ITERATE

IT for Error Remediation And Trapping Emergencies

Specification of test procedures for the simulator experiments

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Editor	**Yvonne Barnard** **Y. Barnard@its.leeds.ac.uk**
Authors	**Yvonne Barnard, Frank Lai, Oliver Carsten, Natasha Merat, (UNIVLEEDS), Magnus Hjälmdahl, Tania Dukic, Henriette Wallén Warner (VTI), Simon Enjalbert, Marianne Pichon, Frédéric Vanderhaegen (UNIVAL)**
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The ITERATE project

This report is produced within the European project ITERATE (IT for Error Remediation And Trapping Emergencies), Grant agreement number 218496. The project started the 1st of January 2009 and will end 31st of December 2011.

The objective of ITERATE is to develop and validate a unified model of driver behaviour (UMD) and driver interaction with innovative technologies in emergency situations. This model will be applicable to and validated for all the surface transport modes. Drivers' age, gender, education and experience and culture (whether regional or company/organisational) are factors that will be considered together with influences from the environment and the vehicle.

Such a unified model of driver behaviour will be of great use when designing innovative technologies since it will allow for assessment and tuning of the systems in a safe and controllable environment without actually putting them to use in real traffic. At the concept stage, the model could guide designers in identifying potential problem areas whilst at the prototype stage, the model could inform on the scenarios to be used in system evaluation. In this way the systems will be better adapted to the drivers before being available on the market and will provide better support to the driver in emergency situations. Along the same lines, the model could be of use for authorities as a guide in assessing and approving innovative technologies without performing extensive simulator experiments or large scale field trials.

ITERATE is based on the assumption that the underlying factors influencing human behaviour such as age, gender, culture etc. are constant between transport modes. This assumption allows for a unified model of driver behaviour, applicable to all surface transport modes, to be developed. This will be done within ITERATE and the model can be used to improve design and safety assessment of innovative technologies and make it possible to adapt these technologies to the abilities, needs, driving style and capacity of the individual driver. The model will also provide a useful tool for authorities to assess ITS which is missing today.

The project consortium consists of seven partners:
Statens väg och Transportforskningsinstitut (VTI) Sweden; University of Leeds (UNIVLEEDS) UK; University of Valenciennes (UNIVAL) France; Kite Solutions s.n.c. (Kite) Italy; Ben Gurion University (BGU) Israel; Chalmers University (Chalmers) Sweden; MTO Psykologi (MTOP) Sweden

For more information regarding the project please see http://www.iterate-project.eu/

I hope you will enjoy this and all other deliverables produced within the ITERATE project. If you seek more information or have questions don't hesitate to contact me.

Magnus Hjälmdahl, VTI
Project coordinator
e-mail: Magnus.Hjalmdahl@vti.se
tel: +46 13 20 40 00

List of abbreviations

AISS	Arnett Inventory of Sensation Seeking
ATP	Automatic Train Protection
AWS	Automatic Warning System
CA	Collision Avoidance
DBQ	Driver Behaviour Questionnaire
EEG	ElectroEncephaloGram
EOG	ElectroOculoGram
FCW	Forward Collision Warning
ISA	Intelligent Speed Adaptation
ITERATE	IT for Error Remediation And Trapping Emergencies
PASAT	Paced Serial Addition Task
PVT	Psychomotor Vigilance Task
RSME	Rating Scale Mental Effort
RT	Reaction Time
SM	Speed Management
SS	Sensation Seeking
SSS	Sensation Seeking Scale
SWAT	Subjective Workload Assessment Technique
SOFI	Swedish Occupational Fatigue Inventory
UMD	Unified Model of Driver behaviour
TIFS	Task-Induced Fatigue Scale
T-LOC	Traffic Locus of Control Scale
TLX	Task Load Index
TPB	Theory of Planned Behaviour
UTAUT	Unified Theory of Acceptance and Use of Technology
VMS	Variable Message Sign

