the safety-related risks of harsh acceleration	II1: plan when and how to accelerate appropriately	S1: demonstrate ability to accelerate appropriately	ATT1: express positive feelings about appropriate acceleration	PN1: express self-regret when they harshly accelerate	SN1: recognize that important others think it is important to accelerate appropriately	SE1: express confidence in their ability to appropriately accelerate	G1: state what performance level they want to achieve in terms of appropriate acceleration	PS1: express sorrow when they are penalized for harsh accelerations	RS1: express joy when they are rewarded for appropriate accelerations	GI1: express shame in case they harshly accelerate when important others do not
PO2: vehicle operators reduce the amount and aggressiveness of harsh decelaration events	K2: state the safety-related risks of harsh deceleration	II2: plan when and how to decelerate appropriately	S2: demonstrate ability to decelerate appropriately	ATT2: express positive feelings about appropriate deceleration	PN2: express self-regret when they harshly decelerate	SN2: recognize that important others think it is important to decelerate appropriately	SE2: express confidence in their ability to appropriately decelerate	G2: state what performance level they want to achieve in terms of appropriate deceleration	PS2: express sorrow when they are penalized for harsh decelerations	RS2: express joy when they are rewarded for appropriate decelerations	GI2: express shame in case they harshly decelerate when important others do not
PO3: vehicle operators reduce the amount and aggressiveness of harsh cornering events	K3: state the safety-related risks of harsh cornering	II3: plan when and how to corner appropriately	S3: demonstrate ability to corner appropriately	ATT3: express positive feelings about appropriate cornering	PN3: express self-regret when they harshly corner	SN3: recognize that important others think it is important to corner appropriately	SE3: express confidence in their ability to appropriately corner	G3: state what performance level they want to achieve in terms of appropriate cornering	PS3: express sorrow when they are penalized for harsh cornerings	RS3: express joy when they are rewarded for appropriate cornerings	GI3: express shame in case they harshly corner when important others do not

Figure 22: Sample matrix for post-trip interventions

Now that the objectives of the i-DREAMS interventions have been defined and logically connected to each other, the next section will focus on the change methods that will be deployed to realize the proposed logic model of change.

6.3 Step 3: Intervention design

One of the key-tasks in terms of intervention design, is the selection of change methods, suitable for the realization of the change objectives previously formulated (see section 6.3.1). In addition, the critical design parameters to be taken into account when translating change methods into practical applications, have to be identified (see section 6.3.2). For the i-DREAMS interventions, persuasive or gamified design will be used to practically implement the selected change methods (see section 6.3.3).

6.3.1 Methods

As already mentioned in section 4.3.2, the BCTTv1 and the IM-TBCM were used for the selection of appropriate change methods. The next section first presents the methods selected for the real-time interventions.

6.3.1.1 Real-time interventions

Figure 23 gives an overview of the change methods selected for the real-time interventions.

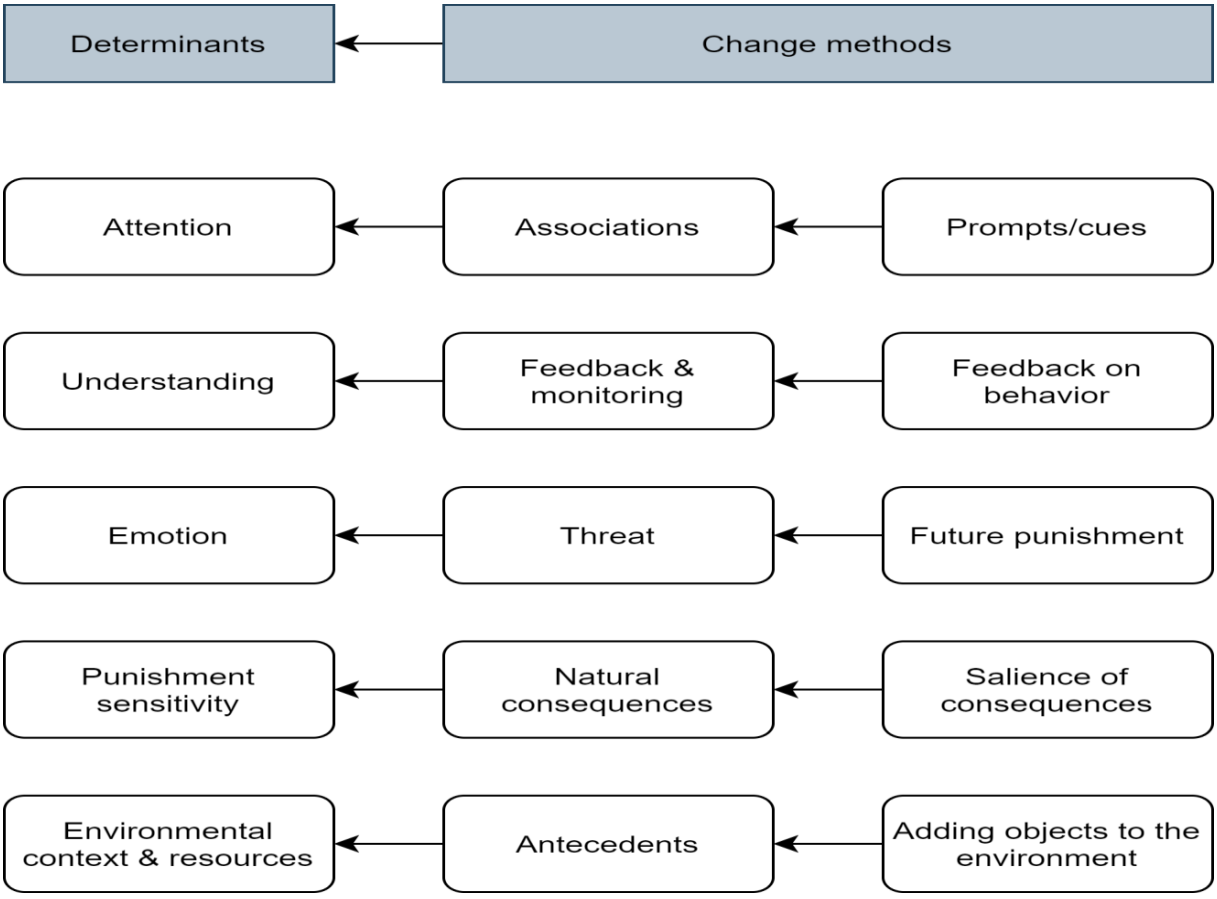


Figure 23: Change methods for the real-time interventions

For formal definitions and illustrative examples of the change methods chosen, see Table 14 in Annex 1. The two most important criteria for the selection of the proposed change methods were whether they matched with the targeted determinant, and whether they were suited for persuasive or gamified design.

For instance, the repetitive activation of a particular **sensory prompt or cue** inside the vehicle cockpit (e.g. a visual symbol or a sound) each time a vehicle operator is exposed to a certain risk (e.g. forward collision or lane departure) is a useful method to associate the sensory prompt with the idea of risk. This **learned association** of an originally neutral stimulus (i.e. the sensory prompt) with the idea of danger or risk, is a powerful leverage to attract **attention**. Real-time **feedback on a specific behavioural parameter** (e.g. speeding, headway time) is one out of several ways to implement the method **feedback and monitoring**. Such feedback can create a better insight or **understanding** for vehicle operators of their current driving performance. The prospect of possible **future punishment** (punishment here to be understood as crash involvement) is one popular way to implement the method of **threat**, which is known to be a powerful trigger of (self-defensive) **emotions** like fear, worry or anxiety. Explicit emphasis or '**salience**' of the possible negative consequences of a certain behaviour (e.g. tailgating) is a method to increase a vehicle operator's awareness of what might be the **natural consequences** of continuing that behaviour. That in turn, can make the vehicle operator more **sensitive** for those negative consequences. Finally, **adding an object** (e.g. a nomadic device) to the cockpit environment to timely warn for possible risks, is a way to provide the vehicle operator with an **antecedent** (i.e. a stimulus that cues to perform a learned behaviour). This in turn, will increase the supportive capacity of the **environmental context and its available resources**.

6.3.1.2 Post-trip interventions

Figure 24 shows a preview of change methods for the post-trip interventions, and more specifically, for **the determinant 'implementation intention' linked to 'psychological capability'**.

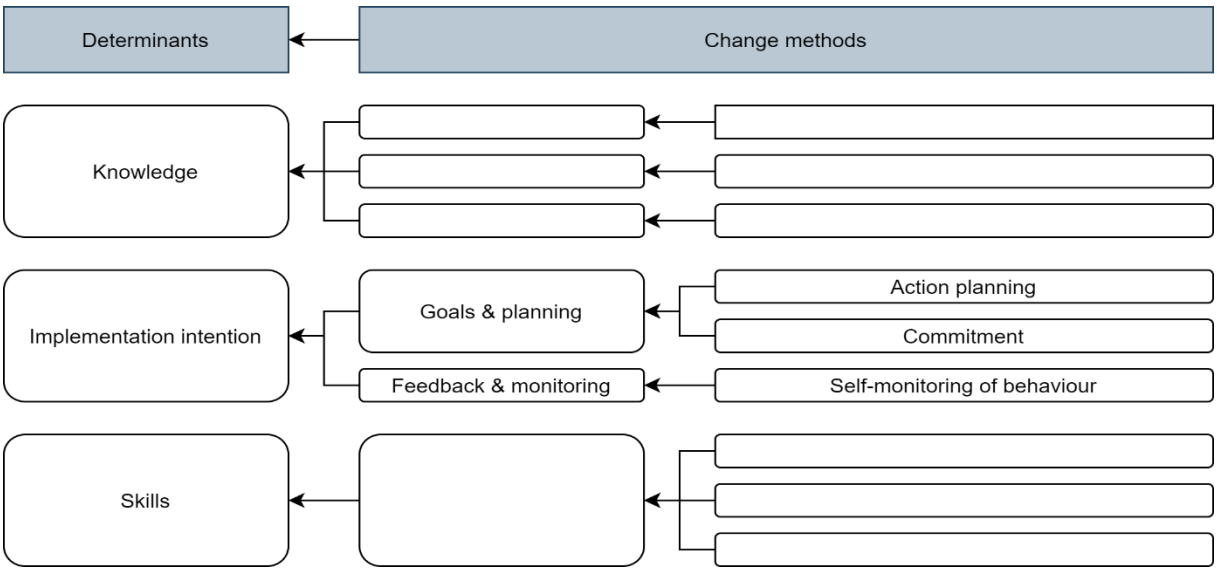


Figure 24: Change methods for the determinants related to psychological capability in the post-trip interventions

Without going into the details of all the change methods proposed for each of the determinants related to psychological capability, the determinant 'implementation intention' will be discussed as an illustrative example here. To increase vehicle operators' **implementation intention**, two change methods have been selected, i.e. goals & planning, and feedback & monitoring. For **goals & planning**, two approaches will be implemented, i.e. action planning, and commitment. While **action planning** implies that an 'if-then' plan is provided, precising context, frequency, duration or intensity of a specific behaviour (e.g. acceleration, deceleration, or steering) in the future, **commitment** relates to the explicit affirmation to act upon that 'if-then' plan, which has been shown to positively influence people's implementation intention (e.g. Cialdini, 2006). Yet, for the method 'goals & planning' to be relevant, vehicle operators should first have an idea of what behaviours require an action plan to commit to. This is why the method **feedback & monitoring** was also proposed, and more specifically, 'self-monitoring of behaviour'. **Behavioural self-monitoring**, indeed, allows vehicle operators to develop better insight into their personal performance on a variety of behavioural parameters. This in turn, helps in more accurately identifying those behavioural parameters for which an action plan is required.

Figure 25 shows the change methods selected for the post-trip interventions, and more specifically, for **the determinants linked to reflective- and automatic motivation**. The determinant '**attitude**' will be discussed as an illustrative example here. Three change methods are selected, i.e. feedback & monitoring, natural consequences, and comparison of outcomes. As for **feedback & monitoring**, '**self-monitoring of outcome(s) of behaviour**' allows vehicle operators to objectify their personally held opinions on what they believe to be the outcomes of their behaviour, and to correct eventual biases in these beliefs, via consultation of feedback that is based on naturalistic data captured by the risk monitoring pillar in the i-DREAMS platform. Since outcome beliefs constitute a key-component of attitudes, this method is particularly suited to influence the cognitive (i.e. belief-based) component of attitudes. **Information about health consequences** (in the case of i-DREAMS, health relates to road safety), and **information about emotional consequences** have been selected as approaches for implementation of natural consequences as a change method. Comparable to 'self-monitoring of outcome(s) of behaviour', information about health (i.e. safety) consequences is meant to influence the cognitive component of attitudes. Yet, different from self-monitoring of outcome(s) of behaviour, information about health consequences is specifically focussed on the safety-related impact (e.g., crash likelihood, or crash severity) of particular behaviours (e.g. speeding, illegal overtaking), instead of other outcomes or consequences like financial impact (e.g. fines), legal impact (e.g. temporary withdrawal of driving licence), or economic impact (e.g. loss of working hours due to licence withdrawal). **Information about emotional consequences** is primarily meant to influence the affective component of attitudes. For instance, the regret or sorrow that will follow when having approached a vulnerable road user too closely, or the satisfaction of being a rule-compliant and thus socially responsible driver. **Comparison of outcomes** is also a method primarily aimed at influencing the cognitive component of attitudes. Credible source together with pros and cons are the selected approaches to implement this method. **Credible source** refers to the presentation of opinions from a respected, believable, trustworthy and expertized person (e.g. a coach, a buddy, a friend) in favour of the desired behaviour or against the undesired behaviour. **Pros and cons** refer to the offering of information about reasons for wanting (pros) the desired behaviour and not wanting (cons) the undesired behaviour. Together, these two methods are aimed at influencing the vehicle operator's decisional balance, which rests to an important extent on his or her underlying attitude towards the (un)desired behaviour.

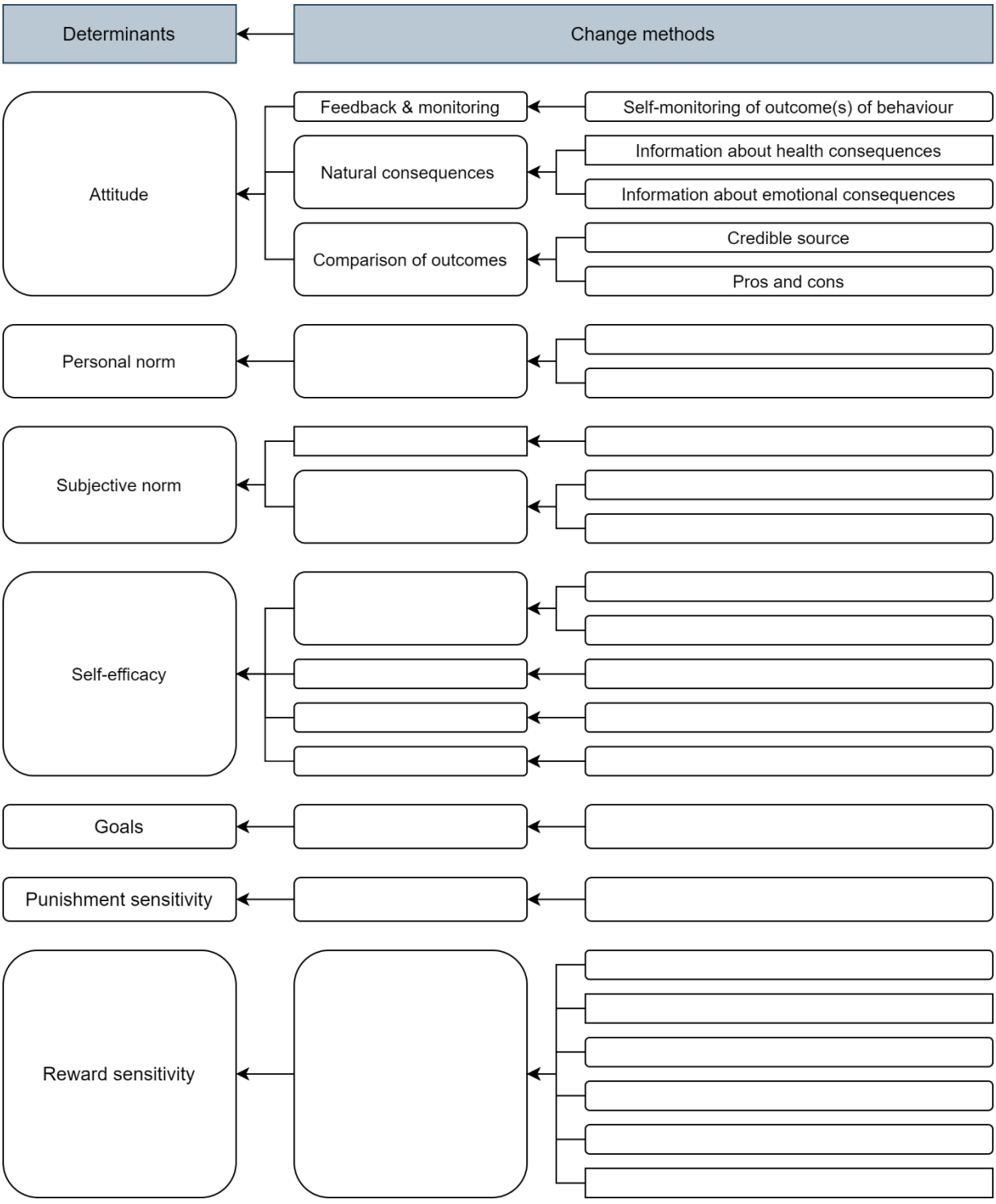


Figure 25: Change methods for the determinants related to reflective- and automatic motivation in the post-trip interventions

Figure 26 shows the change methods selected for the post-trip interventions, and more specifically, for the determinant linked to **social opportunity**. The variable selected is **group identity** and two change methods have been chosen, i.e. reward and antecedents. In the case of **reward**, the more specific approach that will be used, is **social reward**, i.e. a verbal or non-verbal expression from an important person that positively reinforces the desired behaviour demonstrated by the vehicle operator. For instance, a coach or colleague

congratulating the vehicle operator for having respected the speed limits. As already mentioned, antecedents refer to stimuli that cue an organism to perform a learned behaviour, and the method to achieve that is **restructuring the social environment**. This implies that the social environment surrounding the individual vehicle operator is arranged in such a manner that it can facilitate the vehicle operator in performing the wanted behaviour, or create barriers to prevent the unwanted behaviour. For example, a physical meeting with a coach or buddy, or a communication platform where messages can be exchanged between colleagues and management. These are indeed suitable methods to foster group identity, i.e. a sense of group belonging.

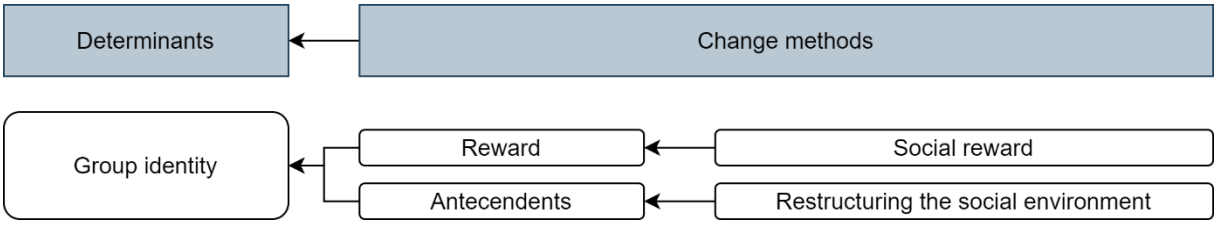


Figure 26: Change methods for the determinants related to social opportunity in the post-trip interventions

Now that the determinants targeted by the i-DREAMS interventions have been linked with appropriate change methods, the next section will address the critical design parameters to be taken into account when further translating change methods into practical applications.

6.3.2 Critical design parameters

In order for the practical application of theoretically defined change methods to have the desired effect, it is important to take into consideration as much as possible, what are the parameters or characteristics of the to-be-applied methods that determine whether they will be effectively used (e.g. de Bruin et al., 2015; Peters et al., 2015). These so-called critical design parameters will be discussed for both the real-time interventions and the post-trip interventions.

6.3.2.1 Real-time interventions

As already mentioned, the real-time interventions can paradigmatically be categorized as nudging. Two specific formats within this nudging paradigm were selected for inclusion in the i-DREAMS project, i.e. vulnerable road user protection and persuasive feedback without active intervention from technology. Based on the change methods proposed, it becomes clear that the real-time interventions indeed will do more than just alert drivers, and attract their attention. Moreover, they are meant to develop a better understanding of current driving behaviour, and to automatically trigger the vehicle operator's motivation to adapt behaviour whenever the risk for a collision with another vehicle or a vulnerable road user would occur. In other words, they are aimed at supporting the vehicle operator in safely carrying out his or her primary task (i.e. driving) by steering his or her decisions as much as possible into the direction of optimal safety, based on a reliable and accurate analysis of his or her behaviour. Or, paraphrased in terms of how the Safety Tolerance Zone was conceptually defined: the real-time interventions are designed to persuade drivers *during a trip* in staying as much as possible in the normal driving phase, and as little as possible in the danger phase or the avoidable crash phase.