Table of contents

EXECUTIVE SUMMARY

In Deliverable 3.1 of Workpackage 3, we discuss the methodology developed and applied in the European ITERATE project (IT for Error Remediation And Trapping Emergencies). This methodology has as its objective to design experiments that will provide data to seed the ITERATE model. In the ITERATE project a high-level theoretical model of vehicle operator behaviour has been developed in Workpackage 1, specifying the factors that play a role in the influence of innovative support systems on vehicle operation in potentially dangerous situations. The model is applicable for different surface transport modes: road vehicles, rail transport and ships. The model will be calibrated by experiments investigating how the different factors interact. One hundred and sixty car drivers and 160 train drivers in five countries will drive with a static driving simulator, and 64 drivers (both train and car) with full motion simulators. Finally an executable simulation model will be constructed with the aim to predict the effects of support systems on operator behaviour and risk.

This deliverable addresses the process of designing experiments based on the ITERATE high-level model, resulting in specifications for the experiments. A major challenge we faced was how to determine what experiments would provide on the one hand scientifically sound information needed to feed the simulation of the ITERATE model in the next stage of the project and on the other hand are feasible from a practical point of view. A scientific approach is based on the testing of hypotheses. We have developed a structured approach to design hypotheses and scenarios that can be used to test the hypotheses.

The ITERATE methodology consists of seven steps, the first three of which were already completed in Workpackage 2:

1. Selection of support systems to be studied.
2. Formulation of hypotheses on the effects of the driver parameters from the model on the interaction with the systems.
3. Final system selection, resulting in the selection of support systems on speed management and collision avoidance.
4. Operationalisation of operator parameters and identification of ways to measure them.
5. Development of scenarios for the selected hypotheses. The template for scenario description contains the following elements: situation in which the system would be active, the characteristics of the participants (the drivers), the trigger (the event that would trigger an action from the system), the expected reaction from the operator, environmental conditions (such as traffic, weather and road/track) and measures to be taken before, during and after the experiment (e.g. questionnaires or workload measures). Seventy-one scenarios have been developed.
6. Development of experimental set-ups. The scenarios have been reviewed for common features. In particular, scenarios sharing the same types of road or track and situations have been identified. They formed the basis for developing an experimental set-up.
7. Specification of simulators and experiments. The experimental set-up forms the basis of a detailed specification of the experiments and the simulators to be used.

The approach we have developed in ITERATE to come from the theoretical model to experiments is a systematic one. This means that a step-by-step approach was taken, although there were also frequent iterations of some of the steps, and the results of each step were discussed until a consensus was reached. Developing hypotheses and scenarios is a creative process, which cannot be undertaken by a single individual in isolation; discussing, critiquing and iterating are essential parts of such a process. The structured and interactive approach was valued by the consortium partners as

fruitful, and stimulated the collaboration and exchange of ideas. This was especially of importance because the partners come from different disciplines and study different transport modes.

1. INTRODUCTION AND METHODOLOGY

In this Chapter we describe the methodology developed and applied in the European ITERATE project (IT for Error Remediation And Trapping Emergencies). This methodology has as its objective to design experiments that will provide data to validate the ITERATE theoretical model of driver behaviour. The objective of ITERATE is to develop and validate a unified model of driver behaviour (UMD) and driver interaction with innovative technologies in emergency situations. This model will be applicable to and validated for different surface transport modes: road vehicles, rail transport and ships.

In all transport modes, new technologies supporting operators in their driving task are being developed and deployed. These systems have the potential to enhance safety. Examples are systems that control and limit the speed of a vehicle or that warn for obstacles, helping to avoid collisions. These driver assistance systems may, however, also cause new problems such as overreliance and increased risk taking. Although different transport modes have different requirements on the kind of support that is needed and on the way in which it is provided, factors playing a role in how humans deal with support systems may show commonalities. For example sleepiness is a dangerous condition that poses problems for both car and train drivers, driver monitoring systems may provide support in both modes, warning drivers that they on the brink of falling asleep. However, some drivers may over-rely on such a system, continuing driving while sleepy and relying on the system to warn them in time before they run into problems. Different human characteristics, such as personality and experience, may cause drivers to behave differently.

To study the behaviour of operators of different transport modes, the ITERATE project has adopted the following three-stage approach:

1. Development of a high level theoretical model of driver behaviour, specifying the factors that play a role in potentially dangerous or risky behaviour of drivers in different environmental conditions. This model is described in Deliverables 1.1 and 1.2 (ITERATE, 2009a and 2009b);
2. Validation of the model by experiments and study of how the different factors interact;
3. Construction of an executable simulation model with which it is possible to predict the effects of support systems on driver behaviour. Such a model could guide designers and evaluators of new systems.

In this deliverable we will address the transition between the first and the second stage, how to arrive at experiments based on the ITERATE high-level model. A summary of the ITERATE model is given in Figure 1.1.

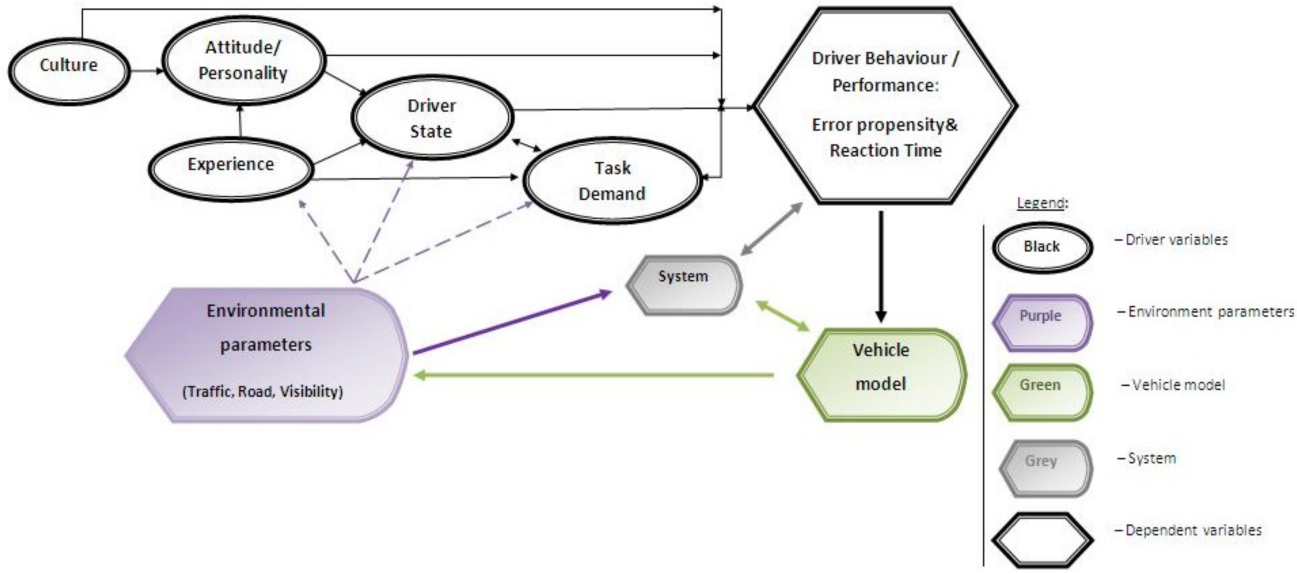

Figure 1.1: The ITERATE Unified Model of Driver behaviour

Looking at the operator-related parameters, we distinguish five factors that influence directly or indirectly operator behaviour and the probability to encounter a dangerous situation, in other words to augment or diminish the propensity to make errors and/or the operator's reaction time. To study these relations, experiments have been designed in which 160 car drivers and 160 train drivers in five countries drive with a static driving simulator, and 64 drivers (both train and car) with a full motion simulator.