The overall success of the real-time interventions hinges substantially on **the effectiveness of how in-car messages will be designed and offered to vehicle operators**. As already discussed in section 4.2.1, for real-time messaging to be effective, it should be **salient** (i.e. it must attract attention), **precise** (i.e. it should trigger a learning process), and **meaningful** (i.e. it should induce the appropriate motivation). These three requirements are primarily dependent upon three specific design features, i.e. **display**, **timing**, and **information**.

Display

In a recent publication by **Naujoks et al. (2019)**, a **framework of guidelines for the design of Human-Machine Interfaces** (HMI) was proposed to allow more informed decision-making in terms of how to deal with information, display, and timing. More in detail, the authors synthesized design recommendations for visual-auditory and visual-vibrotactile HMIs derived from empirical research, applicable standards, and design guidelines pertaining to in-vehicle interfaces. This resulted in **a checklist with 20 items** (see below: based on Naujoks et al., 2019: p. 129, Table 2), which in our case can be interpreted as representing the critical design parameters to be taken into account for the real-time interventions. Even though these guidelines have been developed in the context of automated driving, most of them apply to lower levels of automation (where the driver is still in control) as well:

1. Unintentional activation and deactivation should be prevented.
2. The system mode should be displayed continuously.
3. System state changes should be displayed continuously.
4. Visual interfaces used to communicate system states should be mounted to a suitable position and distance. High-priority information should be presented close to the driver's expected line of sight.
5. HMI elements should be grouped together according to their function to support the perception of mode indicators.
6. Time-critical interactions with the system should not afford continuous attention.
7. The visual interface should have a sufficient contrast in luminance and/or colour between the foreground and background.
8. Texts (e.g. font types and size of characters) and symbols should be easily readable from the permitted seating position.
9. Commonly accepted or standardized symbols should be used to communicate. Use of non-standard symbols should be supplemented by additional text explanations or vocal phrase/s.
10. The semantic of a message should be in accordance with its urgency.
11. Messages should be conveyed using the language of the users (e.g. national language, avoidance of technical language, use of common syntax).
12. Text messages should be as short as possible.
13. Not more than five colours should be consistently used to code system states (excluding white and black).
14. The colours used to communicate should be in accordance with common conventions and stereotypes.
15. Design for colour-blindness by redundant coding and avoidance of red/green and blue/yellow combinations.

16. Auditory output should raise the attention of the driver without startling him/her or causing pain.
17. Auditory and vibrotactile output should be adapted to the urgency of the message.
18. High-priority messages should be multimodal.
19. Warning messages should orient the user towards the source of danger.
20. In case of sensor failures, their consequences and required operator steps should be displayed.

For a more detailed overview of these 20 critical design parameters, Table 17 can be consulted in Annex 4.

Timing

One additional specific design parameter considered as critical for the success of the i-DREAMS real-time interventions, is the **timing of the messages**. It was already mentioned that based on a review of the available literature, **a dynamic 'multi-staged' messaging strategy** where both the activation as well as the sensory modalities and the content of the messages would be **adjusted to each specific stage of the STZ**, is the preferred option (see section 4.2.1). This would align with the idea of a **situation-adaptative driver assist system** (e.g. Inagaki, 2007). A situation-adaptive ADAS-system would operate according to a scheme where the supportive assistance provided would modify dynamically depending on the specificities of a situation (e.g. Scerbo, 1996; Inagaki, 2003). The criteria determining such dynamic modifications can reflect various factors, such as changes in the operating environment, loads or demands to the operators, and operator performance. Over the last decade, **proactive safety technology** that detects a vehicle operator's non-normative behaviour or state in-real time, and provides the driver with appropriately adapted support functions, has played a key-role in automotive safety improvement (e.g. Panou et al., 2007).

Several projects to develop such technologies were conducted worldwide, shortly after the start of the new millennium (e.g. Witt, 2003; Amditis et al., 2005; Cacciabue & Hollnagel, 2005; Panou et al., 2005; Saad, 2005; Tango & Montanari, 2005). These were all rooted in the expectancy that adaptive driver assistance (and automation) would improve comfort and safety of human-machine systems in transportation. One well-known framework for the modelling of driver behaviour developed in that area, is the DRIVABILITY model proposed by Bekiaris et al. (2003). It rests on the notion that **driver behaviour is not necessarily static, but evolving dynamically with time, and sensitive to the context**. Driver behaviour is subjected not only to permanent but also to temporary contributors, which may or may not be independent. In the AWAKE-project, the DRIVABILITY model was used to design the warning levels and strategy for an unobtrusive and personalized real-time driver monitoring device, meant to reliably predict driver hypo-vigilance and effectively and timely warn the driver. It was a good illustration of a system that recognises the importance of actual traffic risk level as well as driver status, and type, and key-environmental factors, working towards a multi-stage driver monitoring and driver warning system that takes such parameters into account. Nevertheless, according to Bekiaris et al. (2003), this new design principle for driver support training and assessment systems (i.e. the **model-based modular and personalized design**) was still in its infancy at that point in time.

Over the last decade, substantial progress has been made in this particular field of research. In different studies, approaches and systems have been proposed with the intention to:

1. learn what is to be considered as a vehicle operator's **normal driving** (e.g. Van Ly et al., 2013; Meiring & Myburgh, 2015; Wu et al., 2016; Vlahogianni & Barmpounakis, 2017; Jachimczyk et al., 2018; Mahdi Bejani & Ghatee, 2018; Reza Eftekhari & Ghatee, 2018; Barendswaard et al., 2019),
2. detect whether **abnormal deviations** from a vehicle operator's 'normal' driving pattern occur (e.g. Ellison et al., 2015; Chawla & Kumar Bathla, 2017; Li et al., 2017), and
3. come to a **dynamic timing of in-vehicle warnings or instructions based on flexible thresholds**, i.e. thresholds that can vary according to current driving circumstances (e.g. Siebert et al., 2017; Zhu et al., 2017; Ba et al., 2019).

Initial empirical evidence indicates there is potential for such a model-based modular and personalized design approach to increase the effectiveness and acceptability of safety-oriented interventions (e.g. Panou, 2018; Voß et al., 2018; Winkler et al., 2018; Sun et al., 2019). In the study by Panou (2018), specific personalized algorithms for longitudinal road axis behaviour were developed to create an **intelligent, dynamic and personalized Collision Avoidance System**. Time to Collision and Time Headway were among the selected parameters to do so, and the proposed algorithms based on Time Headway were assessed on-road with 10 drivers. Results showed **personalized warnings received greater acceptance by the drivers, without exceeding the safety margins**.

To conclude, it would be a great benefit if the i-DREAMS real time interventions would be able to develop an intelligent, dynamic and personalized messaging strategy, based on real-time assessment of actual traffic risk levels, as well as driver status and performance, and key-environmental factors. In Deliverable 3.2 (Katrakazas et al., 2020), more detailed specifications can be found on how such a real-time and dynamic calculation of the STZ based on flexible thresholds can be mathematically modelled.

Information

In order for in-car messages to be effective, they should not only be displayed well and appropriately timed, but be meaningful to vehicle operators as well. As already mentioned, the in-vehicle messages presented by the i-DREAMS real-time interventions should do more than just attract attention or inform the vehicle operator. Actually, they should be **intuitive** in a sense that they are able to steer a driver's decision-making into a certain direction, without coercion or taking over control. As recommended by Sanguinetti (2019), for in-vehicle messages to realize this objective, they should be designed making use of behavioural change techniques (e.g. feedback on behaviour, future punishment, salience of consequences) aimed at **increasing driver capability and motivation** (see also Oinas-Kukkonen & Harjumaa, 2009; Fogg, 2010; van Gent et al., 2019).

The challenge in case of real-time interventions is to do so **within a very short time window**. There simply is no time for processing lengthy messages and elaborate reflection. In the context of real-time interventions, the capability and motivation to act adequately on the circumstances need to be triggered almost immediately and automatically. In terms of formal message design, it is therefore more appropriate to work with **formats that can be instantly interpreted**, without effortful processing being necessary. For instance, by using visual icons or symbols, colour codes, animation, or sound. Semiotic research on the properties and effects of road signs (e.g. Charlton, 2006; Ng & Chan, 2007; Bazire & Tijus,

2009), vehicle icons (e.g., Chi & Dewi, 2014), and audio cues (e.g. Ho & Spence, 2005; Jekosh, 2005; Baldwin & May, 2011; Bazilynskyy & de Winter, 2015) has demonstrated that formal properties of visual signs (e.g. size, colour, font) or sound (e.g. pitch, loudness, and tone) carry typical connotations associated with their signifier. For instance, the colour red almost automatically brings up the idea of danger, or prohibition (e.g. Wagner, 2006). In the field of auditory interfaces, Baldwin & May (2011), for example, found that loudness interacts with semantics. They tested the effectiveness of messages combining words suggesting an intermediate urgency level (i.e. 'notice') or an extreme urgency level (i.e. 'danger') with and auditory cue at 70 or 85 dB. The message combining the word 'danger' with a sound of 70 dB loudness resulted in significant reductions in crash probability when used as part of an in-vehicle collision warning system.

In sum, iconic or symbolic signs scoring high in terms of 'guessability' convey their meaning almost instantly, and thus can be processed, understood, and reacted upon automatically and immediately. **Guessable signs** typically are signs that perform well on the following semiotic criteria: **familiarity**, **concreteness**, **simplicity**, **meaningfulness**, and **semantic closeness** (i.e. the closeness of the relationship between what is depicted and what it is intended to represent) (Ng & Chan, 2007). Formal **visual properties** of such signs, like colour, size, font, shape or level of animation often carry with them a typical **figurative meaning** (e.g. 'danger', 'safe', 'obligation', 'restriction', 'prohibition', 'urgent', 'important'). These connotative values can be further reinforced by means of the **acoustic properties** of sounds (i.e. pitch, loudness, and tone).

A combined manipulation of the visual properties of highly guessable icons and symbols, and the acoustic properties of an accompanying sound is the preferred message design strategy for a real-time setting, where the vehicle operator's capability and motivation to act appropriately must be triggered and steered into the right direction in very short time frames. Through their almost self-evident (e.g. Ng & Chan, 2007) connotative meanings, such visual and acoustic properties can do more than attract attention, or provide purely informative feedback. In addition to that, these connotative meanings invest highly guessable icons and symbols with the potential to instantly persuade vehicle operators.

The next section continues with critical design parameters to be taken into account for the post-trip interventions.

6.3.2.2 Post-trip interventions

The post-trip interventions can paradigmatically be categorized as coaching. Within the coaching paradigm, the format where persuasive feedback is offered in a post-trip setting via app and/or online web-dashboard was selected for the i-DREAMS project. Four different support functionalities will be targeted, i.e. primary task support (i.e. empowering human decision making at each of the hierarchical levels of the driving task), dialogue support (i.e. establishing a longer-term relationship with the end-user), social support (i.e. active involvement of relevant social agents), and system credibility support (i.e. gaining trust via reliable feedback and involvement of respected experts). In order for this coaching format to be effective, four critical design parameters will have to be taken into account.

Stage-matched application of change methods

According to the Transtheoretical Model of Behaviour Change, people are different in terms of how open they are to the idea of changing their behaviour. Self-Determination adds to that the idea that people are motivated differently depending on where they are in the process of behavioural change. These differences in both the quantity (i.e. how much you want to change behaviour) and quality (i.e. why it is you want to change behaviour) of motivation plead in favour of a stage-matched selection and use of the change methods selected for application in the post-trip interventions. As a quick illustration: offering challenges and setting goals targeting an improvement of a person's driving style will probably not motivate people in the precontemplation stage. Making them aware of the present potential and importance of such improvement, and influencing their decisional balance so that the pros of engaging in behavioural change outweigh the cons, are more appropriate techniques to use in that stage of change. A baseline assessment of current readiness for change and of the regulative mechanism behind the motivation to do so before the start of the i-DREAMS post-trip interventions, will be helpful in this regard. Dedicated survey questionnaires can be used for that purpose (see Deliverable 3.4 for more details).

The idea of an **individualized and adaptive approach** was already found to be successful in a study by Pozueco et al. (2017). More in detail, the authors developed and proposed a methodology where drivers are individually 'profiled' in terms of how 'mature' (i.e. how effective) they are regarding the targeted competences and behaviours (e.g. vehicle control, interaction with other road users, speed management, et cetera) at the beginning of an intervention, and the change techniques used systematically adapted to modifications in that personal profile. This methodology was evaluated in a study with 880 professional drivers, and results indicated that drivers' identified weaknesses improved in successive iterations of the learning process.

GDE-matrix as structural blueprint

According to the GDE-matrix, ameliorating a person's driving style, implies an improvement of the vehicle operator's driving performance and of the vehicle operator's deeper-situated and more stable safety-related dispositions (e.g., attitudes, norms, values, life-goals, et cetera). Depending on a person's current performance (e.g. novice vs experienced) and overall safety-related disposition (more safety concerned vs less safety concerned), he or she can be situated in **a hierarchically structured coaching process** that moves from simpler 'lower order competences' to more complex 'higher order competences'. These competences cover various areas of learning, i.e. awareness and knowledge of risk increasing aspects, skills on how to cope with these, and accurate self-assessment, and apply not only to the specific context of a trip or a traffic situation, but to more stable person-related dispositions (and even the supra-personal socio-cultural context) that might affect driving as well. A baseline assessment of current performance levels and of the more stable safety-related dispositions among the vehicle operators that will be participating in the i-DREAMS post-trip interventions to determine which segments of the GDE-matrix would be most relevant to target, will be required (see Deliverable 3.4 for more details). The survey questionnaires discussed in Deliverable 2.1 (see section 6) will be helpful in this regard.

Not only in terms of intervention efficacy, but regarding successful adoption as well, it is of strategic importance to use the GDE-matrix as a guiding instrument to determine and structure the competences to be targeted, as the GDE-matrix gave direction to the requirements proposed in the **EU Directives** that regulate the minimum requirements for

obtaining a private car driving licence, and for initial qualification and periodic training of professional drivers (Directive 2006/126/EC and Directive 2003/59/EC both amended by Directive 2018/645).

Stakeholder involvement in an occupational context

When working with professional drivers, actual involvement of other agents within the workplace setting (besides the targeted end-users), is of essential importance for the success of the i-DREAMS post-interventions. Taking into account findings reported in Deliverable 2.2, it became clear that the combination of an app + web-based dashboard would be an appropriate format to apply in the post-trip interventions. It was also recommended that such a technology-based solution would not operate as a stand-alone solution or a full replacement of human interaction. The i-DREAMS post-trip intervention platform will therefore function as kind of **automated expert system**, meant to provide support to the different key-stakeholders that are actively involved in the process of coaching professional vehicle operators to improve their driving style. According to Bartholomew Eldredge et al. (2016), stakeholders can take up three specific roles in the context of intervention uptake, i.e. adoption, implementation, and consumption. **Adoption** relates to the decision to use an intervention. **Implementation** refers to the execution of the intervention. **Consumption** stands for the actual exposure to and use of the intervention by the targeted end-users. Based on exploratory consultancy of stakeholders in the sectors of professional (public and private) transportation of persons and goods (see for instance, Deliverable 9.1), it has become clear that four stakeholder parties have an important role to play in the context of fleet safety management, i.e. company management (i.e. CEO or fleet safety manager), outdoor service providers, indoor coaches (i.e. planner or buddy), and employees:

1. **Company management** usually takes the decision to use a fleet safety intervention program, or not. This means company management is the stakeholder party taking up the role of **intervention adoption**. In addition to that, it is clear from the literature on safety culture and climate, that company management is also an important party to involve in the execution of a fleet safety intervention. In other words, company management is also taking up the role of **intervention implementation**. More specifically, demonstrated commitment and a good employer-employee relationship contribute to the success of fleet safety interventions. The i-DREAMS post-trip intervention platform will support company management in staying committed throughout the whole intervention duration, for instance, via a user-friendly and company-tailored reporting system that allows to monitor progress on a regular basis (for more technical details on this, see Deliverable 4.3)
2. **Outdoor service providers**: more and more, transport companies call on specialized outdoor services to organize, implement, and follow-up their fleet safety management due to the fact that they do not have the necessary expertise in-house, or because of time constraints. The i-DREAMS platform (especially the web-dashboard) is designed to support such fleet safety service providers in setting up and managing intervention programmes that are tailored to the specificities of the companies they work with. This outdoor service provider is thus to be seen as the intervention's coordinating supervisor, and makes use of the i-DREAMS platform as a kind of super-administrator. He or she is in other words involved in **intervention implementation**. More specifically, the super-administrator is allowed to and provided with the opportunity to set all sorts of configurations (e.g. to define projects, create different user groups, configure functionalities offered by the back-

end gamification engine, draw reports, et cetera). Accordingly, the super-administrator acts as a support for the in-company coaches via the i-DREAMS platform. Furthermore, the super-administrator can use the i-DREAMS platform and all the analytics behind it, to persuade company management to step in and stay committed to a fleet safety-promoting program.

3. **Indoor coaches**: these are people inside the company that collaborate with employees on an almost day-to-day basis, such as a planner or a dedicated in-company mentor (i.e. a 'buddy'). As for the latter, transport companies often rely on and appoint such in-company mentors to support individual colleagues to work on an improvement of their driving style. Most often, these are the more experienced employees who have the expertise and the skills to coach less experienced colleagues. Moreover, in-company mentors have the advantage of personally knowing their coachees, which is important in the context of building up mutual trust and a relationship where coach and coachee are treated and seen as equals. The in-company coach as well as the planner can consult the i-DREAMS web-dashboard to follow-up on coachees' performance and progress in a very low-effort and user-friendly way. This in turn, allows the coach to provide better tailored and personalized feedback, and become more adequate in timely identifying opportunities for improvement, and scheduling in personal appointments whenever necessary. The planner can derive important information from those reports as well to tailor and optimize driving schedules. For instance, whether and how often fatigue or sleep deprivation-related events have been registered for particular drivers. The indoor coaches are thus also involved in **intervention implementation**.
4. **Employees**: the individual vehicle operator him/herself is of course the 'coachee' or 'end-user'. End-users will remain in close contact with an in-company coach, but can consult the i-DREAMS app as an additional support tool on a day-to-day basis. Gamification mechanics integrated in the app serve to keep end-users motivated to work on a stepwise improvement of their driving style, and to identify relevant opportunities to achieve that purpose. Employees thus act in the role of **intervention consumption**.

User engagement & retention

Internet-based interventions (like the one proposed here for the i-DREAMS project) are a very attractive medium for the delivery of behaviour change interventions since they provide the option of delivering sophisticated versions of individualized, computer-tailored interventions. Moreover, they hold the promise of reaching large numbers of people while maintaining relatively low costs. However, it is **difficult to sustain visitors' loyalty to an intervention over an extended period of time**, which may result in premature attrition from a session or in non-use of follow-up sessions (e.g. Brouwer et al., 2008; Crutzen et al., 2008a, b; Brouwer et al., 2010; Brouwer et al., 2011). In two different studies, Crutzen et al. (2008a, b) investigated which factors are important for adolescents in the context of **first visiting** an internet-delivered intervention encouraging a healthy lifestyle, **staying** on such an intervention, and **revisiting** it. Brouwer et al. (2008) did the same, but they focused on adults. Both the studies by Crutzen et al. (2008b) and Brouwer et al. (2008) were based on a Delphi approach where experts coming from different disciplines (i.e. health promotion research, e-marketing and communication, technical implementation) were consulted in three consecutive rounds to identify and evaluate the most important determinants associated with exposure to, and dissemination of internet-delivered healthy lifestyle promoting interventions. After a first consultation round of 33 experts, Crutzen et al. (2008b) ended up with a list of 82

structured items, to be assessed by experts on their importance on a seven-point Likert scale. Furthermore, median scores and interquartile deviations (IQD) were used to summarize the extent to which the experts reached consensus on the importance of those items. The cut-off point for importance was a median score ≥6. An interquartile distance of ≤1 was considered to indicate good consensus. Items were split up with regard to (i) a first-time visit (26 items: see Table 11), (ii) whether a person would stay long enough to engage actively in and process the educational content provided (34 items: see Table 12), and (iii) revisiting (15 items: see Table 13).