A major challenge we faced was how to determine what experiments would provide scientifically sound information needed to feed the simulation of the ITERATE model in the next stage and that at the same time are feasible from a practical point of view. A scientific approach is based on the testing of hypotheses, but designing and especially selecting hypotheses is a difficult task. The number of possible hypotheses may easily become very large. We therefore developed a structured approach, partly based on the FESTA methodology for designing field operational tests, which evaluate the effects of in-vehicle systems (FESTA, 2008; Carsten & Barnard, in press).

Our methodology consists of seven steps:

1. *Selection of systems to be studied*. A review of existing technologies supporting car drivers, vessel pilots and drivers of trains, trams and subways was carried out, using a standardised description. The template described the level of the operation task the system support (strategic, manoeuvre, control), the level of automation (information, advice, assistance, intervention, automation), the time frame to an event that would occur between detection by the system and an action by either operator or system, and the time for the operator to make a decision when alerted by the system. In total 21 systems were reviewed. The standardised description made it easy to identify commonalities and differences between the technologically very different systems. A selection was made of systems that would be further studied, based on the commonalities: (1) systems that support speed management, (2) systems that support object detection and (3) collision avoidance and systems that monitor operator state.

   The system selection was performed in WP2 and is described in Deliverable D2.1 (ITERATE, 2009c).

2. *Formulation of hypotheses*. Hypotheses were formulated on the effects of the operator parameters from the model on the interaction with the systems. The parameters considered were: sensation seeking personality, fatigue, driving experience, and workload. Hypotheses were formulated using a standardised description:
   - *Input*: one of the four model parameters selected (for example, experience);
   - *Pathway*: describing the mechanism by which the input influences the outcome (for example, sensation seekers have a higher tolerance for risk and thus ignore warnings);
   - *Effect on operator's interaction with the system*: describing what the operator would do when interacting with the system (for example, a sensation seeker would respond later to a warning);
   - *Effect on the system functionality:* describing how the system would behave given the operator's behaviour (for example, if more warnings are ignored, the system would intervene);
   - *Risk potential*, describing whether it is hypothesised that the risk for safety would increase or decrease;
   - *Example scenario*: describing a typical situation in which the operator would behave in the hypothesised way and the system would react as expected.

   For each system and for each parameter, several hypotheses were formulated. A synthesis was made of these hypotheses. We carried out a qualitative examination of the commonalities between the hypotheses for the proposed systems, especially by comparing interactions between system and operator behaviour. We formulated 10 general hypotheses addressing a common effect (For example, fatigued operators will rely on the system to warn them about a critical situation).

   The formulation of hypotheses is described in Deliverable D2.2. (ITERATE, 2009d).

3. *Final system selection.* Based on commonalities between the systems and hypotheses identified in step 2, a final selection was made of six systems: Forward Collision Warning, (cars) Radar with Automatic Radar Plotting Aid (ships) and Automatic Warning System (trains) for the collision avoidance functionality and Intelligent Speed Adaptation (cars), Speed Pilot, Electronic Chart Display and Information System (ships) and full Automatic Train Protection and Train Control systems (rail) for the speed management functionality. For all systems we chose to continue with warning systems, not with systems that could take over from the operator.

   The system selection process and outcomes is described in Deliverable D2.2. (ITERATE, 2009d).

4. *Operationalisation of operator parameters* and identification of ways to measure them. For the five operator parameters (sensation seeking, fatigue, experience, workload and culture), an inventory was made on how to define and to measure these. The different measurement methods, such as questionnaires, tests, and psycho-physiological measures are summarised and advantages and disadvantages were discussed.

   This operationalisation is discussed in Chapter 2.