Table 11: Expert consensus on importance for adolescents and adults of items related to a first visit of an Internet-delivered intervention. Source: based on Brouwer et al. (2008: p. 6, Table 2) & Crutzen et al. (2008: p. 432, Table III)

Results for items related to a first visit*	**Adolescents**		**Adults****	
How important do you think each of the following factors are in determining whether an adolescent/adult will make a first visit to an Internet-delivered behaviour change intervention?	Median	IQD	Median	IQD
A. Whether the potential visitor				
1. has sufficient skills to use the Internet	5	2	**6**	**1**
2. has experience with using the Internet	5	1	**6**	**1**
3. has access to the Internet at a private location (e.g. home)	5	1	-	-
4. has positive expectations of behaviour change interventions delivered through the Internet	4	1	-	-
5. is motivated to visit a behaviour change intervention provided through the Internet	5	1	**6**	**1**
6. wants to improve his/her behaviour in relation to the topic of the Internet intervention	5	1	-	-
7. is curious about what the Internet intervention has to offer	5	1	-	-
8. is willing to spend time on visiting an Internet intervention	5	1	-	-
9. has a positive attitude regarding the use of behaviour change interventions delivered through the Internet	4	1	-	-
10. receives an incentive for visiting the Internet intervention	5	1	-	-
11. is referred to the Internet intervention by a professional	4	1	-	-
12. gets a positive recommendation about the Internet intervention by word of mouth (e.g. friends, family)	**6**	**0**	-	-
13. receives a reminder to visit the Internet intervention	5	0	-	-
14. perceives the Internet intervention as relevant for him/herself	**6**	**1**	**6**	**1**
15. knows that the Internet intervention is effective	4	2	-	-
16. perceives the source (the providing organization) of the Internet intervention as credible	4	1	-	-
17. perceives the source (the providing organization) of the Internet intervention as reliable	4	2	-	-

B. Whether the Internet intervention	Median	IQD	Median	IQD
1. has an easy to remember domain name (URL)	5	1	-	-
2. has a high search-engine ranking (e.g. Google, Yahoo!, AltaVista)	5	2	-	-
3. can be used with all types of Internet connections, like dial-up, DSL, cable and fibreglass	5	2	-	-
4. can be used instantly without downloading special software by the potential visitor (e.g. plug-ins)	5	1	**6**	**0**
5. has an attractive interface at first sight	**6**	**0**	-	-
6. has a navigation structure that appears to be easy to use at first sight	5	0	**6**	**0**
7. is created by experts in health behaviour change	3	1	-	-
8. is endorsed by health professionals	4	1	-	-
9. is based on scientific knowledge	4	1	-	-

* Only items with median scores ≥6 and IQDs ≤1 are marked in bold. Results refer to scores known in 3rd consultation round

** For adults, only scores ≥6 and IQDs ≤1 are known

In sum, according to the experts consulted, important determinants for **a first visit** to an internet-delivered behaviour change intervention for **adolescents** are:

- the potential visitor having received a recommendation about the Internet intervention by **word of mouth** (e.g. friends, family)
- the potential visitor perceiving the Internet intervention as **personally relevant**
- the Internet intervention having an **attractive interface** at first sight

For **adults** to **first visit** an Internet-delivered behaviour change intervention, experts agree the following determinants to be important:

- the potential visitor having **sufficient skills** to use the Internet
- the potential visitor **having experience** with using the Internet
- the potential visitor **being motivated** to visit a behaviour change intervention provided through the Internet
- the potential visitor perceiving the Internet intervention as **personally relevant**
- the Internet intervention **allowing instant use** without downloading special software
- the Internet intervention having a navigation structure that appears to be **easy to use** at first sight

Table 12: Expert consensus on importance for adolescents and adults of items related to staying long enough on an Internet-delivered intervention. Source: based on Brouwer et al. (2008: p. 6, Table 2) & Crutzen et al. (2008: p. 433-434, Table IV)

Results for items related to staying on an intervention long enough*	**Adolescents**		**Adults****	
How important do you think each of the following factors are in determining whether an adolescent/adult will stay on an Internet-delivered behaviour change intervention long enough to actively engage and process the educational content provided in the intervention?	Median	IQD	Median	IQD
A. Whether the visitor				
1. can associate him/herself with the look and feel of the Internet intervention	**6**	**1**	-	-
2. knows in advance how long it will take to go through the whole intervention	5	1	**6**	**1**
3. has to provide sensitive information to register (e.g. home address)	5	0	-	-
4. wants to improve his/her behaviour in relation to the topic of the Internet intervention	5	0	**6**	**1**
5. perceives the topic and content of the entire Internet intervention as being personally relevant	**6**	**1**	**6**	**0**
6. experiences the use of the Internet intervention as rewarding	**6**	**1**	**6**	**1**
7. experiences the use of the Internet intervention as challenging	5	1	-	-
8. experiences the use of the Internet intervention as enjoyable	**6**	**0**	-	-
9. likes receiving (tailored) feedback on the answers he/she provided on questions	**6**	**1**	**6**	**1**
B. Whether the source (organization providing) the Internet intervention				
1. is identifiable as credible by the visitor (e.g. through a logo, link to the website of the source, a disclaimer)	4	1	-	-
2. is identifiable as reliable by the visitor (e.g. through a logo, link to the website of the source, a disclaimer)	4	1	-	-
C. Whether the Internet intervention				
1. provides the option of a trial before starting for real	3	1	-	-
2. uses visual materials (e.g. graphs, videos, pictures)	**6**	**0**	-	-
3. provides interactive features (e.g. tests, forums, games)	**6**	**1**	-	-
4. displays personal progress through the program (e.g. progress bar, page numbers)	5	1	**6**	**1**

5. provides the opportunity for a visitor to stop at any moment and to proceed at a later time	**6**	**1**	**6**	**1**
6. uses a virtual guide to guide a visitor through the Internet intervention	4	1	-	-
7. is attractive for the visitor to use	**6**	**0**	-	-
8. has a brief registration procedure (e.g. the registration of login name and password)	5	1	-	-
9. has an aim that is clear to the visitor	5	1	**6**	**1**
10. provides testimonials of successes of previous visitors	4	1	-	-
11. provides information that appears reliable to the visitor	5	1	**6**	**1**
12. provides information that is easy to understand for the visitor	**6**	**1**	**6**	**1**
13. provides information that is perceived to be useful for the visitor to help him/her in changing behaviour	**6**	**1**	**6**	**0**
14. has a tone of voice that is appealing to the visitor	**6**	**0**	**6**	**1**
15. has an easy to follow navigation structure	**6**	**1**	**6**	**0**
16. provides brief textual information (i.e. does not involve a lot of reading)	**6**	**0**	-	-
17. uses a short questionnaire for providing tailored feedback	**6**	**1**	-	-
18. does not take much time to complete entirely	**6**	**1**	-	-
19. provides tailored feedback	**6**	**1**	**6**	**1**
20. provides tailored feedback which is perceived as relevant to the visitor	**6**	**1**	**6**	**1**
21. provides tailored feedback in sequence of brief questionnaires and brief feedback sections	5	1	-	-
22. provides behaviour change information that seems achievable to the visitor	6	2	**6**	**0**
23. can be used free of charge	**7**	**1**	**6**	**0**

* Only items with median scores ≥6 and IQDs ≤1 are marked in bold. Results refer to scores known in 3rd consultation round

** For adults, only scores ≥6 and IQDs ≤1 are known

To summarize, according to the experts consulted, important determinants for **staying long enough on an internet-delivered behaviour change intervention** to actively engage in and process the educational content provided for **adolescents and adults** are:

- the visitor being able to associate him/herself with the **look and feel** of the Internet intervention (adolescents)
- the visitor **knowing in advance how long it will take** to go through the whole Internet intervention (adults)

- the visitor **wanting to improve his/her behaviour** in relation to the topic of the Internet intervention (adults)
- the visitor perceiving the topic and content of the entire Internet intervention as being **personally relevant** (adolescents & adults)
- the visitor experiencing the use of the Internet intervention as **rewarding** (adolescents & adults)
- the visitor experiencing the use of the Internet intervention as **enjoyable** (adolescents)
- the visitor liking to receive **(tailored) feedback** on the answers he/she provided on questions (adolescents & adults)
- the Internet intervention using **visual materials** (e.g. graphs, videos, pictures) (adolescents)
- the Internet intervention providing **interactive features** (e.g. tests, forums, games) (adolescents)
- the Internet intervention **displaying personal progress** through the program (e.g. progress bar, page numbers) (adults)
- the Internet intervention providing the **opportunity** for a visitor **to stop at any moment and to proceed at a later time** (adolescents & adults)
- the Internet intervention being **attractive** for the visitor to use (adolescents)
- the Internet intervention having **an aim that is clear** to the visitor (adults)
- the Internet intervention providing information that appears **reliable** to the visitor (adults)
- the Internet intervention providing information that is **easy to understand** for the visitor (adolescents & adults)
- the Internet intervention providing information that is perceived to be **useful for the visitor to help him/her in changing behaviour** (adolescents & adults)
- the Internet intervention having a **tone of voice that is appealing** (adolescents & adults)
- the Internet intervention having an **easy to follow navigation structure** (adolescents & adults)
- the Internet intervention providing **brief textual information** (i.e. it does not involve a lot of reading) (adolescents)
- the Internet intervention using a **short questionnaire for providing tailored feedback** (adolescents)
- the Internet intervention **not taking much time** to complete entirely (adolescents)
- the Internet intervention providing **tailored feedback** (adolescents & adults)
- the Internet intervention providing **tailored feedback which is perceived as relevant** (adolescents & adults)
- the Internet intervention being **free of charge** (adolescents & adults)

Table 13: Expert consensus on importance for adolescents and adults of items related to revisiting an Internet-delivered intervention. Source: based on Brouwer et al. (2008: p. 6, Table 2) & Crutzen et al. (2008: p. 435, Table V)

Results for items related to revisiting an intervention*	**Adolescents**		**Adults****	
How important do you think each of the following factors are in determining whether an adolescent/adult will revisit an Internet-delivered behaviour change intervention?	Median	IQD	Median	IQD
A. Whether the visitor				
1. receives a reminder to revisit the Internet intervention	6	2	**6**	**1**
2. is committed to revisiting the internet intervention	**6**	**1**	**6**	**1**
3. wants to improve his/her behaviour in relation to the topic of the Internet intervention	**6**	**1**	**6**	**1**
4. has a positive experience with the previous visit to the Internet intervention	**6**	**1**	**6**	**1**
5. has a chance to receive an incentive by revisiting the Intervention	5	1	-	-
B. Whether the Internet intervention				
1. provides new content on a regular basis	**6**	**0**	**6**	**1**
2. provides the possibility for a visitor to monitor his/her progress in changing a behaviour	**6**	**1**	**6**	**1**
3. includes the option for the visitor to communicate with others (e.g. chat rooms, blogs, forums)	**6**	**1**	-	-
4. makes clear what the visitor can expect during a revisit (e.g. by a preview)	5	0	-	-
5. provides the possibility to post questions for professionals	4	1	-	-
6. uses a modular approach in which a new visit provides access to the next module	5	1	-	-
7. has previously been experienced as easy to use by the visitor	5	1	**6**	**1**
8. has previously been experienced as rewarding by the visitor	**6**	**1**	**6**	**1**
9. has previously been experienced as challenging by the visitor	5	1	-	-
10. has previously been experienced as enjoyable by the visitor	**6**	**0**	**6**	**1**

* Only items with median scores ≥6 and IQDs ≤1 are marked in bold. Results refer to scores known in 3rd consultation round

** For adults, only scores ≥6 and IQDs ≤1 are known

To synthesize, according to the experts consulted, important determinants for **revisiting an internet-delivered behaviour change intervention** for **adolescents and adults** are:

- the visitor receiving **a reminder** to revisit the Internet intervention (adults)
- the visitor **being committed** to revisiting the Internet intervention (adolescents & adults)
- the visitor **wanting to improve his/her behaviour** in relation to the topic of the Internet intervention (adolescents & adults)
- the visitor having a **positive experience with the previous visit** to the Internet intervention (adolescents & adults)
- the Internet intervention providing **new content on a regular basis** (adolescents & adults)
- the Internet intervention providing the possibility for a visitor to **monitor his/her progress in changing a behaviour** (adolescents & adults)
- the Internet intervention including the **option for the visitor to communicate with others** (e.g. chat rooms, blogs, forums) (adolescents)
- the Internet intervention having been **previously experienced as easy to use** by the visitor (adults)
- the Internet intervention having been **previously experienced as rewarding** by the visitor (adolescents & adults)
- the Internet intervention having been **previously experienced as enjoyable** by the visitor (adolescents & adults)

Now that the critical design parameters for both the real-time and the post-trip interventions have been identified and discussed, the next section will be dedicated to how more precisely the selected change methods will be practically applied.

6.3.3 Practical application

This section will address how theoretically defined change methods will be translated into practical applications in the i-DREAMS interventions. As already mentioned, the principles of gamified or persuasive design will be adopted to ‘materialize’ the abstractly formulated change methods into concrete functionalities or ‘mechanics’ and observable features. More specifically, two elements will be highlighted.

Firstly, for both the real-time and post-trip interventions, a recommendation will be proposed as to the preferred technology support to be adopted in the i-DREAMS project, yet, without a final decision in this Deliverable already as to what the more precise choice will be. Secondly, a selection of specific gamification mechanics will be proposed for adoption in the i-DREAMS project, even though a final decision on which mechanics to include for the post-trip interventions is still to be made.

The final choice of technology support to be used will be part of Deliverable 4.4 (for the nomadic device supporting the real-time interventions), Deliverable 4.5 (for the smartphone app supporting the post-trip intervention), and Deliverable 4.6 (for the web platform supporting the post-trip intervention). The final selection of gamification mechanics that will be included in the post-trip interventions, is also part of Deliverables 4.5 and 4.6.

6.3.3.1 Real-time interventions

The real-time interventions are meant to steer the vehicle operator's decision-making while driving. For that purpose, in-vehicle messages will be used. The success of these messages will depend on properties related to the display used to deliver those messages, the timing, and the type of information.

Display

In Deliverable 2.2 (see section 3) a detailed review was presented of technologies utilized in real-time interventions to come to a selection of suitable intervention technologies for the i-DREAMS project. It was highlighted that, besides the critical design parameters proposed by Naujoks et al. (2019), for the on-road testing, **feasibility** is another critical consideration. More in detail, it was mentioned that the chosen technologies should be capable of providing custom designed interventions, based on sensor measurements and the STZ algorithm. This means that **interfacing with an i-DREAMS processing unit** is a requirement. This constraint means that OEM-controlled technologies (e.g. the dashboard or a centre display) cannot be used within i-DREAMS during the on-road experiment. Another aspect that needs to be considered is **ease of installation**. Given the significant number of vehicles that will be equipped with i-DREAMS technology, an efficient installation process is essential. This can only be achieved when the installation process is standardised as much as possible, meaning that haptic devices such as driver seat vibration, pedal vibration, and steering wheel vibration are not ideal because they require custom fabrication of parts and/or require (dis)assembly of larger vehicle parts. Based on these constraints, the **most convenient solution** for the on-road experiments would be the use of **a carefully chosen nomadic device that is able to prompt visual and auditory cues**. A nomadic device is any device that is at times connected to the home network and at times connected to the home via other networks. As an illustrative example, see Figure 27 for the Nomadic Pi Car Computer (i.e. a Raspberry Pi based car computer with 1TB storage providing music, in car WiFi hotspot, live GPS backed location, and speed information). There are many different types of nomadic devices that can be used to generate visual, auditory and haptic real-time signals, ranging from all-round devices such as smartphones to devices that are specifically designed for real-time interventions. A final choice as to which specific device to select will be reported in Deliverable 4.4.

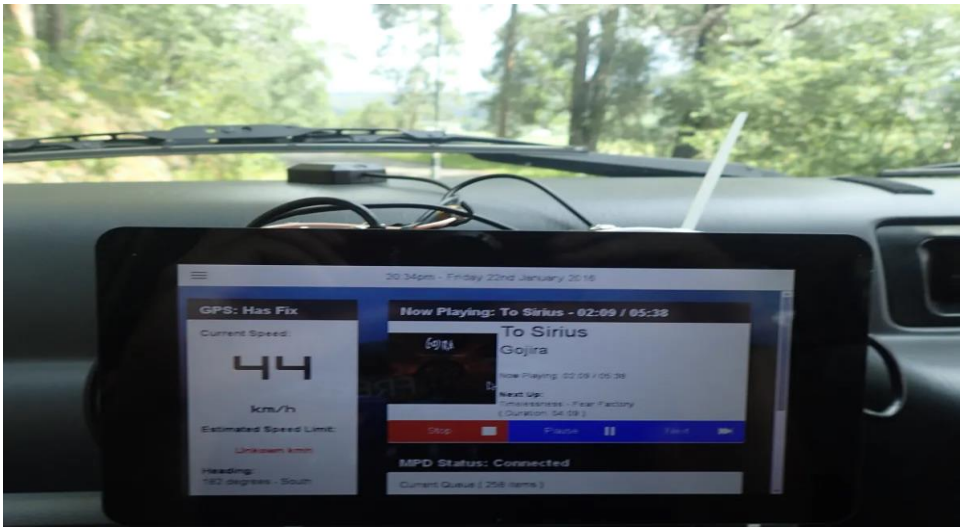


Figure 27: Illustrative example of a nomadic device: the Nomadic Pi Car Computer. Source: www.nomadicpi.com

Timing & information

Figure 28 provides more details on the timing and information of the messages that will be delivered via the nomadic device. From left to right, it can be seen which gamification mechanics will be used to translate the change methods selected for the real-time interventions (see section 6.3.1.1) into message components meant to support the vehicle operator in his or her primary task (i.e. safely operating the vehicle). More in particular, these gamification mechanics should instantly and automatically trigger the awareness and motivation required to take safety-optimal decisions and execute these timely. To enable that, the selected **gamification mechanics will be designed (i.e. made observable) as formal visual and acoustic properties of a set of highly guessable icons and symbols, and accompanying sounds prompted by the nomadic device.** In other words, the gamification mechanics are operational through the visual and acoustic properties of these icons, symbols and sounds. More specifically, as shown in the column 'application in i-DREAMS', it is through the connotative meanings implicitly associated with these visual and acoustic properties (e.g. the colour red expressing 'danger', or the loudness of a sound expressing 'high urgency'), that instant and automatic activation of the required capability and motivation to act, becomes possible. Put differently, through this semiotic process of conveying connotated messages to vehicle operators, the gamified nomadic device becomes a persuasive system. Moreover, Figure 28 shows that in terms of timing, **a situation-adaptive strategy for the activation of messages will be implemented**.

To explain Figure 28 a bit more in detail: the change method 'adding objects to the environment' refers to the fact that for the i-DREAMS real-time interventions, a nomadic device will be added to the vehicle cockpit environment, to enable in-vehicle messaging while driving. The method 'prompts and cues' refers to the messages that will be delivered through the nomadic device. Paraphrased in gamification terminology, the nomadic device and the messages delivered by that device, are a way of applying the gamification mechanic 'signposting'. In a typical gaming context, **signposts** are cues that are aimed at providing guidance and support to gamers on how they can proceed their journey. Signposts are little nudges that should prevent someone from getting stuck or lost. They keep players on track without literally holding a hand or leading the way. In the context of the i-DREAMS project, the messages conveyed by the nomadic device also act as a kind of signpost: they are meant to hint the vehicle operator into the direction of a safe(r) driving style. It is evident that the nomadic device (and the messages it is meant to push), remains constantly active while driving, irrespective of where inside the STZ a vehicle operator is situated. This is why, in terms of activation, it is indicated in Figure 28 that signposting is an active game mechanic in each of the three phases of the STZ.

Feedback is another game mechanic applied in the i-DREAMS real-time interventions. The nomadic device will indeed provide continuous information about several behavioural parameters (see Figure 18 for an overview) that are monitored while driving. This information will not always be purely descriptive, but can be evaluative as well. For instance, regarding the behavioural parameter 'tailgating', from a certain threshold onwards (e.g. ≤2.5 seconds), the 'headway time' will be communicated to the vehicle operator as a two-digit number displayed in green colour (meaning 'safe headway'), but turning into red colour (meaning 'unsafe headway') once another threshold value (e.g. ≤0.6 seconds) has been exceeded. As can be derived from Figure 28, feedback is a gamification mechanic that is continuously active, irrespective of where in the STZ a vehicle operator is situated. However, as will become clear in section **Error! Reference source not found.**, the visual and acoustic

properties of the feedback messages will vary in function of the conceptual status of the STZ (i.e. normal driving, danger phase, avoidable crash phase).

Consequences in gamification refers to the fact that players risk to be confronted with negative outcomes (e.g. penalty points, loss of lives, level regression) in case of insufficient performance, unwanted behaviours or failed missions. Emphasizing the risk for such negative outcomes to exist, or to be imminent (e.g. a life bar turning red indicating a player is close to losing a life), will make players extra aware of that risk. This risk salience in turn, is a powerful leverage for triggering another, related game mechanic, i.e. loss aversion. **Loss aversion** is the tendency of humans to try and avoid negative outcomes or 'future punishments' as much as possible. In the context of the i-DREAMS project, the game mechanic 'consequences' refers to visual and/or acoustic message features that carry the connotation of risk. Depending on whether that risk refers to a dangerous situation or an avoidable crash, those features can vary. Through making the risk for a dangerous situation or an avoidable crash salient to the vehicle operator (e.g. with a high pitched beep or a flickering red icon), he or she will be triggered to avoid such situations from happening out of loss aversity. As shown in Figure 28, both consequences and loss aversion are only active in case a danger unfolds or when an avoidable crash situation occurs since these two game mechanics are only relevant in those two phases of the STZ.

Change methods	PRACTICAL APPLICATION					
	Game mechanic	Targeted support strategy	Application in i-DREAMS	Activation		
				Normal driving phase	Danger phase	Avoidable accident phase
Prompts/cues	Signposting	Primary task support	The i-DREAMS in-vehicle device offers visual signals (multi-colour pictograms and symbols) and audio signals to timely trigger the desired behaviour while driving	x	x	x
Feedback on behaviour	Feedback	Primary task support	The i-DREAMS in-vehicle device informs about current driving conditions (e.g. speed limits, overtaking signs) and provides evaluative feedback on current performance for specific driving-related parameters	x	x	x
Future punishment	Loss aversion	Primary task support	The i-DREAMS in-vehicle device informs the vehicle operator about potential safety risks and threats that might result from current unwanted behaviour		x	x
Salience of consequences	Consequences	Primary task support	The i-DREAMS in-vehicle device uses red colour, flickering visuals and (progressively intrusive) audio signals to increase salience of warning messages		x	x
Adding objects to the environment	Signposting	Primary task support	The driver cockpit will be equipped with an i-DREAMS in-vehicle device display to support the vehicle operator in his/her primary task	x	x	x

Figure 28: Practical application of change methods in real-time interventions

6.3.3.2 Post-trip interventions

The post-trip interventions are aimed at empowering vehicle operators outside the context of a trip to take optimal safety decisions during the trips they make. Based on an extensive multi-modal review in Deliverable 2.2 (see section 4.1), it became apparent that the **combination of smartphone and a web-based platform with a coaching dashboard**, is the predominant technology setting used to coach vehicle operators. Figure 29 and Figure 30 propose illustrative test mock-ups of the i-DREAMS mobile application and the i-DREAMS web-based dashboard, respectively.

Figure 29: Illustrative test mock-ups of i-DREAMS app to coach drivers in a post-trip setting.

Both the app and the web-platform are fed with sensor data collected by the i-DREAMS telematic recording module. Through the use of big data and machine learning algorithms, the risk associated with a specific driving behaviour (e.g. speeding, number and severity of harsh events (braking and acceleration), harsh cornering, or driving aggressiveness), can be reliably quantified. Moreover, expressed in STZ terminology, besides registration of what can be considered as a vehicle operator's 'normal driving' style, risk-related events can be further categorized as falling under 'danger phase' or 'avoidable crash phase'. This information in turn, can be consulted by the vehicle operator after or prior to a trip, and is employed to offer personal and contextualized feedback (i.e. individual events can be consulted on a roadmap

to learn more about the specific circumstances where an event took place). In combination with that, a gamification engine in the back-end (for more details: see Deliverable 3.5) allows a variety of gamification mechanics to be deployed in order to keep vehicle operators motivated and support them to work on an improvement of their driving style.

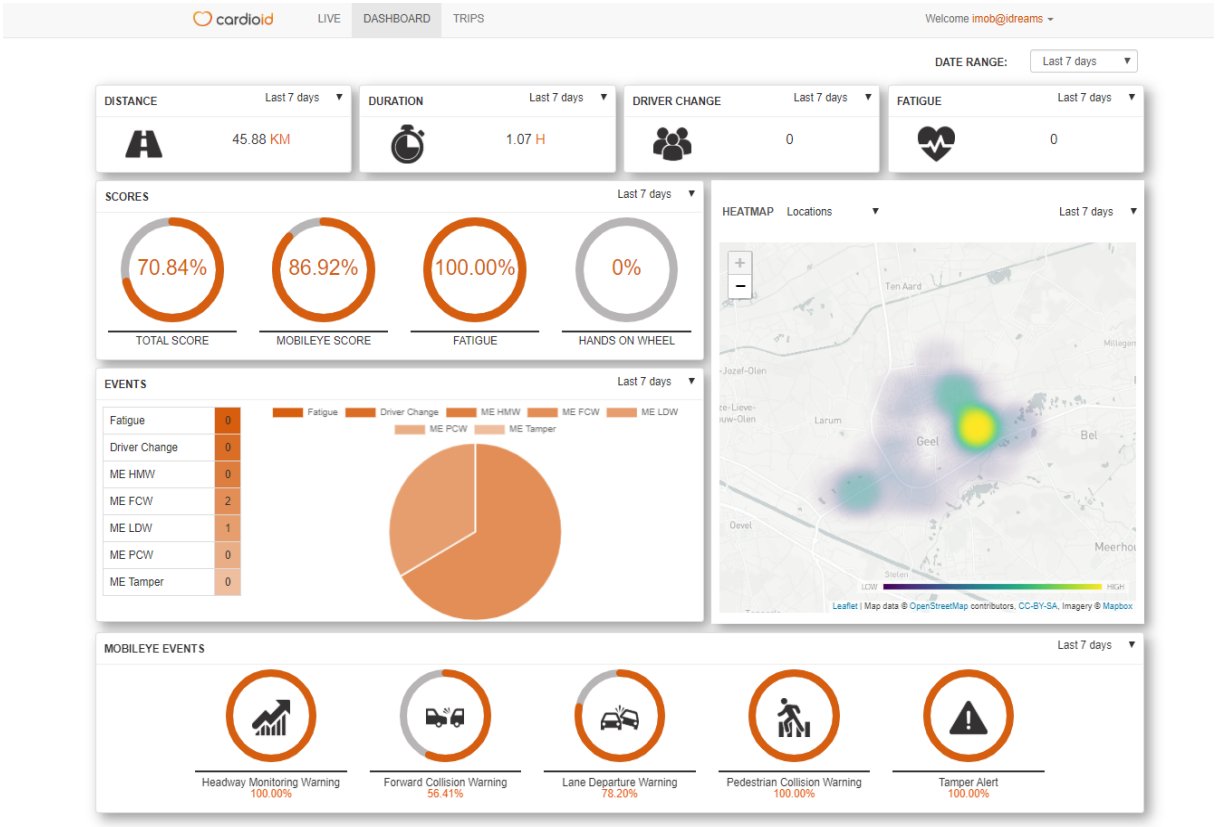


Figure 30: Illustrative test mock-up of the i-DREAMS web dashboard to coach drivers in a post-trip setting

As for the real-time interventions, gamification mechanics are thus used to translate the selected change methods into usable and observable functionalities in the app and the web-platform. Since the post-trip interventions are targeting a wider variety of determinants (see section 6.1.3.2), more gamification mechanics than in the real-time interventions will be employed. Even though a final selection is to be made (see Deliverable 4.6), Figures 31-34 give an overview of what, based on a review of the available literature, can be considered as relevant gamification mechanics to be used for the selected change methods.

More specifically, Figure 31 shows the gamification mechanics meant **to support the vehicle operator in his or her primary task** (i.e. driving safely). This implies change methods and related **gamification mechanics that are primarily useful to influence capability-related determinants** (i.e. knowledge, implementation intention, and skills). Different from the real-time interventions, the post-trip interventions take place outside the context of a trip, and thus focus on capability-building determinants that require longer-term follow-up. For instance, mastering the skill of how to safely decelerate when approaching an intersection, or how to self-detect symptoms of fatigue, might be lacking because vehicle operators do not have the knowledge on how to do that. Creating that knowledge after or prior to a trip can be expected to have a positive impact on how vehicle operators decelerate or cope with fatigue during the next trip(s).

Change methods	PRACTICAL APPLICATION		
	Game mechanic	Targeted support strategy	Application in i-DREAMS
Graded tasks	Flow	Primary task support	The i-DREAMS platform sets easy-to-perform tasks, making them increasingly difficult, but achievable
Behaviour substitution	Quests	Primary task support	The i-DREAMS platform prompts users to engage in a set of challenges that gradually increase in difficulty
Habit reversal	Quests	Primary task support	The i-DREAMS platform prompts users to engage in a series of challenge sets that gradually increase in terms of difficulty
Instruction on how to perform behaviour	Learning	Primary task support	The i-DREAMS platform advises or agrees on how to perform the wanted behaviour
Feedback on behaviour	Feedback	Primary task support	The i-DREAMS platform monitors and provides informative or evaluative feedback on performance of the wanted behaviour
Demonstration of behaviour	Learning	Primary task support	The i-DREAMS platform provides an observable example of the performance of the behaviour, directly in person, or indirectly (e.g. via pictures, film)
Action planning	Signposting	Primary task support	The i-DREAMS platform prompts detailed planning of performance of the behaviour, including at least one of the following items: context, frequency, duration or intensity
Commitment	Investment	Primary task support	The i-DREAMS platform asks the person to affirm or reaffirm statements indicating commitment to change the behaviour
Self-monitoring of behaviour	Progress	Primary task support	The i-DREAMS platform establishes a method for the person to monitor and record his/her behaviour as part of a behaviour change

Figure 31: Practical application of change methods for PRIMARY TASK SUPPORT in post-trip interventions

Without going into the details of all the gamification mechanics shown in Figure 31, those selected to practically apply the change methods 'graded tasks', 'behaviour substitution' and 'habit reversal' will be discussed briefly. These three methods are targeting the determinant 'skills', and thus aim at creating a vehicle operator's ability to become performant in executing a certain behaviour (e.g. keeping a safe distance, or decelerating smoothly).

Certainly in the case of deeply ingrained bad habits or difficult to learn higher-order skills, reaching the required competence level might be time- and effort-consuming. In order not to demotivate vehicle operators to work on their personal improvement, **graded tasks** might be an appropriate method to adopt, and flow a relevant gamification mechanic to apply this method. **Flow**, i.e. a state of optimal experience characterized as being fully focused and engaged in an activity (e.g. Csíkszentmihályi, 1990), has been regarded as one of the most important psychological outcomes of gamification and games, and particularly relevant in activities requiring perseverance and commitment (e.g. Hamari et al., 2014). Flow is usually achieved through the provision of optimally difficult challenges (i.e. gradually increasing in difficulty) and feedback (Hamari & Koivisto, 2014). The i-DREAMS post-trip interventions will set easy-to-perform tasks, making them increasingly difficult, but achievable.

Once taken up the engagement to gradually improve the targeted skills, the process of replacing unwanted by wanted behaviour can start. **Behaviour substitution** is a method to do that, and the gamification mechanic 'quests' is appropriate for the practical application of that method. A **quest** is to be understood as a journey or expedition where challenges are overcome to result in reward (i.e. an improvement in skill mastery). In the context of e-learning for instance, a quest could be a theme for the apprentice with learning objectives or goals along the way. The i-DREAMS post-trip interventions will prompt users to engage in a set of challenges (i.e. a kind of 'quest') that gradually increase in difficulty.

With vehicle operators improving competences required to execute the wanted behaviour, the old 'bad' habits can be reversed into new 'good' habits. This method is called **habit reversal**, and quests are again a suitable gamification mechanic to use for that purpose. The difference with quests in the context of behaviour substitution, is that for habits to change, more time is needed, and thus, a longer journey is to be set out. This is why the i-DREAMS post-trip interventions prompt users to take up a series of challenge sets that gradually increase in terms of difficulty.

Next,

Figure 32 and

Figure 33 show the gamification mechanics meant to provide **dialogue support** (i.e. establishing a longer-term relationship with the end-user). This implies change methods and related gamification mechanics that are primarily useful to influence **motivation**-related determinants (i.e. attitude, personal norm, subjective norm, self-efficacy, goals, punishment & reward sensitivity). Dialogue support is an essential design element in the field of persuasive technology, especially when it comes to **engage and retain users** long enough so that interventions can be successfully taken up, and premature drop-out can be limited as much as possible. As an illustration, the gamification mechanics selected for application of the method labelled 'focus on past success' will be explained.

Change methods	PRACTICAL APPLICATION		
	Game mechanic	Targeted support strategy	Application in i-DREAMS
Self-monitoring of outcome(s) of behaviour	Progress	Dialogue support	The i-DREAMS platform establishes a method for the person to monitor and record the outcome(s) of his/her behaviour as part of a behaviour change strategy
Information about health consequences	Loss aversion	Dialogue support	The i-DREAMS platform provides information (written, verbal or visual) about health/safety consequences of performing a certain behaviour
Information about emotional consequences	Loss aversion	Dialogue support	The i-DREAMS platform provides information (written, verbal or visual) about emotional consequences of performing a certain behaviour
Credible source	Social pressure	Dialogue support	The i-DREAMS platform presents verbal or visual communication form a credible source in favour of the desired behaviour or against the undesired behaviour
Pros and cons	Consequences	Dialogue support	The i-DREAMS platform identifies and compares reasons for wanting (pros) and not wanting (cons) to change behaviour
Identification of self as role-model	Care taking	Dialogue support	The i-DREAMS platform informs that one's own behaviour may be an example to others
Identity associated with changed behaviour	Investment	Dialogue support	The i-DREAMS platform advises the person to construct a new self-identity as someone who is used to engage with the unwanted behaviour
Information about social consequences	Social pressure	Dialogue support	The i-DREAMS platform provides information (written, verbal or visual) about social consequences of performing a certain behaviour
Social comparison	Competition	Dialogue support	The i-DREAMS platform offers the possibility to compete with others
	Leaderboard	Dialogue support	The i-DREAMS platform draws attention to others' performance to allow comparison with the person's own performance
Information about others' approval	Social pressure	Dialogue support	The i-DREAMS platform provides information about what other people think about a certain behaviour. The information clarifies whether others will like, approve, or disapprove of what the person is doing or will do
Feedback on behaviour	Feedback	Dialogue support	The i-DREAMS platform monitors and provides informative or evaluative feedback on performance of the wanted behaviour
Self-monitoring of outcome(s) of behaviour	Progress	Dialogue support	The i-DREAMS platform establishes a method for the person to monitor and record the outcome(s) of his/her behaviour as part of a behaviour change strategy
Graded tasks	Flow	Dialogue support	The i-DREAMS platform sets easy-to-perform challenges, making them increasingly difficult, but achievable
Reward approximation	Progression	Dialogue support	The i-DREAMS platform arranges for reward following any approximation to the target behaviour, gradually rewarding only performance closer to the wanted behaviour

Figure 32: Practical application of change methods for DIALOGUE SUPPORT in post-trip interventions-part 1

Change methods	PRACTICAL APPLICATION		
	Game mechanic	Targeted support strategy	Application in i-DREAMS
Verbal persuasion aboiut capability	Care taking	Dialogue support	The i-DREAMS platform tells the person that he/she can successfully perform the wanted behaviour, arguing against self-doubts and asserting that he/she can and will succeed
Focus on past success	Points	Dialogue support	The i-DREAMS platform awards points in function of how users scored in terms of performance for the wanted behaviour
	Levels	Dialogue support	The i-DREAMS platform allows a person to progress in a ladder or level system in function of how well he/she performs on the wanted behaviour
	Badges	Dialogue support	The i-DREAMS platform offers status badges for the succesful completion of a challenge set
	Leaderboard	Dialogue support	The i-DREAMS platform allows a person to folloow up on the personal position in a rank ordering
Behaviour-oriented goal setting	Challenges	Dialogue support	The i-DREAMS platform offers challenges to a person to be taken up as goals
Punishment	Consequences	Dialogue support	The i-DREAMS platform arranges for aversive consequences (e.g. loss of points) contigent on the performance of unwanted behaviour
Material incentive (behaviour)	Virtual economy	Dialogue support	The i-DREAMS platform informs that credits (i.e. virtual currency to be exchanged for gifts in a shop) will be delivered if and only if there has been effort and/or progress in performing the wanted behaviour
Material reward (behaviour)	Physical rewards	Dialogue support	The i-DREAMS platform arranges for the delivery of money, vouchers or other valued objects will be delivered if and only if there has been effort and/or progress in performing the wanted behaviour
Non-specific incentive (behaviour)	Virtual economy	Dialogue support	The i-DREAMS platform informs that credits (i.e. virtual currency to be exchanged for gifts in a shop) will be delivered if and only if there has been effort and/or progress in performing the wanted behaviour
	Badge collection	Dialogue support	The i-DREAMS platform informs that status badges can be collected that will be delivered if and only if there has been effort and/or progress in performing the wanted behaviour
Non-specific reward (behaviour)	Prizes	Dialogue support	The i-DREAMS platform arranges for the delivery of a prize if and only if there has been effort and/or progress in performing the wanted behaviour
	Badges	Dialogue support	The i-DREAMS platform arranges for the delivery of status badges if and only if there has been effort and/or progress in performing the wanted behaviour
Incentive (outcome)	Virtual economy	Dialogue support	The i-DREAMS platform informs that credits (i.e. virtual currency to be exchanged for gifts in a shop) will be delivered if and only if there has been effort and/or progress in performing the wanted behavioural outcome(s)
Reward (outcome)	Prizes	Dialogue support	The i-DREAMS platform arranges for the delivery of a prize if and only if there has been effort and/or progress in achieving the behavioural outcome(s)

Figure 33: Practical application of change methods for DIALOGUE SUPPORT in post-trip interventions-part 2

As can be derived from

Figure 33, four different gamification mechanics have been selected for the application of the method ‘focus on past success’. **Focus on past success** is a method meant to increase a vehicle operator’s self-efficacy (i.e. the personally held confidence that one is able to perform a certain behaviour). Positively stimulating such confidence has been demonstrated to contribute to the motivation to change behaviour.

The gamification mechanics used to stimulate self-efficacy (i.e. points, levels, badges, leaderboards) all allow vehicle operators to follow-up on their performance, and gain confidence from earlier successes. For instance, the i-DREAMS post-trip interventions will award **points** to vehicle operators in function of how they scored in terms of performance on a wanted behavioural parameter (e.g. keeping a safe headway distance, respecting speed limits, distraction avoidance) at the end of a trip. These points in turn, allow vehicle operators to acquire competence **levels**. These competence levels are organized in a so-called ‘ladder or level system’. Thus, in order to proceed through the level system, vehicle operators need to collect points. **Badges** are another mechanic aimed at making vehicle operators become more self-efficacious. They are symbolic ways of acknowledging vehicle operators’ competency and can be earned for successful completion of challenge sets (or ‘quests’). Finally, for those vehicle operators that are already quite advanced in terms of performing the desired behavioural parameters, there is the free-to-chose option to appear in a **leaderboard**. A leaderboard is a kind of rank ordering allowing vehicle operators to follow-up on their position in a group. When used appropriately, it can be helpful to stimulate self-efficacy.

Finally, Figure 34 shows which gamification mechanics are suitable to provide **social support**. Restructuring the social environment and social reward are possible methods to deliver social support. The gamification mechanism **social network** is suitable for the application of both methods. In the case of **restructuring the social environment**, social network actually refers to the fact that an opportunity is created for important social referents (e.g. fleet safety manager, planner, buddy) to reach out to and communicate with vehicle operators. This could be done for instance, via a messaging platform. Accordingly, performance of the wanted behaviour can be facilitated. When specifically used to deliver verbal (or non-verbal) praise or encouragement to vehicle operators for effort and/or progress in performing the wanted behaviour, the mechanic ‘social network’ serves to accomplish **social reward**. **Guilds and teams** are a mechanic that enables vehicle operators to compose groups, and work together on commonly shared challenges.

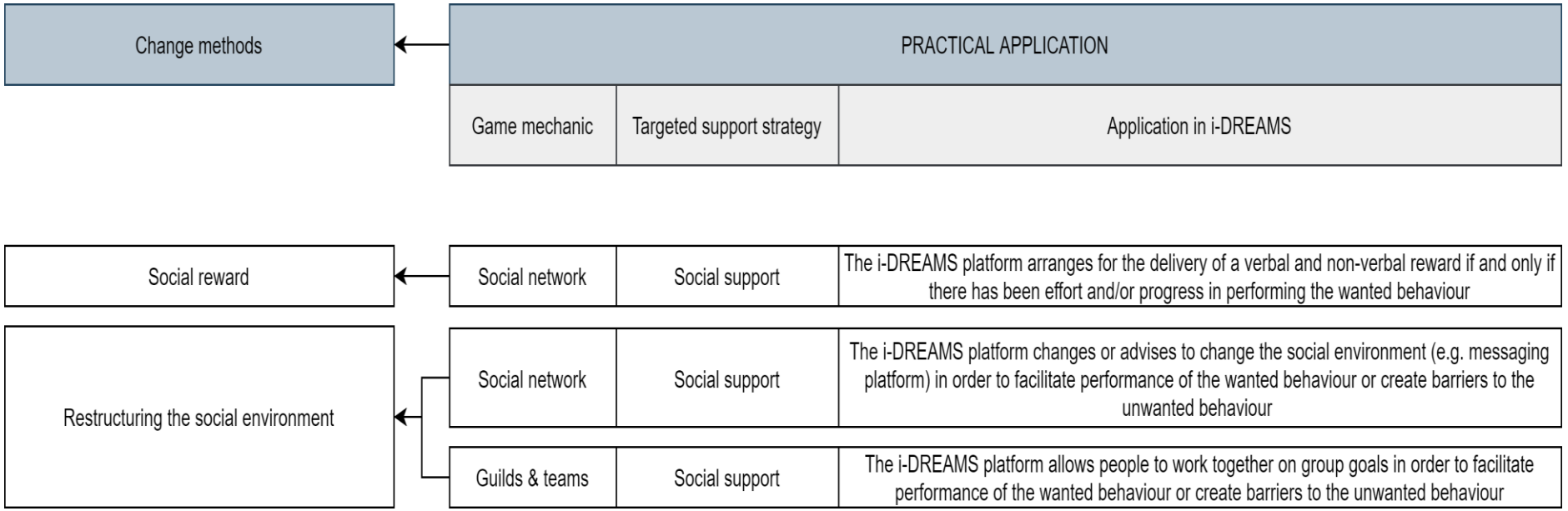


Figure 34: Practical application of change methods for SOCIAL SUPPORT in post-trip interventions

Taking into account the critical design parameters identified for the post-trip interventions (see section 6.3.2.2), the proposed gamification mechanics will be applied in a stage-matched manner, i.e. taking into account the quantity and quality of motivation available in the vehicle operator to change behaviour.