5. *Development of scenarios* for the selected hypotheses. For all car and train hypotheses, scenarios were developed that could be used in a first set of experiments (ships will be addressed in the second set). The template for scenario description contains the following elements:
   - Situation in which the system would be active (for example, change in speed limit);

- *The characteristics and state of the participants* (the operators) (for example, experienced drivers, or drivers with high workload induced by means of a secondary task);
- *The trigger*: the event that would trigger an action from the system (for example, a speed limit sign)
- *The expected reaction from the operator on the trigger and on the systems' warning* (for example, the driver does not pay attention to the sign and only reduces speed after the warning);
- *Environmental conditions*, such as traffic, weather and light conditions, and type of road or track (for example, low traffic density, night time, rural road)
- *Measures to be taken before, during and after the experiment*, to determine the effect of the scenario or to establish the level of one of the parameters. The measures may be driving related, measured automatically by the simulator, measured by the experimenter or the participant may give a subjective opinion. (For example, number of warnings received, amount of deceleration, reaction time, questionnaire on sensation seeking, subjective workload rating on a scale).

In total, for the speed management systems 24 scenarios were developed for cars and 12 for trains. For collision avoidance systems 21 scenarios were developed for cars and 14 for trains. For trains fewer scenarios were developed because the train driving task is much more restricted and regulated than the car driving task. This means that it is harder to come up with different situations in which the driver can act differently.

The scenarios are described in Chapter 3.

6. *Development of experimental set-ups*. The 71 scenarios were analysed and reviewed on common features. Scenarios sharing the same types of road or track and/or environment were identified. Furthermore scenarios that are familiar for all countries and that do not require too many resources for implementation were selected. They formed the basis for developing an experimental set-up in which several scenarios could play sequentially, addressing most of the 10 general hypotheses defined in step 2. In the experiments with static simulators, train drivers and car drivers will drive for some 90 minutes along a road or track, encountering different situations in which they have to change their speed (to test driving with a speed management system) and to act to avoid a collision (to test driving with a collision avoidance system). A selection was made from the scenarios addressing these situations and events. The group of participants will be split up in experienced and inexperienced operators. Half of the participants will be made fatigued before starting the experimental drive. All participants will drive under conditions of high and low workload. Culture will be studied by looking at differences in results from the experiments in the five different countries. Sensation seekers will be identified by means of a questionnaire. In this way we are able to investigate the influence of the different operator parameters as well as the interactions between them.

   The experimental set-ups are discussed in Chapter 4.

7. *Specification of simulators and experiments*. The experimental set-up forms the basis of a detailed specification of the experiments and the simulations.

   These specifications are described In Chapters 5 and 6.

The approach we have taken in ITERATE to come from the operator model to experiments is a systematic one. This means that a step-by-step approach was taken, although there were also frequent iterations of some of the steps, and the results of each step were discussed until a consensus was reached. Many of the steps were first initiated by a workshop in which all partners of the ITERATE participated, during which we regularly worked in small groups. Between workshops and consortium meetings, discussion took place by email, telephone and on-line conferences. Developing hypotheses and scenarios is a creative process, which cannot be undertaken by a single individual in isolation; discussing, critiquing and iterating are essential parts of such a process. The structured approach was valued by the consortium partners as a fruitful one and boosted the collaboration and exchange of ideas. This was especially of importance because the partners come from different disciplines and study different transport modes. Although some system descriptions, hypotheses and scenarios were developed that will not be used in the first set of experiments, we do not regard them as a loss of effort. They will be used for the next set of experiments aiming to validate the simulation of the model to be developed, and they will also be useful for further research in this area.

2. OPERATIONALISATION OF OPERATOR PARAMETERS

2.1 Introduction

In this chapter we discuss the different operator parameters and the way in which they can be operationalised. By operationalisation we mean the ways in which they can be measured or established so that they can be used in the experiments. For example operationalisation of operator experience may mean that experience can be measured in years after getting a license, or in the amount of kilometres driven annually, or as a score on a hazard perception test.

The model parameters identified in WP1 were:

- Attitude: sensation seeking
- Experience: hazard perception
- Operator state: fatigue
- Task demand: workload
- Culture

In this chapter it is specified how those parameters may be measured in different ways. The operationalisation forms the input for developing scenarios and experimental set-up. The experiments in WP4 will only address car and train drivers, so they will be our main focus in this chapter. No all measures and operationalisations described in this chapter will be used during the experiments. The final choices that are made as well as the justification for these choices are described in Chapter 4.

2.2 Attitudes/personality: Sensation seeking

2.2.1 Sensation seeking

The parameter selected in WP1 for attitude is sensation seeking. Attitudes are defined in D1.1 as: "Attitudes / Personality mean a complex mental state involving beliefs, feelings, values and dispositions to act in certain ways. These are static parameters that affect the input data of the driver model (i.e. their values do not change during the dynamic simulation of a case study) associated with each driver (Cacciabue & Carsten, 2009)." (ITERATE, 2009a)

Sensation Seeking is defined by Zuckerman (1994) as 'seeking of varied, novel, complex and intense sensations and experiences and the willingness to take physical, social, legal and financial risk for the sake of such experience'. In D1.1 (ITERATE, 2009a) several articles are discussed that show a correlation between Sensation Seeking and some aspects of risky driving.

No literature has been found on sensation seeking and train driving. Only in the road vehicle domain many studies have been conducted.

Sensation seeking has been found to be higher in males than females, and it declines with age. There seems to be a positive relationship with the level of education and occupational status (Zuckerman, 1994). When selecting participants, age and gender have to be taken into account.

The most common way to measure sensation seeking is by using a questionnaire. In the FESTA project (Deliverable 2.1), sensation seeking tests are described. The Sensation Seeking Scale (SSS) Form V (Zuckerman, 1994) is the most widely used measure of sensation seeking, consisting of four sub-scales:

- Thrill and adventure seeking;

- Experience seeking;
- Boredom susceptibility;
- Disinhibition.

These subscales have been found to relate differently to various risky behaviours (Zuckerman, 1994) but Thrill and Adventure Seeking appears to have the strongest relationship to risky driving. The scale contains 40 items. Respondents have to choose between alternatives, stating which one describes them best. Examples of items are:

I like "wild" uninhibited parties
I prefer quiet parties with good conversation

Another scale is Arnett Inventory of Sensation Seeking (AISS; Arnett 1994), consisting of two subscales:

- Novelty;
- Intensity.

This scale is shorter and contains 20 items, asking respondents to rate how likely each describes them. An example item is:

"I would like to travel to places that are strange and far away."
(1 = describes me very well, 2 = describes me somewhat, 3 = does not describe me very well, 4 = does not describe me at all)"

Sensation seeking scales have been translated in many different languages, but the resulting tests are not always standardised and formalised. Translation brings its own problems, sometimes wording or even complete items have to be changed in order to be made more understandable for some cultures and language groups. Studies performed with subjects with different nationalities and cultural backgrounds have found differences, sometimes in interaction with variables like gender and age. We may assume that there are cultural differences in how people perceive, for example, risk and sensation, and thus value items in a test.

The sensation seeking test is sometimes used in driver education, so that drivers can test themselves. Some participants may be familiar with the test. Sensation seeking tests are available on-line, for example:

http://www.bbc.co.uk/science/humanbody/mind/surveys/sensation/
http://www.rta.nsw.gov.au/licensing/tests/driverqualificationtest/sensationseekingscale/

Psychology Today provides a driver personality test:

http://psychologytoday.tests.psychtests.com/take_test.php?idRegTest=1309

2.2.2 Related personality tests:

Another option could be to use the Locus of Control trait (Rotter, 1966). Individuals with an internal locus of control (internals) tend to perceive events as a consequence of their own behaviour. Individuals with an external locus of control (externals) tend to believe events are under the control of external factors or powers that cannot be influenced.

The relationship between risky driving is not as conclusive as with sensation seeking. Both groups may engage in risky driving behaviour, but for different reasons. Externals may be less likely to take precautionary steps and engage in responsible driving because they think their own behaviour does not improve safety very much. Internals, on the other hand, may overestimate their skills and since they believe that accidents are a consequence of their own behaviour, they may engage in risky behaviour, confident that they possess the skills to avoid an accident (see also FESTA D2.1).