Moreover, the GDE-matrix will serve as a blueprint to structure the competences targeted by the post-trip interventions, thereby not only focussing on knowledge and skills, but on the higher level of the GDE-matrix as well, i.e. also targeting motivation-related determinants (e.g. attitudes, norms, self-efficacy, et cetera). In doing so, the i-DREAMS platform aligns with competences and requirements stipulated in the various EU Directives regulating minimum requirements for obtaining a private car licence or a Certificate of Professional Competence.

Furthermore, the post-trip interventions will not be exclusively technology-mediated. Especially in a professional setting, several important stakeholders in the context of driver coaching (e.g. fleet safety manager, outdoor service provider, in-company planner or buddy) will remain involved in the post-trip interventions, each in their specific role of adopter, implementer or consumer. Personal contact with day-to-day co-workers (like the planner or a buddy) remains an important complement to the i-DREAMS technology platform, and the general coordinator or 'super-administrator' can tailor platform configurations and settings depending on how the situation inside companies evolves. The i-DREAMS platform is rather to be considered as a 'facilitating tool', i.e. a highly automated expert system, supporting each of the involved stakeholders in their respective roles and responsibilities.

Finally, through user-friendly design and the use of a variety of gamification mechanics, the i-DREAMS post-trip interventions have the intention to develop a longer-term relationship with end-users. This last consideration leads to the next section where a selection of first mock-ups for 'front-end' of the real-time and post-trip interventions will be presented.

6.4 Step 4: Intervention production

The final step of IM that falls within the scope of this Deliverable, is intervention production (i.e. step 4). First draft designs should give an impression of the 'look and feel' of the i-DREAMS interventions' front-end. This section contains a selection of mock-up designs for the real-time and the post-trip interventions.

6.4.1 Mock-up designs for real-time interventions

As mentioned, both real-time and post-trip interventions are in the end aimed at influencing behavioural parameters that relate to behaviours that are causally linked to crashes. For the real-time interventions, recommendations were to adopt a situation-adaptive timing strategy using highly guessable icons and/or symbols in combination with sound, and with visual and acoustic properties carrying connotative meanings for instant and automatic persuasion of the vehicle operator. Figure 35 gives an overview of how these recommendations can be taken into account for designing the in-vehicle messaging strategy.

As can be seen, a situation-adaptive approach is proposed where the activation as well as the sensory modality and the content of messages is dependent on where inside the STZ a driver can be situated (i.e. normal driving phase, danger phase or avoidable crash phase).

For a selection of behavioural parameters targeted by the real-time interventions, it is indicated per STZ-phase, what the vehicle operator would receive at the front-end.

Two remarks are to be taken into account. Firstly, the proposed designs are not definite yet. Final designs will be proposed in Deliverable 4.4, and the concepts presented here are meant to illustrate the overall messaging strategy. Secondly, a situation-adaptive approach will not necessarily be possible for all the behavioural parameters targeted by the real-time interventions. It is still to be determined for which parameters a situation-adaptive messaging strategy is technically feasible. Final decisions in this regard, are also for Deliverable 4.4. Furthermore, it was mentioned that the thresholds marking the boundaries between the three different phases inside the STZ, would be made flexible as to improve the effectiveness of the i-DREAMS real-time interventions. For example, in the case of 'tailgating', with a slippery road surface (e.g. rain or ice), the threshold value marking the beginning of the danger phase or the avoidable crash phase for headway timing-related messages could be extended, so that the vehicle operator is warned more in advance for the risk of a danger or an avoidable crash, and left with more time to safely adapt his or her headway time. It is yet to be decided which metrics permit such a flexible threshold-based situation-adaptive approach. This will also be addressed in Deliverable 4.4.

MATERIAL DESIGN						
	Normal driving phase		**Danger phase**		**Avoidable accident phase**	
	Visual	Audio	Visual	Audio	Visual	Audio
Tailgating						A single chime
Lane discipline				Series of short sharp beeps		Series of short sharp beeps
Illegal overtaking				A single beep		Series of short sharp beeps
Forward collision avoidance						Series of short loud high-pitched beeps
Fatigue warning				A single chime		A double chime

Vulnerable road user collision avoidance						Series of short loud high-pitched beeps
Speeding (speed limit exceedance)				A single chime		A double chime

Figure 35: Illustrative mock-ups for messages for real-time interventions

The most appropriate candidate-metrics for such a flexible threshold-based situation-adaptive approach however, are the ones that are time-dependent (e.g. headway timing). The best parameter to illustrate this, is tailgating. As can be seen, the messaging strategy for this parameter indeed varies in function of where inside the STZ a driver is situated. When a lead vehicle inside the driving lane is detected by the i-DREAMS sensors (i.e. the Mobileye®), and the vehicle operator maintains a headway timing that remains above a certain threshold indicating there is no indication whatsoever that a crash course might be initiated (e.g. > 2.5 seconds), the vehicle operator receives a not all too intrusive message, i.e. a small green car icon (without sound). From a certain threshold onwards (e.g. ≤2.5 seconds), the 'headway time' will be communicated to the vehicle operator as a two-digit number displayed in green colour (meaning 'safe headway'), but turning into red colour (meaning 'unsafe headway') accompanied by an audio cue (e.g. a single chime) once another threshold value (e.g. ≤0.6 seconds) has been exceeded. In case of a slippery road surface, the threshold values for entering the danger phase and the avoidable crash phase could be momentarily adapted to that condition, for instance, by extending the boundaries of those two phases and issuing headway warnings sooner.

As can be derived from Figure 35, the icons and symbols proposed are scoring high on guessability-related criteria. For overtaking and speeding, the standard road sign formats can be used as a visual cue. These are very well known and familiar to vehicle operators. The icon for vulnerable road user collision avoidance is also a widely known symbol representing a walking pedestrian. For lane discipline and lane departure avoidance, two full white lines intuitively refer to the lane edges being detected. A dotted white line combined with a series of short sharp beeps represents an edge line being crossed (i.e. an unintended lane departure, or an intended one without use of the indicator). The colour codes used for some of the icons and symbols (green vs red) are also invested with widespread and well-known connotative meanings (safe vs dangerous). Moreover, animated (i.e. more intrusive) effects are proposed in potentially critical situations (e.g. enlargement of the pedestrian icon when entering the avoidable crash phase for vulnerable road user collision warnings, or flickering of an enlarged car icon in case of a critical forward collision avoidance warning). Acoustic properties of sound vary as well (e.g. changes in loudness and pitch) in function of how critical a warning is, with the level of intrusiveness increasing from danger phase to avoidable crash phase. The final designs are still to be determined and will be subjected to pre-testing in the simulator experiments (see Work Package 5) with a focus on both efficacy and acceptance.

6.4.2 Mock-up designs for post-trip interventions

The i-DREAMS post-trip interventions will be supported by an app and a web-based platform, and are to be considered as a 'facilitating tool', i.e. a highly automated expert system, supporting each of the stakeholders involved in driver coaching in their respective roles and responsibilities. In this section, a selection of mock-up designs will be presented for both the app and the web-platform. These mock-ups are not final yet and serve just to illustrate a few of the gamification mechanics discussed, and how these will be applied in the app and the web-platform. The mock-ups are meant to give a first impression of the 'look and feel' of the i-DREAMS post-trip interventions' front-end. The designs presented here will be finalized in the context of Work Package 4 (see Deliverable 4.5 for the app designs and Deliverable 4.6 for the web platform designs). Figures 36 and 37 show six screen mock-ups for the app. Figures 38-41 show four screen mock-ups for the web platform.

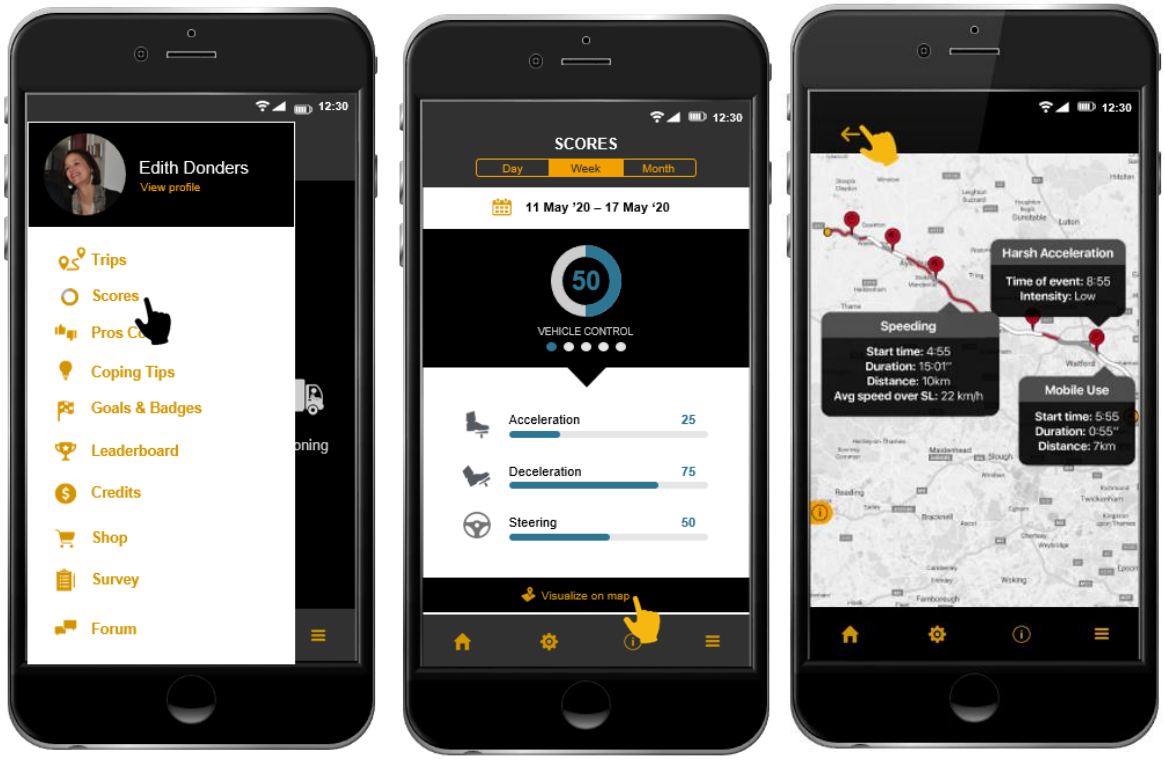


Figure 36: Mock-up screens for the i-DREAMS app: contextualized scores

As mentioned, the app is the main tool for the end-user. Figure 36 on the left side shows the app screen where vehicle operators receive an overview of the different gamification mechanics activated in their personal profile. Depending on the stage of change a user is in, the set of gamification mechanics activated will be different. The user has the possibility to click on one of the gamification mechanics shown to obtain more detailed information. In this illustrative case, the end-user wants to know more about his or her scores. The centre screen shows how scores are presented to the user in the app. As can be seen on top of the screen, users can consult scores over different time episodes (i.e. day, week, month). More in detail, scores are calculated (in the back-end of the application) at the level of safety promoting goals (here, that is 'vehicle control'), and at the level of behavioural parameters

linked to the safety promoting goal in question (in this case: acceleration, deceleration, and steering). Pressing on the 'map' icon, the user arrives in the screen shown on the right side. Individual events related to harsh acceleration, deceleration or cornering registered during the last trip for instance, are located on a road map to offer more contextual background.

In Figure 37, the user decides to consult 'coping tips' and 'leaderboard' from the menu of gamification mechanics (see left side). The middle screen shows how coping tips are offered to users in the app. As can be seen on top, users can select the safety promoting goal for which they would like to receive tips to improve their current performance (e.g. vehicle control, speed management, sharing the road with others). In this case, the user has opted for vehicle control, and more specifically for the parameter 'acceleration'. Three different coping tips are provided. These tips can be in the form of text, a picture or photo, or even a video fragment. On the right side, the leaderboard screen is presented. Leaderboards can apply to different time periods (i.e. day, week, month) and present a rank ordering of those users who agreed to appear in a leaderboard. More in detail, the best ranked user appears on top of the list. A colour-coded (i.e. green means 'progression', yellow means 'status quo', red means 'regression') number represents how many positions a user progressed or regressed within the selected time period.

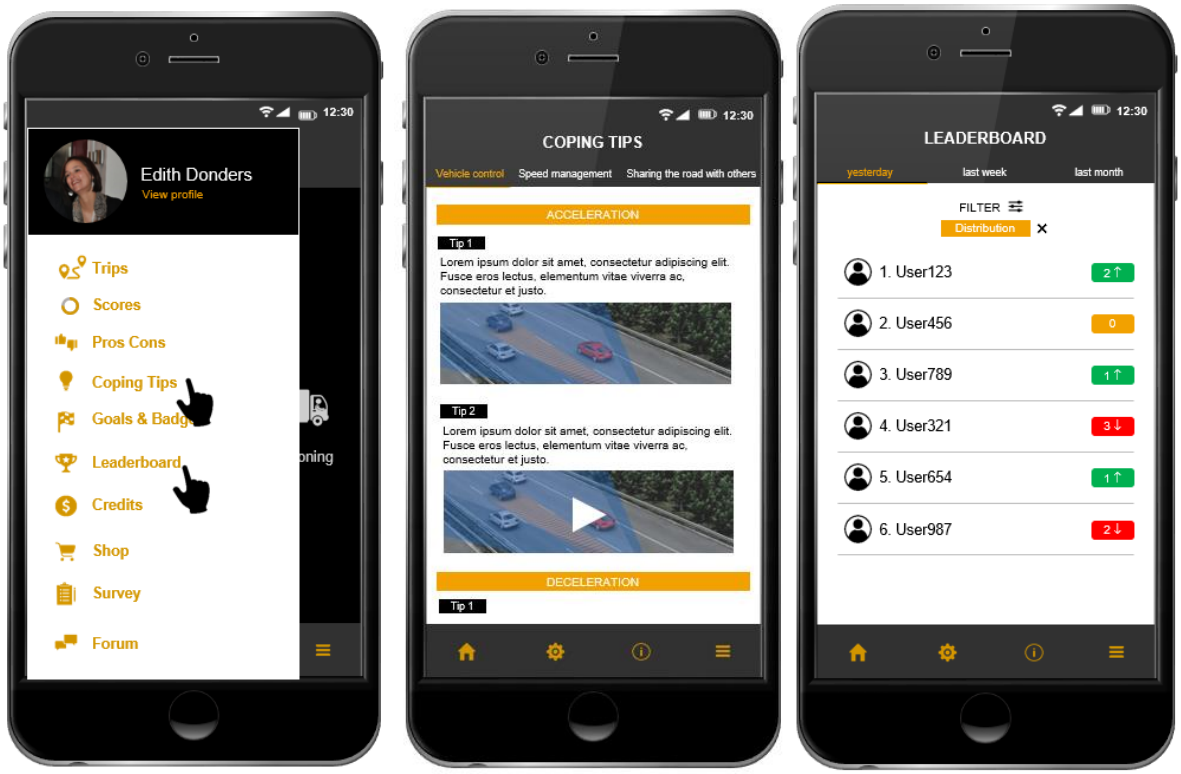


Figure 37: Mock-up screens for the i-DREAMS app: coping tips & leaderboard

The mock-up screens following relate to the i-DREAMS web platform. As explained, in an occupational context, several stakeholders will be actively involved in the i-DREAMS interventions, whether as adopter, implementer or consumer. One key-stakeholder is the overall program coordinator, i.e. often an outdoor service provider specialized in fleet safety

management and driver coaching. This intervention program coordinator uses the i-DREAMS web platform as a kind of 'super-administrator', allowed to define projects, allocate drivers to groups, adapt configurations and settings, create new contents, et cetera. The mock-up screens presented here all apply to this super-administrator. Other stakeholders involved in driver coaching (e.g. planner, indoor buddy) will use the web platform mainly as a supportive consultation tool, and do not get to see the screens presented here.

For instance, Figure 38 shows a mock-up screen that relates to the i-DREAMS web platform. More precisely, this screen allows the super-administrator to create and consult lists of drivers within a certain company. For each individual driver, the super-administrator files the following information: username, current employment status (the red bar left to the user name indicates that those drivers are currently not employed in the company anymore), transport type (e.g. long haul, construction, distribution, heavy haulage), the stage of change where the driver is currently situated in terms of overall performance (i.e. unaware, aware, considering, determined, consolidating), the group to which a driver belongs within the company (e.g., kipper-novice, -apprentice, -senior), the total distance currently driven and the total driving time in hours, the number of trips completed, and the number of credits (i.e. virtual currency to be exchanged in a web shop for items). In this illustrative example, the super-administrator can see there are four persons within the group 'kipper-novice', of which two are not currently working in the company anymore. The super-administrator could decide to remove the non-employed drivers from this group and add new ones.

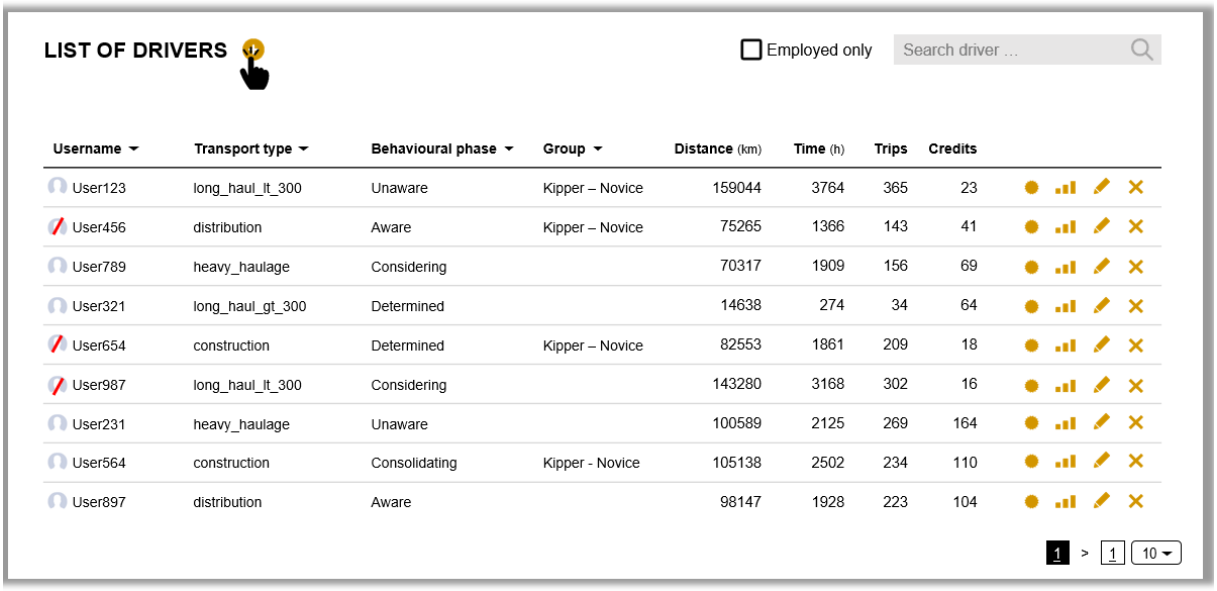


Figure 38: Mock-up screen for the i-DREAMS web platform: List of drivers

Figure 39 shows the screen where the super-administrator can consult, set, and change group details.

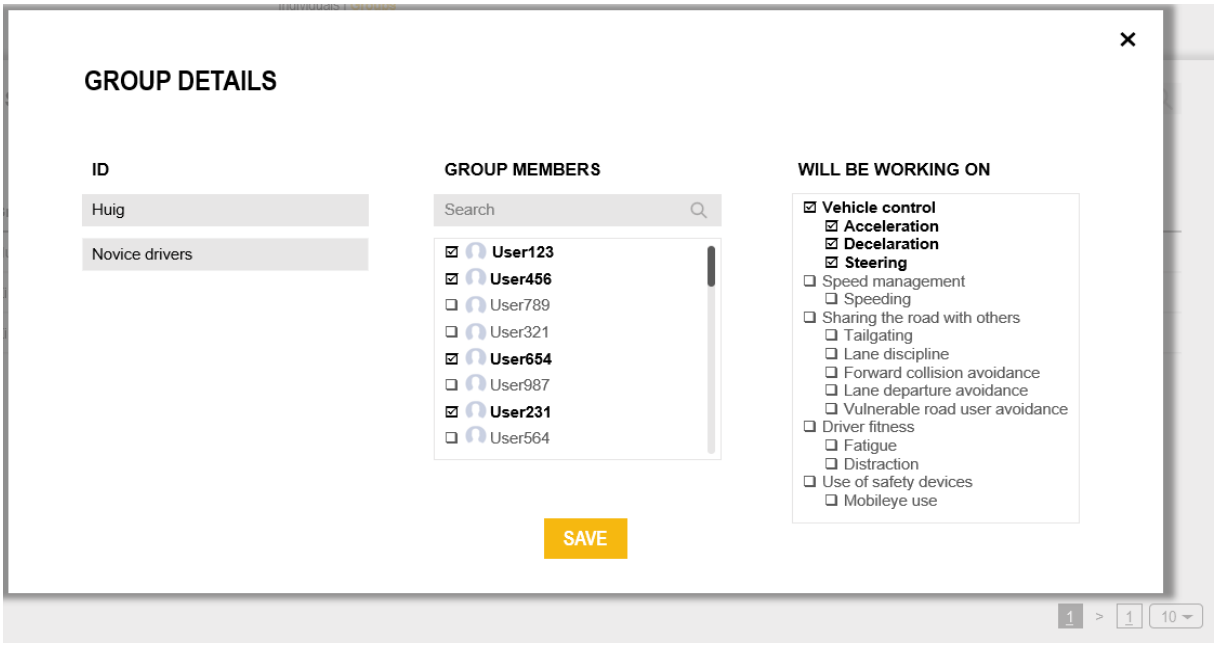


Figure 39: Mock-up screen for the i-DREAMS web platform: Group details

Under group ID, the group label can be found (in this case: novice drivers operating a bashed (semi-)trailer. Under group members, the list of drivers belonging to this group is shown. Finally, the super-administrator can see, select, or change the safety promoting goals and related parameters that this group of drivers will be working on during a certain period. In line with the philosophy behind the GDE-matrix, the super-administrator indicates that the drivers in this group (i.e. novice drivers with almost no experience), will work on parameters that pertain to the lowest level of the GDE-matrix (i.e. vehicle control).