For train drivers it is unknown what the relationship is with risky behaviour and whether the group of train drivers is also homogenous with regard to this trait.

FESTA D2.1 describes several tests for measuring Locus of Control. Montag and Comrey (1987) have developed a test for locus of control consisting of two scales, a Driving Internality scale and a Driving Externality scale, designed to measure these constructs with specific reference to driving. Özkan and Lajunen (2005) have developed a driving targeted *multidimensional* locus of control scale. There are four scales within their Traffic Locus of Control Scale (T-LOC):

- "Other Drivers" (causes of accidents attributed to other drivers);
- "Self" (causes of accidents attributed to oneself);
- "Vehicle and Environment" (causes of accidents attributed to external factors);
- "Fate" (causes of accidents attributed to fate or bad luck).

In the T-LOC, participants are given a list of 16 possible causes of accidents. They are asked to indicate on a five-point scale how possible it is that those 16 reasons had caused or would cause an accident when they think about their own driving style and conditions. An example item is:

"Whether or not I get into car accident depends mostly on shortcomings"

2.2.3 Attitudes and intended behaviour

We could also look at attitudes and intended behaviour. The theory of planned behaviour (TPB) (Ajzen, 1988) distinguishes three categories of beliefs which explain an intended behaviour:

- Behavioural: beliefs about the likely outcomes of behaviour;
- Normative: beliefs about the normative expectations of others and motivation to comply with these expectations;
- Control: beliefs about the presence of factors that may facilitate or impede performance of the behaviour and the perceived power of these factors.

For measuring beliefs and intentions it is possible to create a dedicated questionnaire, based on the TPB. The University of Leeds has experience in doing this. Guidelines from Ajzen (2006) may be found at http://people.umass.edu/aizen/pdf/tpb.measurement.pdf.

Such a questionnaire could also be used to develop questionnaires about intentions on how to use the systems under investigation. A theory derived from the TPB is the Unified Theory of Acceptance and Use of Technology (UTAUT), which also allows constructing questionnaires about the acceptance of the systems under investigation.

2.2.4 Attitudes and self-perceived behaviour

The most commonly used way of measuring self-perceived behaviour is the Driver Behaviour Questionnaire (DBQ) in which respondents are asked to judge the frequency with which they committed various types of lapses, errors and violations when driving (Reason et al., 1990). The respondents have to indicate on a 6 point scale the frequency with which they committed each type of aberrant behaviour. The original test has 50 items, but a 24 item test is also used often (Parker et al., 1995). An example item is:

"Misjudge speed of oncoming vehicle" (0 = Never to 5 = nearly all the time)

2.2.5 Measuring train drivers' attitudes

As there is a lack of studies and scientific tools to measure train drivers' attitudes and personality traits, we may adopt three approaches:

- Use general personality or attitude tests. For example sensation seeking is a general trait, not specific for drivers. However, for sensation seeking we assume that this trait is underrepresented in the train drivers population, as sensation seekers are either not likely to pursue a career as a train driver, or because in the selection process they fall out. If the population is too homogenous we will not find a relation between the personality trait or attitude and risky behaviour.
- Use tests specific for road vehicle drivers. We may ask how train drivers behave or see themselves in their role as car driver, and investigate whether this correlates with differences in the experimental outcomes. For example we can use the DBQ to measure their self-perceived car driver behaviour.
- Develop an adapted DBQ specific for train drivers, based on findings from other train-related studies.

2.3 Operator State: Fatigue

2.3.1 Operator fatigue

Operator fatigue issues can be divided into two categories in terms of experimental design: pre-sessional and task-induced.