In Figure 40, it can be seen how the super-administrator is able to create new content. More in particular, this screen is dedicated to the creation of so-called pros and cons related to the parameter ‘acceleration’. In fact, pros and cons refer to advantages and disadvantages related to speed limit compliance and speeding, respectively. Pros and cons are important leverages to influence the decisional balance of people who are not yet decided on whether they will change their behaviour or not. Preferably, pros and cons are evidence-based and supported by credible and authoritative sources and refer to factual information. Pros and cons can be defined as text, but be supported by illustrative materials, like pictures, photos, or videos. The super-administrator can build up an ‘open’ thematically structured library of pros and cons for each of the parameters targeted by the i-DREAMS platform.

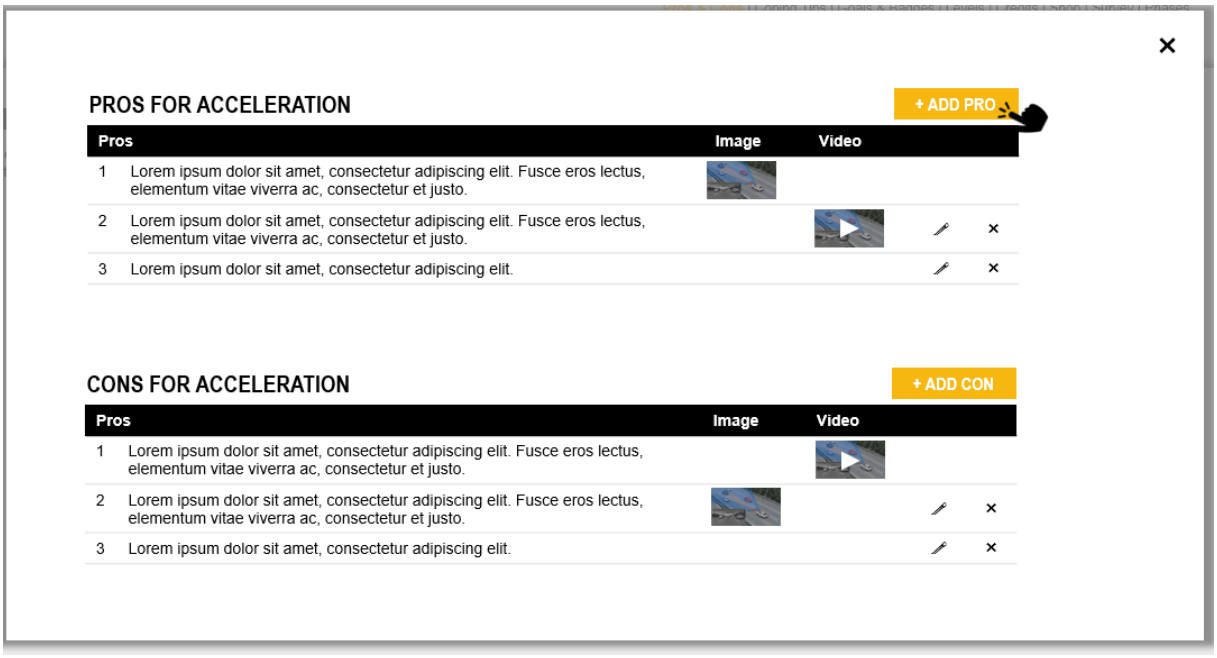


Figure 40: Mock-up screen for the i-DREAMS web platform: Pros and Cons

Finally Figure 41, shows the screen where the super-administrator is managing goals. Goal setting is a crucial gamification mechanic. As already explained, in the i-DREAMS platform goals are set for specific parameters (in this case, steering), and based on a methodology aimed at progressive substitution of unwanted behaviour by wanted behaviour, and stepwise reversal of bad habits into good ones. In order to do that, challenges are defined that gradually increase in terms of difficulty, and achievable but attractive enough for drivers. The difficulty level of challenges can be determined in function of two criteria, i.e. the minimum score to be achieved, and the distance over which a certain minimum score needs to be maintained. Per challenge, four goals can be defined. This is to make sure that there is continuity, and that the platform remains relevant over longer time episodes. In this illustrative case, the super-administrator has defined four goals in challenge 8, which is a challenge where the targeted scores need to be maintained, each time over a distance of 1750 km. If all goals within a challenge are completed, the driver receives a badge. The super-administrator can add or remove goals as he or she finds appropriate.

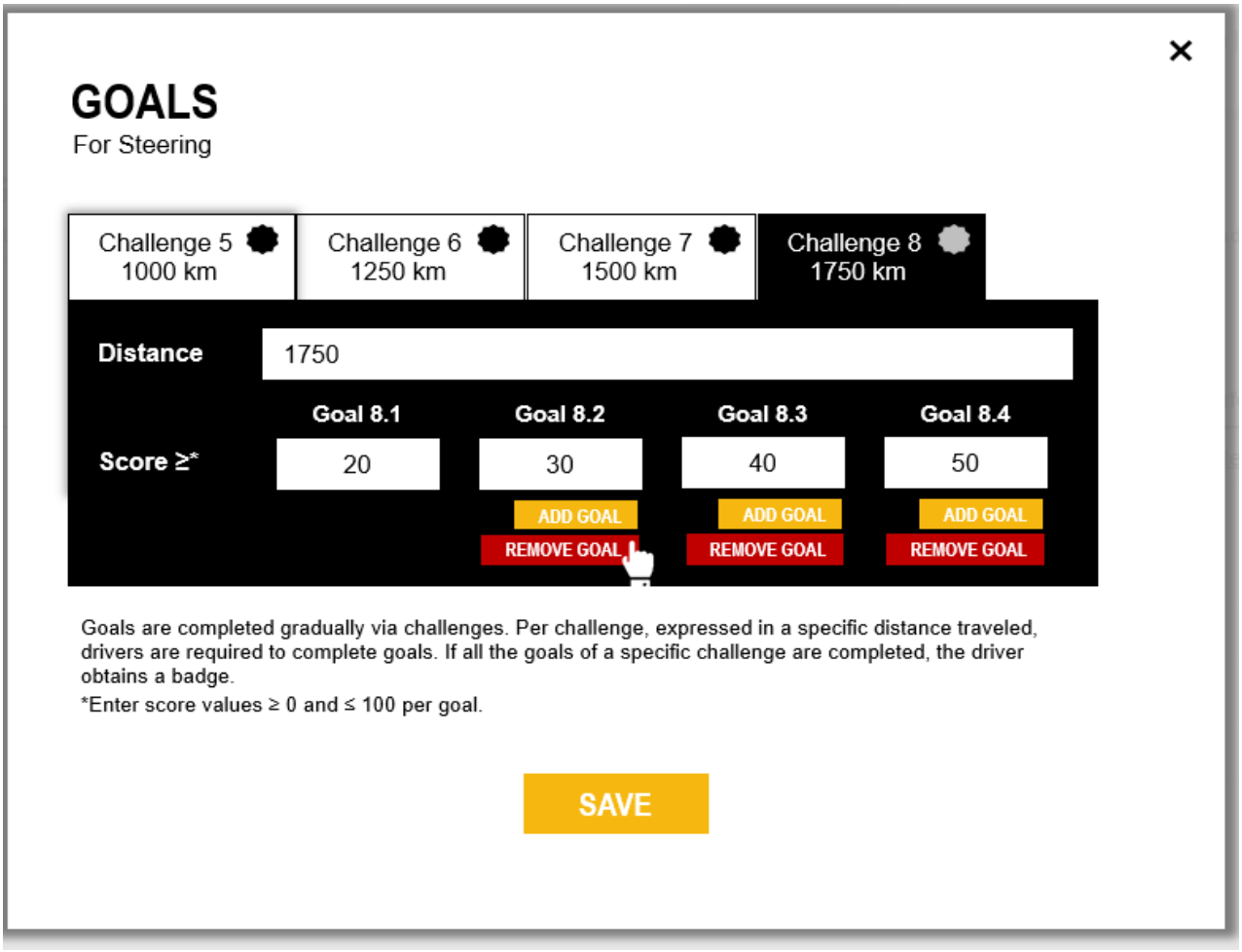


Figure 41: Mock-up screen for the i-DREAMS web platform: Goals

Now that the four first steps of IM falling within the scope of this Deliverable have been completed, the most important conclusions will be drawn.

7 Conclusions and recommendations

The main purpose of this Deliverable was to develop and propose an operational toolbox for the i-DREAMS interventions. Intervention Mapping was used as a roadmap to take evidence-based and well-informed decisions in each of the first four steps of this protocol. Based on review work done in Work Package 2, and reported in Deliverable 2.1 and Deliverable 2.2, a logic problem analysis was carried out. This served as input for the creation of a logic model of change with different safety outcomes, safety promoting goals, performance objectives and change objectives linked with each other to form a causal chain of effects. Next, suitable methods for the realization of this logic model of change were identified and proposed. Specific attention went to critical design parameters that will determine whether the selected methods will be applied effectively. These critical design parameters were taken into consideration in the following step of the protocol, i.e. intervention production. At this point, the selected change methods were turned into practical applications, i.e. gamification mechanics. Finally, test mock-ups were proposed to illustrate the look and feel of what users will receive at the front-end of the in-vehicle and post-trip interventions.

The main conclusion is that the i-DREAMS in-vehicle and post-trip interventions are meant to complement and mutually reinforce each other, which is why they will be combined in an integrated framework. More in particular, the in-vehicle interventions (i.e. nudging) are operational during a trip and primarily meant to steer vehicle operators' decision-making while driving. Post-trip interventions (i.e. coaching) are operational prior to or after a trip and primarily meant to empower vehicle operators in taking appropriate decisions while driving. Nudging and coaching are complementary in a sense that nudging aims to improve the vehicle operator's safety via manipulation of the driving context (i.e. creating a safer driving environment), while coaching aims to improve the vehicle operator's safety via manipulation of the human operator him or herself (i.e. creating a safer driver). The principles of gamified or persuasive design play a key-role in the development of the i-DREAMS interventions. Several critical parameters related to design, and implementation however, have been identified that need to be taken into account with an eye on intervention effectiveness.

Logically, the recommendations mostly relate to the critical design parameters that will determine the effectiveness of the methods selected for application in the i-DREAMS interventions. Several Work packages and project tasks connect to and depart from ideas included in this Deliverable. **Key-recommendations are**:

- For **Work Package 4**: Technical implementation of i-DREAMS interventions:
    - In respect to the in-vehicle interventions:
        - As for the selection of a suitable display for the delivery of in-vehicle messages, the most preferred option taking into account feasibility and ease of installation would be a (cost affordable) nomadic device allowing visual and auditory feedback.
        - The design of this display would preferably be based on the guidelines for Human-Machine Interfaces, as proposed by Naujoks et al. (2019).
        - In terms of message timing, preference should go towards a situation-adaptive approach with an intelligent, personalized, and multi-staged activation of in-vehicle messages.
        - Regarding message information, a multi-sensory approach (i.e. visual information and sound) is the preferred option with level of

intrusiveness and information specificity changing in function of how critical a detected risk is for the safety of the vehicle operator. To guarantee instant comprehension and persuasion, it is recommended to opt for highly guessable icons and symbols and appropriate manipulation of the acoustic properties of sound (i.e. loudness, pitch, and tone).

- In respect to the post-trip interventions:
  - Differences in both the quantity (i.e. how much you want to change behaviour) and quality (i.e. why it is you want to change behaviour) of motivation plead in favour of a person-tailored and a stage-matched use of the change methods.
  - Not only in terms of intervention efficacy, but regarding successful adoption as well, it is of strategic importance to use the GDE-matrix as a guiding instrument to determine and structure the competences to be targeted, as the GDE-matrix gave direction to the requirements proposed in the EU Directives that regulate the minimum requirements for obtaining a private car driving licence, and for initial qualification and periodic training of professional drivers.
  - In a professional work context, the post-trip intervention platform should function as a kind of automated expert system, meant to provide support to the different key-stakeholders that are actively involved in the process of coaching professional vehicle operators to improve their driving style (e.g. company management, outdoor service providers coordinating fleet safety interventions, indoor planners and coaches or buddies, end-users).
  - In order to maximize user engagement and retention, it is recommended to take into account the factors identified in the studies by Brouwer et al. (2008) and Crutzen et al. (2008).

- For **Work Package 5**: 5-country experiment:
  - For successful implementation of the i-DREAMS interventions in a professional working context, it is important to have an implementation protocol that clarifies which stakeholders will be involved, what their role will be, what is expected from them, and how they are to interact with the app and/or web-based platform. Preferably, such a stakeholder implementation plan is to be developed in Deliverable 3.4 (Experimental protocol).
  - The post-trip interventions as outlined in this Deliverable are to be seen as a multi-modular program (i.e. vehicle operators can work on competences situated at different levels of the GDE-matrix, like vehicle control, road user interaction, speed management, driver fitness and use of safety devices), meant to engage and retain vehicle operators for several weeks or even months. In terms of time and duration, the empirical framework of the i-DREAMS project will not allow the post-trip interventions to be fully deployed for all participants involved (i.e. participants in the field trials will only be exposed to the post-trip interventions for a few weeks). Taking into account these time constraints, it is advisable to adopt a modular implementation strategy with different sub-groups of participants being exposed to specific modules that match with their baseline profile in terms of current performance (e.g. novice vs experienced) and personal safety-

orientations (e.g. safety-related opinions and attitudes, sensation-seeking inclination, et cetera).

- For **Work Package 7**: Evaluation of safety interventions:
  - In this Deliverable several safety outcomes have been proposed at the highest (i.e. epidemiological) level of impact. For now, these have been stated in terms of crash types. However, more specific and suitable (surrogate) measures will have to be proposed to appropriately operationalize objectives set at this highest level of impact. This is an important consideration for Deliverable 7.1 (Methodology for the evaluation of interventions).
  - In order not to lose the logic strength of the change strategy proposed in this Deliverable (i.e. change objectives → performance objectives → safety promoting goals → safety outcomes), it is important that suitable measures for each of the links in this causal chain are proposed and considered in relation to each other when assessing intervention effects. This does not only apply to Deliverable 7.1 but to Deliverable 3.4 as well.
  - For the interventions taking place in a professional work setting, data analysis and interpretation of results will have to take companies' safety climate into account, as this is can be expected to be a crucial environmental factor influencing intervention effectiveness.
  - In line with corporate safety climate, individual user acceptance is to be included in the analysis and interpretation of intervention effectiveness.
- For **Work Package 8**:
  - For successful adoption of the i-DREAMS post-trip interventions, it could be a strategic advantage to stress their alignment with the EU Directives that regulate the minimum requirements for obtaining a private car driving licence, and for initial qualification and periodic training of professional drivers.

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Annex 1: Behaviour Change Techniques Taxonomy v1

Table 14: The Behaviour Change Techniques Taxonomy v1. Source: Michie et al.(2014: appendix 4)

No.	Label	Definition	Examples
1. Goals and planning			
1.1	**Goal setting (behaviour)**	Set or agree on a goal defined in terms of the behaviour to be achieved *Note: only code goal-setting if there is sufficient evidence that goal set as part of intervention; if goal unspecified or a behavioural outcome, code **1.3, Goal setting (outcome)**; if the goal defines a specific context, frequency, duration or intensity for the behaviour, also code **1.4, Action planning***	Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal Set the goal of eating 5 pieces of fruit per day as specified in public health guidelines
1.2	**Problem solving**	Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes '**Relapse Prevention**' *and* '**Coping Planning**') *Note: barrier identification without solutions is not sufficient. If the BCT does not include analysing the behavioural problem, consider **12.3, Avoidance/changing exposure to cues for the behaviour, 12.1, Restructuring the physical environment, 12.2, Restructuring the social environment,** or **11.2, Reduce negative emotions***	Identify specific triggers (e.g. being in a pub, feeling anxious) that generate the urge/want/need to drink and develop strategies for avoiding environmental triggers or for managing negative emotions, such as anxiety, that motivate drinking Prompt the patient to identify barriers preventing them from starting a new exercise regime e.g., lack of motivation, and discuss ways in which they could help overcome them e.g., going to the gym with a buddy
1.3	**Goal setting (outcome)**	Set or agree on a goal defined in terms of a positive **outcome** of wanted behaviour *Note: only code guidelines if set as a goal in an intervention context; if goal is a behaviour, code **1.1, Goal setting (behaviour)**; if goal unspecified code **1.3, Goal setting (outcome)***	Set a weight loss goal (e.g. 0.5 kilogram over one week) as an outcome of changed eating patterns

1.4	**Action planning**	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive) (includes '**Implementation Intentions**') *Note: evidence of action planning does not necessarily imply goal setting, only code latter if sufficient evidence*	Encourage a plan to carry condoms when going out socially at weekends Prompt planning the performance of a particular physical activity (e.g. running) at a particular time (e.g. before work) on certain days of the week
1.5	**Review behaviour goal(s)**	Review behaviour goal(s) jointly with the person and consider modifying goal(s) or behaviour change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change *Note: if goal specified in terms of behaviour, code **1.5, Review behaviour goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behaviour and goal***	Examine how well a person's performance corresponds to agreed goals e.g. whether they consumed less than one unit of alcohol per day, and consider modifying future behavioural goals accordingly e.g. by increasing or decreasing alcohol target or changing type of alcohol consumed
1.6	**Discrepancy between current behaviour and goal**	Draw attention to discrepancies between a person's current behaviour (in terms of the *form, frequency, duration, or intensity* of that behaviour) and the person's previously set outcome goals, behavioural goals or action plans (goes beyond self-monitoring of behaviour) *Note: if discomfort is created only code **13.3, Incompatible beliefs** and not **1.6, Discrepancy between current behaviour and goal**; if goals are modified, also code **1.5, Review behaviour goal(s)** and/or **1.7, Review outcome goal(s)**; if feedback is provided, also code **2.2, Feedback on behaviour***	Point out that the recorded exercise fell short of the goal set

1.7	**Review outcome goal(s)**	Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to resetting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first *Note: if goal specified in terms of behaviour, code **1.5, Review behaviour goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behaviour and goal***	Examine how much weight has been lost and consider modifying outcome goal(s) accordingly e.g., by increasing or decreasing subsequent weight loss targets
1.8	**Behavioural contract**	Create a written specification of the behaviour to be performed, agreed on by the person, and witnessed by another *Note: also code **1.1, Goal setting (behaviour)***	Sign a contract with the person e.g. specifying that they will not drink alcohol for one week
1.9	**Commitment**	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour *Note: if defined in terms of the behaviour to be achieved also code **1.1, Goal setting (behaviour)***	Ask the person to use an "I will" statement to affirm or reaffirm a strong commitment (i.e. using the words "strongly", "committed" or "high priority") to start, continue or restart the attempt to take medication as prescribed
2. Feedback and monitoring			
2.1	**Monitoring of behaviour by others without feedback**	Observe or record behaviour with the person's knowledge as part of a behaviour change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behaviour, do not code; if feedback given, code only **2.2, Feedback on behaviour**, and not **2.1, Monitoring of behaviour by others without feedback**; if monitoring outcome(s) code **2.5, Monitoring outcome(s) of behaviour by others without feedback**; if self-monitoring behaviour, code **2.3, Self-monitoring of behaviour***	Watch hand washing behaviours among health care staff and make notes on context, frequency and technique used

2.2	**Feedback on behaviour**	Monitor and provide informative or evaluative feedback on performance of the behaviour *(e.g. form, frequency, duration, intensity)* *Note: if Biofeedback, code only **2.6, Biofeedback** and not **2.2, Feedback on behaviour**; if feedback is on **outcome(s)** of behaviour, code **2.7, Feedback on outcome(s) of behaviour**; if there is no clear evidence that feedback was given, code **2.1, Monitoring of behaviour by others without feedback**; if feedback on behaviour is evaluative e.g. praise, also code **10.4, Social reward***	Inform the person of how many steps they walked each day (as recorded on a pedometer) or how many calories they ate each day (based on a food consumption questionnaire).
2.3	**Self-monitoring of behaviour**	Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behaviour, do not code; if monitoring of outcome of behaviour, code **2.4, Self-monitoring of outcome(s) of behaviour**; if monitoring is by someone else (without feedback), code **2.1, Monitoring of behaviour by others without feedback***	Ask the person to record daily, in a diary, whether they have brushed their teeth for at least two minutes before going to bed Give patient a pedometer and a form for recording daily total number of steps
2.4	**Self-monitoring of outcome(s) of behaviour**	Establish a method for the person to monitor and record the **outcome(s)** of their behaviour as part of a behaviour change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behaviour, do not code ; if monitoring behaviour, code **2.3, Self-monitoring of behaviour**; if monitoring is by someone else (without feedback), code **2.5, Monitoring outcome(s) of behaviour by others without feedback***	Ask the person to weigh themselves at the end of each day, over a two week period, and record their daily weight on a graph to increase exercise behaviours

2.5	**Monitoring outcome(s) of behaviour by others without feedback**	Observe or record outcomes of behaviour with the person's knowledge as part of a behaviour change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behaviour, do not code; if feedback given, code only **2.7, Feedback on outcome(s) of behaviour**; if monitoring behaviour code **2.1, Monitoring of behaviour by others without feedback**; if self-monitoring outcome(s), code **2.4, Self-monitoring of outcome(s) of behaviour***	Record blood pressure, blood glucose, weight loss, or physical fitness
2.6	**Biofeedback**	Provide feedback about the body *(e.g. physiological or biochemical state)* using an external monitoring device as part of a behaviour change strategy *Note: if Biofeedback, code only **2.6, Biofeedback** and not **2.2, Feedback on behaviour** or **2.7, Feedback on outcome(s) of behaviour***	Inform the person of their blood pressure reading to improve adoption of health behaviours
2.7	**Feedback on outcome(s) of behaviour**	Monitor and provide feedback on the outcome of performance of the behaviour *Note: if Biofeedback, code only **2.6, Biofeedback** and not **2.7, Feedback on outcome(s) of behaviour**; if feedback is on **behaviour** code **2.2, Feedback on behaviour**; if there is no clear evidence that feedback was given code **2.5, Monitoring outcome(s) of behaviour by others without feedback;** if feedback on behaviour is evaluative e.g. praise, also code **10.4, Social reward***	Inform the person of how much weight they have lost following the implementation of a new exercise regime
3. Social support			

3.1	**Social support (unspecified)**	Advise on, arrange or provide social support *(e.g. from friends, relatives, colleagues,' buddies' or staff)* or noncontingent praise or reward for performance of the behaviour. It includes encouragement and counselling, but only when it is directed at the **behaviour** *Note: attending a group class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned; if practical, code **3.2, Social support (practical)**; if emotional, code **3.3, Social support (emotional)*** (includes '**Motivational interviewing**' and **'Cognitive Behavioural Therapy'**)	Advise the person to call a 'buddy' when they experience an urge to smoke Arrange for a housemate to encourage continuation with the behaviour change programme Give information about a self-help group that offers support for the behaviour
3.2	**Social support (practical)**	Advise on, arrange, or provide **practical** help *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour *Note: if emotional, code **3.3, Social support (emotional)**; if general or unspecified, co e **3.1, Social support (unspecified)** If only restructuring the physical environment or adding objects to the environment, code **12.1, Restructuring the physical environment** or **12.5, Adding objects to the environment;** attending a group or class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned.*	Ask the partner of the patient to put their tablet on the breakfast tray so that the patient remembers to take it
3.3	**Social support (emotional)**	Advise on, arrange, or provide **emotional** social support *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour *Note: if practical, code **3.2, Social support (practical)**; if unspecified, code **3.1, Social support (unspecified)***	Ask the patient to take a partner or friend with them to their colonoscopy appointment
4. Shaping knowledge			

4.1	**Instruction on how to perform a behaviour**	Advise or agree on how to perform the behaviour (includes '**Skills training**') *Note: when the person attends classes such as exercise or cookery, code **4.1, Instruction on how to perform the behaviour, 8.1, Behavioural practice/rehearsal** and **6.1, Demonstration of the behaviour***	Advise the person how to put a condom on a model of a penis correctly
4.2	**Information about antecedents**	Provide information about antecedents (*e.g. social and environmental situations and events, emotions, cognitions)* that reliably predict performance of the behaviour	Advise to keep a record of snacking and of situations or events occurring prior to snacking
4.3	**Re-attribution**	Elicit perceived causes of behaviour and suggest alternative explanations *(e.g. external or internal and stable or unstable)*	If the person attributes their over-eating to the frequent presence of delicious food, suggest that the 'real' cause may be the person's inattention to bodily signals of hunger and satiety
4.4	**Behavioural experiments**	Advise on how to identify and test hypotheses about the behaviour, its causes and consequences, by collecting and interpreting data	Ask a family physician to give evidence-based advice rather than prescribe antibiotics and to note whether the patients are grateful or annoyed
5. Natural consequences			
5.1	***Information about health consequences***	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour *Note: consequences can be for any target, not just the recipient(s) of the intervention; emphasising importance of consequences is not sufficient; if information about emotional consequences, code **5.6, Information about emotional consequences**; if about social, environmental or unspecified consequences code **5.3, Information about social and environmental consequences***	Explain that not finishing a course of antibiotics can increase susceptibility to future infection Present the likelihood of contracting a sexually transmitted infection following unprotected sexual behaviour

5.2	***Salience of consequences***	Use methods specifically designed to **emphasise** the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences) *Note: if information about consequences, also code **5.1, Information about health consequences**, **5.6, Information about emotional consequences** or **5.3, Information about social and environmental consequences***	Produce cigarette packets showing pictures of health consequences e.g. diseased lungs, to highlight the dangers of continuing to smoke
5.3	***Information about social and environmental consequences***	Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour *Note: consequences can be for any target, not just the recipient(s) of the intervention; if information about health or consequences, code **5.1, Information about health consequences**; if about emotional consequences, code **5.6, Information about emotional consequences**; if unspecified, code **5.3, Information about social and environmental consequences***	Tell family physician about financial remuneration for conducting health screening Inform a smoker that the majority of people disapprove of smoking in public places
5.4	***Monitoring of emotional consequences***	Prompt assessment of **feelings** after attempts at performing the behaviour	Agree that the person will record how they feel after taking their daily walk
5.5	***Anticipated regret***	Induce or raise awareness of expectations of future regret about performance of the unwanted behaviour *Note: <u>not</u> including **5.6, Information about emotional consequences**; if suggests adoption of a perspective or new perspective in order to change cognitions <u>also</u> code **13.2, Framing/reframing***	Ask the person to assess the degree of regret they will feel if they do not quit smoking

5.6	***Information about emotional consequences***	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour *Note: consequences can be related to emotional health disorders (e.g. depression, anxiety) and/or states of mind (e.g. low mood, stress); not including **5.5, Anticipated regret**; consequences can be for any target, not just the recipient(s) of the intervention; if information about health consequences code **5.1, Information about health consequences**; if about social, environmental or unspecified code **5.3, Information about social and environmental consequences***	Explain that quitting smoking increases happiness and life satisfaction
6. Comparison of behaviour			
6.1	***Demonstration of the behaviour***	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate (includes '**Modelling**'). *Note:* if advised to practice, also code, ***8.1, Behavioural practice and rehearsal;*** *If provided with instructions on how to perform, also code **4.1, Instruction on how to perform the behaviour***	Demonstrate to nurses how to raise the issue of excessive drinking with patients via a roleplay exercise
6.2	***Social comparison***	Draw attention to others' performance to allow comparison with the person's own performance *Note: being in a group setting does not necessarily mean that social comparison is actually taking place*	Show the doctor the proportion of patients who were prescribed antibiotics for a common cold by other doctors and compare with their own data
6.3	***Information about others' approval***	Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Tell the staff at the hospital ward that staff at all other wards approve of washing their hands according to the guidelines
7. Associations			

7.1	***Prompts/cues***	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance *Note: when a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity also code* ***1.4, Action planning.***	Put a sticker on the bathroom mirror to remind people to brush their teeth
7.2	***Cue signalling reward***	Identify an environmental stimulus that reliably predicts that reward will follow the behaviour (includes ***'Discriminative cue'***)	Advise that a fee will be paid to dentists for a particular dental treatment of 6-8 year old, but not older, children to encourage delivery of that treatment (the 6- 8 year old children are the environmental stimulus)
7.3	***Reduce prompts/cues***	Withdraw gradually prompts to perform the behaviour (includes ***'Fading'***)	Reduce gradually the number of reminders used to take medication
7.4	***Remove access to the reward***	Advise or arrange for the person to be separated from situations in which unwanted behaviour can be rewarded in order to reduce the behaviour (includes ***'Time out'***)	Arrange for cupboard containing high calorie snacks to be locked for a specified period to reduce the consumption of sugary foods in between meals
7.5	***Remove aversive stimulus***	Advise or arrange for the removal of an aversive stimulus to facilitate behaviour change (includes ***'Escape learning'***)	Arrange for a gym-buddy to stop nagging the person to do more exercise in order to increase the desired exercise behaviour
7.6	***Satiation***	Advise or arrange repeated exposure to a stimulus that reduces or extinguishes a drive for the unwanted behaviour	Arrange for the person to eat large quantities of chocolate, in order to reduce the person's appetite for sweet foods
7.7	***Exposure***	Provide systematic confrontation with a feared stimulus to reduce the response to a later encounter	Agree a schedule by which the person who is frightened of surgery will visit the hospital where they are scheduled to have surgery

7.8	***Associative learning***	Present a neutral stimulus jointly with a stimulus that already elicits the behaviour repeatedly until the neutral stimulus elicits that behaviour (includes ***'Classical/Pavlovian Conditioning'***) *Note: when a BCT involves reward or punishment, code one or more of:* ***10.2, Material reward (behaviour); 10.3, Nonspecific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Present repeatedly fatty foods with a disliked sauce to discourage the consumption of fatty foods
8. Repetition and substitution			
8.1	***Behavioural practice/ rehearsal***	Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill *Note: if aiming to associate performance with the context, also code* ***8.3, Habit formation***	Prompt asthma patients to practice measuring their peak flow in the nurse's consulting room
8.2	***Behaviour substitution***	Prompt substitution of the unwanted behaviour with a wanted or neutral behaviour *Note: if this occurs regularly, also code* ***8.4, Habit reversal***	Suggest that the person goes for a walk rather than watches television
8.3	***Habit formation***	Prompt rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour *Note: also code* ***8.1, Behavioural practice/rehearsal***	Prompt patients to take their statin tablet before brushing their teeth every evening
8.4	***Habit reversal***	Prompt rehearsal and repetition of an alternative behaviour to **replace** an unwanted habitual behaviour *Note: also code* ***8.2, Behaviour substitution***	Ask the person to walk up stairs at work where they previously always took the lift
8.5	***Overcorrection***	Ask to repeat the wanted behaviour in an exaggerated way following an unwanted behaviour	Ask to eat only fruit and vegetables the day after a poor diet
8.6	***Generalisation of a target behaviour***	Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation	Advise to repeat toning exercises learned in the gym when at home

8.7	***Graded tasks***	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behaviour is performed	Ask the person to walk for 100 yards a day for the first week, then half a mile a day after they have successfully achieved 100 yards, then two miles a day after they have successfully achieved one mile
9. Comparison of outcomes			
9.1	***Credible source***	Present verbal or visual communication from a **credible source** in favour of or against the behaviour *Note: code this BCT if source generally agreed on as credible e.g., health professionals, celebrities or words used to indicate expertise or leader in field and if the communication has the aim of persuading; if information about health consequences, also code **5.1, Information about health consequences**, if about emotional consequences, also code **5.6, Information about emotional consequences**; if about social, environmental or unspecified consequences also code **5.3, Information about social and environmental consequences***	Present a speech given by a high status professional to emphasise the importance of not exposing patients to unnecessary radiation by ordering x-rays for back pain
9.2	***Pros and cons***	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour (includes '**Decisional balance'**) *Note: if providing information about health consequences, also code **5.1, Information about health consequences**; if providing information about emotional consequences, also code **5.6, Information about emotional consequences**; if providing information about social, environmental or unspecified consequences also code **5.3, Information about social and environmental consequences***	Advise the person to list and compare the advantages and disadvantages of prescribing antibiotics for upper respiratory tract infections
9.3	***Comparative imagining of future outcomes***	Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged behaviour	Prompt the person to imagine and compare likely or possible outcomes following attending versus not attending a screening appointment

10. Reward and threat			
10.1	***Material incentive (behaviour)***	Inform that money, vouchers or other valued objects ***will be*** delivered if and only if there has been effort and/or progress in performing the behaviour (includes ***'*****Positive reinforcement'**) *Note: if incentive is social, code **10.5, Social incentive** if unspecified code **10.6, Non-specific incentive,** and not **10.1, Material incentive (behaviour)**; if incentive is for **outcome,** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that a financial payment will be made each month in pregnancy that the woman has not smoked
10.2	***Material reward (behaviour)***	Arrange for the delivery of money, vouchers or other valued objects if and only if there ***has been*** effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**) *Note: If reward is social, code **10.4, Social reward**, if unspecified code **10.3, Nonspecific reward**, and not **10.1, Material reward (behaviour)**; if reward is for **outcome**, code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money that would have been spent on cigarettes if and only if the smoker has not smoked for one month
10.3	***Non-specific reward***	Arrange delivery of a reward if and only if there ***has been*** effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**) *Note: if reward is material, code **10.2, Material reward (behaviour)**, if social, code **10.4, Social reward**, and not **10.3, Nonspecific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of**: 10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Identify something (e.g. an activity such as a visit to the cinema) that the person values and arrange for this to be delivered if and only if they attend for health screening

10.4	***Social reward***	Arrange verbal or non-verbal reward if and only if there ***has been*** effort and/or progress in performing the behaviour (includes '**Positive reinforcement**') *Note: if reward is material, code **10.2, Material reward (behaviour)**, if unspecified code **10.3, Non-specific reward**, and not **10.4, Social reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of**: 10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Congratulate the person for each day they eat a reduced fat diet
10.5	***Social incentive***	Inform that a verbal or non-verbal reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**) *Note: if incentive is material, code **10.1, Material incentive (behaviour)**, if unspecified code **10.6, Non-specific incentive**, and not **10.5, Social incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of**: 10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that they will be congratulated for each day they eat a reduced fat diet
10.6	***Non-specific incentive***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**) *Note: if incentive is material, code **10.1, Material incentive (behaviour)**, if social, code **10.5, Social incentive** and not **10.6, Non-specific incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of**: 10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Identify an activity that the person values and inform them that this will happen if and only if they attend for health screening

10.7	***Self-incentive***	Plan to reward self in future if and only if there has been effort and/or progress in performing the behaviour *Note: if self-reward is material, also code **10.1, Material incentive (behaviour)**, if social, also code **10.5, Social incentive**, if unspecified, also code **10.6, Non-specific incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Encourage to provide self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet
10.8	***Incentive (outcome)***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in achieving the behavioural **outcome** (*includes **'Positive reinforcement'***) *Note: this includes social, material, self- and non-specific incentives for outcome; if incentive is for the **behaviour** code **10.5**, **Social incentive**, **10.1, Material incentive (behaviour)**, **10.6, Non-specific incentive** or **10.7**, **Self-incentive** and not **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform the person that they will receive money if and only if a certain amount of weight is lost
10.9	***Self-reward***	Prompt self-praise or self-reward if and only if there ***has been*** effort and/or progress in performing the behaviour *Note: if self-reward is material, also code **10.2, Material reward (behaviour)**, if social, also code **10.4, Social reward**, if unspecified, also code **10.3, Non-specific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome***	Encourage to reward self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet

10.10	***Reward (outcome)***	Arrange for the delivery of a reward if and only if there ***has been*** effort and/or progress in achieving the behavioural **outcome** (includes '**Positive reinforcement**') *Note: this includes social, material, self- and non-specific rewards for outcome; if reward is for the* ***behaviour*** *code* ***10.4****,* ***Social reward****,* ***10.2, Material reward (behaviour)****,* ***10.3, Non-specific reward*** *or* ***10.9****,* ***Self-reward*** *and not* ***10.10, Reward (outcome).*** *If informed of reward in advance of rewarded behaviour, also code one of****: 10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money if and only if a certain amount of weight is lost
10.11	***Future punishment***	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behaviour (may include fear arousal) (includes ***'Threat'***)	Inform that continuing to consume 30 units of alcohol per day is likely to result in loss of employment if the person continues
11. Regulation			
11.1	***Pharmacological support***	Provide, or encourage the use of or adherence to, drugs to facilitate behaviour change *Note: if pharmacological support to reduce negative emotions (i.e. anxiety) then also code* ***11.2, Reduce negative emotions***	Suggest the patient asks the family physician for nicotine replacement therapy to facilitate smoking cessation
11.2	***Reduce negative emotions***	Advise on ways of reducing negative emotions to facilitate performance of the behaviour (includes '**Stress Management**') *Note: if includes analysing the behavioural problem, also code* ***1.2****,* ***Problem solving***	Advise on the use of stress management skills, e.g. to reduce anxiety about joining Alcoholics Anonymous
11.3	***Conserving mental resources***	Advise on ways of minimising demands on mental resources to facilitate behaviour change	Advise to carry food calorie content information to reduce the burden on memory in making food choices
11.4	***Paradoxical instructions***	Advise to engage in some form of the unwanted behaviour with the aim of reducing motivation to engage in that behaviour	Advise a smoker to smoke twice as many cigarettes a day as they usually do Tell the person to stay awake as long as possible in order to reduce insomnia

12. Antecedents			
12.1	***Restructuring the physical environment***	Change, or advise to change the **physical** environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments) *Note: this may also involve **12.3, Avoidance/reducing exposure to cues for the behaviour**; if restructuring of the social environment code **12.2, Restructuring the social environment;** if only adding objects to the environment, code **12.5, Adding objects to the environment***	Advise to keep biscuits and snacks in a cupboard that is inconvenient to get to Arrange to move vending machine out of the school
12.2	***Restructuring the social environment***	Change, or advise to change the **social** environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments) *Note: this may also involve **12.3, Avoidance/reducing exposure to cues for the behaviour**; if also restructuring of the physical environment also code **12.1, Restructuring the physical environment***	Advise to minimise time spent with friends who drink heavily to reduce alcohol consumption
12.3	***Avoidance/reducing exposure to cues for the behaviour***	Advise on how to avoid exposure to specific social and contextual/physical cues for the behaviour, including changing daily or weekly routines *Note: this may also involve **12.1, Restructuring the physical environment*** and/or ***12.2, Restructuring the social environment***; if the BCT includes analysing the behavioural problem, only code ***1.2*, *Problem solving***	Suggest to a person who wants to quit smoking that their social life focus on activities other than pubs and bars which have been associated with smoking
12.4	***Distraction***	Advise or arrange to use an alternative focus for attention to avoid triggers for unwanted behaviour	Suggest to a person who is trying to avoid between-meal snacking to focus on a topic they enjoy (e.g. holiday plans) instead of focusing on food

12.5	***Adding objects to the environment***	Add objects to the environment in order to facilitate performance of the behaviour *Note: Provision of information (e.g. written, verbal, visual) in a booklet or leaflet is insufficient. If this is accompanied by social support, also code **3.2, Social support (practical)**; if the environment is changed beyond the addition of objects, also code **12.1, Restructuring the physical environment***	Provide free condoms to facilitate safe sex Provide attractive toothbrush to improve tooth brushing technique
12.6	***Body changes***	Alter body structure, functioning or support **directly** to facilitate behaviour change	Prompt strength training, relaxation training or provide assistive aids (e.g. a hearing aid)
13. Identity			
13.1	***Identification of self as role model***	Inform that one's own behaviour may be an example to others	Inform the person that if they eat healthily, that may be a good example for their children
13.2	**F*raming/reframing***	Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour (includes '**Cognitive structuring**'); *If information about consequences then code **5.1, Information about health consequences, 5.6, Information about emotional consequences** or **5.3, Information about social and environmental consequences** instead of **13.2, Framing/reframing***	Suggest that the person might think of the tasks as reducing sedentary behaviour (rather than increasing activity)
13.3	***Incompatible beliefs***	Draw attention to discrepancies between current or past behaviour and self-image, in order to create discomfort (includes ***'*Cognitive dissonance'**)	Draw attention to a doctor's liberal use of blood transfusion and their self-identification as a proponent of evidence-based medical practice
13.4	***Valued self-identity***	Advise the person to write or complete rating scales about a cherished value or personal strength as a means of affirming the person's identity as part of a behaviour change strategy (includes ***'*Self-affirmation'**)	Advise the person to write about their personal strengths before they receive a message advocating the behaviour change
13.5	***Identity associated with changed behaviour***	Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behaviour'	Ask the person to articulate their new identity as an 'ex-smoker'
14. Scheduled consequences			

14.1	***Behaviour cost***	Arrange for withdrawal of something valued if and only if an unwanted behaviour is performed (includes '**Response cost'**). Note if withdrawal of contingent reward code, ***14.3, Remove reward***	Subtract money from a prepaid refundable deposit when a cigarette is smoked
14.2	***Punishment***	Arrange for aversive consequence contingent on the performance of the unwanted behaviour	Arrange for the person to wear unattractive clothes following consumption of fatty foods
14.3	***Remove reward***	Arrange for discontinuation of contingent reward following performance of the unwanted behaviour (includes **'Extinction'**)	Arrange for the other people in the household to ignore the person every time they eat chocolate (rather than attending to them by criticising or persuading)
14.4	***Reward approximation***	Arrange for reward following any approximation to the target behaviour, gradually rewarding only performance closer to the wanted behaviour (includes ***'Shaping'***) *Note: also code one of* ***59-63***	Arrange reward for any reduction in daily calories, gradually requiring the daily calorie count to become closer to the planned calorie intake
14.5	***Rewarding completion***	Build up behaviour by arranging reward following final component of the behaviour; gradually add the components of the behaviour that occur earlier in the behavioural sequence (includes ***'Backward chaining'***) *Note: also code one of* ***10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Reward eating a supplied low calorie meal; then make reward contingent on cooking and eating the meal; then make reward contingent on purchasing, cooking and eating the meal
14.6	***Situation-specific reward***	Arrange for reward following the behaviour in one situation but not in another (includes ***'Discrimination training'***) *Note: also code one of* ***10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome***	Arrange reward for eating at mealtimes but not between meals
14.7	***Reward incompatible behaviour***	Arrange reward for responding in a manner that is incompatible with a previous response to that situation (includes ***'Counter-conditioning'***) *Note: also code one of* ***10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for ordering a soft drink at the bar rather than an alcoholic beverage

14.8	***Reward alternative behaviour***	Arrange reward for performance of an alternative to the unwanted behaviour (includes ***'Differential reinforcement'***) *Note: also code one of **10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome);** consider also coding **1.2, Problem solving***	Reward for consumption of low fat foods but not consumption of high fat foods
14.9	***Reduce reward frequency***	Arrange for rewards to be made contingent on increasing duration or frequency of the behaviour (includes ***'Thinning'***) *Note: also code one of **10.2, Material reward (behaviour); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for each day without smoking, then each week, then each month, then every 2 months and so on
14.10	***Remove punishment***	Arrange for removal of an unpleasant consequence contingent on performance of the wanted behaviour (includes ***'Negative reinforcement'***)	Arrange for someone else to do housecleaning only if the person has adhered to the medication regimen for a week
15. Self-belief			
15.1	***Verbal persuasion about capability***	Tell the person that they can successfully perform the wanted behaviour, arguing against self-doubts and asserting that they can and will succeed	Tell the person that they can successfully increase their physical activity, despite their recent heart attack.
15.2	***Mental rehearsal of successful performance***	Advise to practise imagining performing the behaviour successfully in relevant contexts	Advise to imagine eating and enjoying a salad in a work canteen
15.3	***Focus on past success***	Advise to think about or list previous successes in performing the behaviour (or parts of it)	Advise to describe or list the occasions on which the person had ordered a non-alcoholic drink in a bar
15.4	***Self-talk***	Prompt positive self-talk (aloud or silently) before and during the behaviour	Prompt the person to tell themselves that a walk will be energising
16. Covert learning			
16.1	***Imaginary punishment***	Advise to imagine performing the **unwanted** behaviour in a real-life situation followed by imagining an unpleasant consequence (includes ***'Covert sensitisation'***)	Advise to imagine overeating and then vomiting
16.2	***Imaginary reward***	Advise to imagine performing the **wanted** behaviour in a real-life situation followed by imagining a pleasant consequence (includes ***'Covert conditioning'***)	Advise the health professional to imagine giving dietary advice followed by the patient losing weight and no longer being diabetic

16.3	***Vicarious consequences***	Prompt observation of the consequences (including rewards and punishments) for others when they perform the behaviour *Note: if observation of health consequences, also code **5.1, Information about health consequences**; if of emotional consequences, also code **5.6, Information about emotional consequences**, if of social, environmental or unspecified consequences, also code **5.3, Information about social and environmental consequences***	Draw attention to the positive comments other staff get when they disinfect their hands regularly

Annex 2: Gamification mechanisms: descriptive definitions

Table 15: Gamification mechanisms: descriptive definitions. Source: Gamified UK (2019)

Player type	Game mechanic	Description
General	On-boarding/tutorial	A tutorial or introduction meant to support people to get used to a system.
	Signposting	Sometimes, even the best people need to be pointed in the right direction. Signposting next actions helps smoothing the early stages of a journey. 'Just in time' cues might help people who are stuck.
	Loss aversion	No one likes to lose things. Fear of losing status, friends, points, achievements, possessions, progress, et cetera can be a powerful reason for people to do things
	Progress/feedback	Progress and feedback can come in many forms and have many mechanics available. All user types need some sort of measure of progress or feedback, but some types work better than others.
	Theme	A theme, often linked with a narrative can be anything from company values to a fantasy. Important is to make sure people can make sense of it.
	Narrative/story	Telling a story and letting people tell theirs can be a powerful leverage for engagement.
	Curiosity/mystery box	Curiosity s a strong force. Not everything has to be fully explained. A little mystery can encourage people in new directions.
	Time pressure	Reducing the amount of time people have to do things can focus them on the problem and can lead to different decisions.
	Scarcity	Making something rare can make it more desirable.
	Strategy	Make people think about what they are doing, why they are doing it and how it might affect outcomes.
	Flow	Balance is the key: getting the perceived levels of challenge and skill just right can lead to a state of flow.
	Consequences	If the user gets things wrong, what are the consequences? Can they lose a life, points or levels they have earned?
	Investment	When people invest time, effort, emotions or money, they will value the outcomes more.
Reward schedules	Random rewards	Unexpected rewards surprise and delight people. It keeps them on their toes and can create a positive experience.
	Fixed rewards	People can be rewarded based on defined actions and events, for instance for realizing milestone events.

	Time-dependent rewards	People can be rewarded at specific times or at occasions that are only available for a set period of time. Users have to be there to benefit.
Socialiser	Guilds/teams	Let people build close-knit guilds or teams. Small groups can be much more effective than large sprawling ones. Create platforms for collaboration but also pave the way for team-based competitions.
	Social network	Allow people to connect and be social with an easy to use and accessible social network. It can be much more fun to play with other people than to play on your own.
	Social status	Status can lead to greater visibility for people, creating opportunities to develop new relationships. It can also feel good. Feedback mechanics such as leaderboards and certificates can be useful.
	Social discovery	A way to find people and to be found is essential to building new relationships. Matching people based on interests and status can help get people started.
	Social pressure	People often don't like feeling they are the odd one out. In a social environment, this can be used to encourage people to be like their friends. It can demotivate however, if expectations are unrealistic.
	Competition	Competition gives people a chance to prove themselves against others. It can be a way to win rewards, but can also be a place where new friendships and relationships are born.
Free spirit	Exploration	Give people room to move and explore. Some people will want to find the boundaries, so give them something to find.
	Branching choices	Let the user choose his or her path and destiny. From multiple learning paths to responsive narratives. Important is that choice has to be or at least feel meaningful to be most effective and appreciated.
	Easter eggs	Easter eggs are a fun way to reward and surprise people for just having a look around. For some, the harder they are to find, the more exciting it is.
	Unlockable/rare content	Unlockable or rare contents can add to the feeling of self-expression and value.
	Creativity tools	Allow people to create their own content and express themselves. This may be for personal gain, for pleasure, or to help other people (e.g. teaching materials, FAQ, et cetera).
	Customisation	Give people the tools to customise their experience. Let them express themselves and choose how they will present themselves to others.
Achiever	Challenges	Challenges help keep people interested, testing their knowledge and allowing them to apply it. Overcoming challenges will make people feel they have earned their achievement.
	Certificates	Different from general rewards and trophies, certificates are a physical symbol of mastery and

		achievement. They carry meaning, status, and are useful.
	Learning/new skills	No better way to achieve mastery than to learn something new. Give your users the opportunity to learn and expand.
	Quests	Quests give users a fixed goal to achieve. They are often made up from a series of linked challenges, multiplying the feeling of achievement.
	Levels/progression	Levels and goals help to map a user's progression through a system. It can be as important to see where you can go next as it is to see where you have been.
	Boss battles	Boss battles are a chance to consolidate everything a user has learned and mastered in one epic challenge. Usually boss battles signal the end of a journey, and the beginning of a new one.
Philanthropist	Meaning/purpose	Some people just need to understand the meaning or the purpose of what they are doing (epic or otherwise). Others need to feel they are part of something greater than themselves.
	Care-taking	Looking after other people can be very fulfilling. Create roles for administrators, moderators, curators, et cetera. Allow users to take a parental role.
	Access	Access to more features and abilities in a system can give people more ways to help others and to contribute. It also helps to make them feel valued.
	Collect and trade	Many people love to collect things. Give people a way to collect and trade items in your system. I can help build relationships and feelings of purpose and value.
	Gifting/sharing	Allow gifting or sharing of items to other people to help them achieve their goals. Whilst a form of altruism, the potential for reciprocity can be a strong motivator.
	Sharing knowledge	For some, helping other people by sharing knowledge with them is a reward on its own. Build in the ability for people to answer questions and teach others.
Disruptor	Innovation platform	Some people think outside the box and boundaries of your system. Give them a way to channel that and you can generate great innovations.
	Voting/voice	Give people a voice and let them know that it is being heard. Change is much easier if everyone is on the same page.
	Development tools	Think modifications rather than hacking and breaking. Let people develop new add-ons to improve and build on the system.
	Anonymity	If you want to encourage total freedom and lack of inhibitions, allow your users to remain anonymous. However, be very careful with anonymity because it can bring out the worst in people.

	Light touch	Whilst you must have rules, if you are encouraging disruption, apply them with a light touch. Keep a watchful eye and listen to feedback of users.
	Anarchy	Sometimes, you have to throw the rule book out of the window and see what happens. Short ‘no rules’ events can be considered.
Player	Points/experience points	Points and experience points are feedback mechanics. They allow to track progress and be used as a way to unlock new things.
	Physical rewards/prizes	Physical rewards and prizes can promote lots of activity and when used well, can create engagement. Be careful of promoting quantity over quality.
	Leaderboards/ladders	Leaderboards come in different forms, most commonly relative or absolute. Commonly, they are used to show people how they compare to others and so others can see them. They are not for everyone.
	Badges/achievements	Badges and achievements are a form of feedback. Award them to people for accomplishments. Use them wisely and in a meaningful way to make them more appreciated.
	Virtual economy	Create a virtual economy and allow people to spend their virtual currency on real or virtual goods. Look into the legalities of this type of system and consider the long-term financial costs.
	Lottery/game of chance	Lotteries and games of chance are a way to win rewards with very little effort from the user. You have to be in it to win it though.

Annex 3: Research-based web design & usability guideline

Table 16: Research-based web design & usability guidelines. Source: HHS & GSA (2006)

Optimizing the user experience
Do not display unsolicited windows or graphics
Increase web site credibility
Standardize task sequences
Reduce the user's workload
Design for working memory limitations
Minimize page download time
Warn of 'time outs'
Display information in a directly usable format
Format information for reading and printing
Provide feedback when users must wait
Inform users of long download times
Develop pages that will print properly
Do not require users to multitask while reading
Use users' terminology in help documentation
Provide printing options
Provide assistance to users
Accessibility
Comply with requirements for people with disabilities
Design forms for users using assistive technologies
Do not use colour alone to convey information
Enable users to skip repetitive navigation links
Provide text equivalents for non-text elements
Test plug-ins and applets for accessibility
Ensure that scripts allow accessibility
Provide equivalent pages
Provide client-side image maps
Synchronize multimedia elements
Do not require style sheets
Provide frame titles
Avoid screen flicker
Hardware and software
Design for common browsers
Account for browser differences
Design for popular operating systems

Design for users' typical connection speed
Design for commonly used screen resolutions
The homepage
Enable access to the homepage
Show all major options on the homepage
Create a positive first impression of your site
Communicate the web site's value and purpose
Limit prose text on the homepage
Ensure the homepage looks like a homepage
Limit homepage length
Announce changes to a website
Attend to homepage panel width
Page layout
Avoid cluttered displays
Place important items consistently
Place important items at top centre
Structure for easy comparison
Establish level of importance
Optimize display density
Align items on a page
Use fluid layouts
Avoid scroll stoppers
Set appropriate page lengths
Use moderate white space
Choose appropriate line lengths
Use frames when functions must remain accessible
Navigation
Provide navigational options
Differentiate and group navigation elements
Use a clickable 'list of contents' on long pages
Provide feedback on user's location
Place primary navigation menus in the left panel
Use descriptive tab labels
Present tabs effectively
Keep navigation-only pages short
Use appropriate menu types
Use site maps
Use 'glosses' to assist navigation

Breadcrumb navigation
Scrolling and paging
Eliminate horizontal scrolling
Facilitate rapid scrolling while reading
Use scrolling pages for reading comprehension
Use paging rather than scrolling
Scroll fewer screenfuls
Headings, titles, and labels
Use clear category labels
Provide descriptive page titles
Use descriptive headings liberally
Use unique and descriptive headings
Highlight critical data
Use descriptive row and column headings
Use headings in the appropriate HTML order
Provide users with good ways to reduce options
Links
Use meaningful link labels
Link to related content
Match link names with their destination pages
Avoid misleading cues to click
Repeat important links
Use text for links
Designate used links
Provide consistent clickable cues
Ensure that embedded links are descriptive
Use ‘pointing-and-clicking’
Use appropriate text link lengths
Indicate internal vs. external links
Clarify clickable regions of images
Link to supportive information
Text appearance
Use black text on plain, high-contrast backgrounds
Format common items consistently
Use mixed-case for prose text
Ensure visual consistency
Use bold text sparingly
Use attention-attracting features when appropriate

Use familiar fonts
Use at least 12-point font
Colour-coding and instructions
Emphasize importance
Highlighting information
Lists
Order elements to maximize user performance
Place important items at top of the list
Format lists to easy scanning
Display related items in lists
Introduce each list
Use static menus
Start numbered items at one
Use appropriate list style
Capitalize first letter of first word in lists
Screen-based controls (Widgets)
Distinguish required and optional data entry fields
Label pushbuttons clearly
Label data entry fields consistently
Do not make user-entered codes case sensitive
Label data entry fields clearly
Minimize user data entry
Put labels close to data entry fields
Allow users to see their entered data
Use radio buttons for mutually exclusive selections
Use familiar widgets
Anticipate typical user errors
Partition long data items
Use a single data entry method
Prioritize push buttons
Use checkboxes to enable multiple selections
Label units of measurement
Do not limit viewable list box options
Display default values
Place cursor in first data entry field
Ensure that double-clicking will not cause problems
Use open lists to select one from many
Use data entry fields to speed performance

Use a minimum of two radio buttons
Provide auto-tabbing functionality
Minimize use of the shift key
Graphics, images, and multimedia
Use simple background images
Label clickable images
Ensure that images do not slow downloads
Use video, animation, and audio meaningfully
Include logos
Graphics should not look like banner ads
Limit large images above the fold
Ensure web site images convey intended messages
Limit the use of images
Include actual data with data graphics
Display monitoring information graphically
Introduce animation
Emulate real-world objects
Use thumbnail images to preview larger images
Use images to facilitate learning
Using photographs of people
Writing web content
Make action sequences clear
Avoid jargon
Use familiar words
Define acronyms and abbreviations
Use abbreviations sparingly
Use mixed case with prose
Limit the number of words and sentences
Limit prose text on navigation pages
Use active voice
Write instructions in the affirmative
Make first sentences descriptive
Content organization
Organize information clearly
Facilitate scanning
Ensure that necessary information is displayed
Group related elements
Minimize the number of clicks or pages

Design quantitative content for quick understanding
Display only necessary information
Format information for multiple audiences
Use colour for grouping
Search
Ensure usable search results
Design search engines to search the entire site
Make upper- and lowercase search terms equivalent
Provide a search option on each page
Design search around users' terms
Allow simple searches
Notify users when multiple search options exist
Include hints to improve search performance
Provide search templates

Annex 4: Critical design parameters for HMIs

Table 17: Critical design parameters for Human-Machine Interfaces. Source: Naujoks et al., 2019: p.132-133, Table 3

GUIDELINES	+	-
1. Unintentional activation and deactivation should be prevented	- System design ensures driver readiness before transfer of control (e.g., pushing two buttons simultaneously, need to have both hands on the steering wheel, need to have eyes on the road, etc.)	- Surprising or inexplicable driver-initiated activation/deactivation during regular use
2. The system mode should be displayed continuously	- Minimum set of mode indicators present (1) functioning properly (2) currently engaged in an automated driving mode (3) currently unavailable for automated driving (4) experiencing a malfunction (5) requesting a control transition from the automated driving system to the operator * Indicators missing * Indicators not distinguishable from each other * Indicators only displayed for short periods of time * Mode indication discontinued	/
3. System state changes should be effectively communicated	- Recognizable change of pictorial indicator - Auditory/haptic feedback - Communication of responsibility (e.g., by disclaimer) - Pop-up messages - Error messages are provided in case (e.g., failed activation) - Delayed reaction to control input displayed in Human-Machine interface (HMI)	/
4. Visual interfaces used to communicate system states should be mounted to a suitable position and distance. High-priority information should be presented close to the driver's expected line of sight	- Important information displayed in 30° cone about normal line of sight - Safety-critical information displayed in 20° cone about normal line of sight - Peripheral displays support noticing of mode changes (e.g., movement or size of displays) - Status information mirrored on NDRT device	/
5. HMI elements should be grouped together according to their function to support the perception of mode indicators	- Indicators pertaining to the automation are grouped together - High priority messages are easily distinguished from low-priority messages	- Unnecessary glances to retrieve information from display (e.g., to interpret a symbol and perceive accompanying text)
6. Time-critical interactions with the	/	- Important information is displayed too shortly

system should not afford continuous attention		(e.g., only for a few seconds) - While the driver is responsible for the DDT, sustained attention (longer than 1.5s) is needed to accomplish an interaction
7. The visual interface should have a sufficient contrast in luminance and/or colour between foreground and background	- Sufficient colour and/or luminance contrast to identify different automation modes	/
8. Texts (e.g., font types and size of characters) and symbols should be easily readable from the permitted seating position	- Displayed text and symbols are big enough to be easily readable - Display resolution is good enough to be easily readable - Character width and stroke width appear to be appropriate - Text-fonts are easily readable	/
9. Commonly accepted or standardized symbols should be used to communicate the automation mode. Used of non-standard symbols should be supplemented by additional text explanations or vocal phrase/s	- Commonly accepted or standardized symbols are used - Non-standard symbols are supplemented with a text label - The symbols are representative for the responsibility of the driver (e.g., displaying hands on a steering wheel in case of a hands-on-request)	/
10. The semantic of a message should be in accordance with its urgency	- Use of notification-style to present non-critical information - Use of command-style to present critical information - Wording in accordance with criticality of situation (e.g., “caution”, “danger”, “warning”)	/
11. Messages should be conveyed using the language of the users (e.g., National language, avoidance of technical language, use of common syntax)	- Use of national language - Use of simple language - Avoidance of abbreviations - Displaying functionality rather than SAE/NHTSA/BASt-level	/
12. Text messages should be as short as possible	- Messages are as short as possible - Not more than four chunks of information are displayed	/
13. Not more than five colours should be consistently used to code system states	- Colours are used consistently throughout an automated driving mode - Note more than five colours are used	/

(excluding black and white)		
14. The colours used to communicate system states should be in accordance with common conventions and stereotypes	- Colours are in accordance with common stereotypes of the user population - Red = imminent danger, yellow/amber = caution, green = hazard-free operation state	/
15. Design for colour-blindness by redundant coding and avoidance of red/green and blue/yellow combinations	- Green/red and yellow/blue combinations are avoided - System states are redundantly coded in a suitable way	/
16. Auditory input should raise the attention of the driver without startling her/him or causing pain	*Generic auditory output:* - Suitable length (100-500 ms) - Suitable loudness (50-90 dB, should be 15 dB above background noise) - Frequencies between 500 and 4000 Hz *Vibrotactile output:* - Suitable length (50-200 ms) - Comfortable stimuli 15-20 dB above threshold - Frequencies between 150 and 300 Hz	/
17. Auditory and vibrotactile output should be adapted to the urgency of the message	*Generic auditory output* - Auditory output of varying urgency is distinguishably different by pulse rate, frequency of loudness - Low priority information is either unobtrusive or without auditory output *Vibrotactile output* - Vibrotactile output of varying urgency is distinguishably different by pulse rates, intensities, vibrating area, etc. Different information is coded through a variation of location and timing, not frequency and amplitude	/
18. High-priority messages should be multimodal	- High-priority information is presented in more than one modality - Auditory of vibrotactile stimuli are also visually presented	/
19. Warning messages should orient the user towards the source of danger	- Warning messages lead to an orienting response to the source of danger, causing the driver took in the direction of the hazard - Warning messages to not focus the driver's attention to a display	/
20. In case of sensor failures, their consequences and required operator	- Unavailability of sub-systems because of sensor degradation is displayed - Consequences of sensor degradation are displayed	/

steps should be displayed	- Required operator behaviours is displayed	