2.3.2 Pre-session fatigue

Pre-session fatigue is likely to be caused by a variety of factors, e.g. sleep deprivation, extended duration of wakefulness and time of day (circadian rhythm effect), or disruption to normal sleep patterns etc, which would cause participants feeling tiredness prior to commence of experiment, and hence would affect task performance.

In the field of medical research, fatigue due to sleepiness could be assessed subjectively via a sleep diary or objectively by means of activity monitor. These assessments generally are lengthy and require several days for data collection for the state of the individual be evaluated – perhaps not quite fit for purpose in terms of the ITERATE experiments.

Subjective rating scales on the other hands would be easier to administer for experimental purposes; for example, Fatigue Proneness Scale (Matthews, Desmond, Joyner, Carcary, Gililand, 1997), which demonstrates a strong relationship between subjective fatigue and objective performance.

A reaction time test would provide objective assessment of operator state; for example, the psychomotor vigilance task (PVT; Dinges and Powell, 1985). The PVT requires responses to a visual stimulus by pressing a response button as soon as the stimulus appears. It is well evidenced that extended wakefulness and cumulative sleep restriction results in an increase in reaction time, a decrease in response speed, and an increase in lapses (e.g. responses > 500 ms).

DLR developed an assessment toolkit assess professional drivers fitness to drive prior to commence of the shift. The test has three components:

- Checklist
- Subjective fatigue and sleepiness scales
- Performance tests (i.e. reaction time)

The subjective rating scales included are the Samn-Perelli fatigue scale (Samn and Perelli, 1982) and the Karolinska sleepiness scale (Åkerstedt, 1990). Such a toolkit offers assessment of operator state both subjectively and objectively.

2.3.3 Task induced fatigue

Task induced fatigue is caused by task demand or duration; i.e. the operator has to invest excessive attentional resources to meet the task requirement. Task induced fatigue can be broadly related to workload – it could be caused by either the operator being overloaded or underloaded. Task induced fatigue can also be assessed by subjective as well as objective methods.

Subjective rating scales again are cost effective and easy to administer; e.g.:

- Task-Induced Fatigue Scale (TIFS) (Matthews and Desmond, 1998)
- Swedish Occupational *Fatigue* Inventory (*SOFI*) (Ahsberg, Gamberale, Gustafsson, 2000)

The SOFI seems to have widely adopted by the research community. It has been translated into other languages (e.g. González Gutiérrez, Jiménez, Hemández, López, 2005; Leung, Chan, Ng, Wong, 2006) as well as other transport modes (e.g. high-speed boat; Leung et al, 2006).

It would also be possible to ask the participants to verbally report perceived fatigue (e.g. 1-10) during the course of task performance.

Objectively task induced fatigue can be observed by an experimenter or detected by equipment. For example:

- Eye blinking behaviour (PERCLOS)
- Eye and head movement detection (e.g. Seeing Machine's faceLAB)

2.3.4 Physiological measures

A large number of physiological measures of vigilance and fatigue have been proposed (Freund, Wylie and Woodall, 1995). They include:

- heart-related parameters such as heart rate and heart rate variability
- EEG measures
- EOG measures

2.3.4.1 Heart parameters

Two kinds of parameters are in use for measuring heart-related parameters. **Raw heart rate**, for example, has been observed to decrease during prolonged night-time driving (Lal and Craig, 2001b) and to decrease in accordance other measures of fatigue. However, it has not always been found to be reliable (e.g. Hefner, Edwards, Heinze, Sommer, Golz, Sirois, Trutschel, 2009). **Heart rate variability** has more general support as an indicator of fatigue (e.g. Egelund, 1982; Hefner et al. 2009).

2.3.4.2 EEG

Early work showed that there was correspondence between lateral deviation and the **alpha band** of EEG (ElectroEncephaloGram), in that both lateral deviation and alpha grew substantially in amplitude with time on task, indicating the promise of detecting loss of vigilance from purely vehicle-based parameters (Brookhuis, Schrievers, Tarriere, Petit, Chaput, 1991). This relationship is illustrated in Figure 2.1.

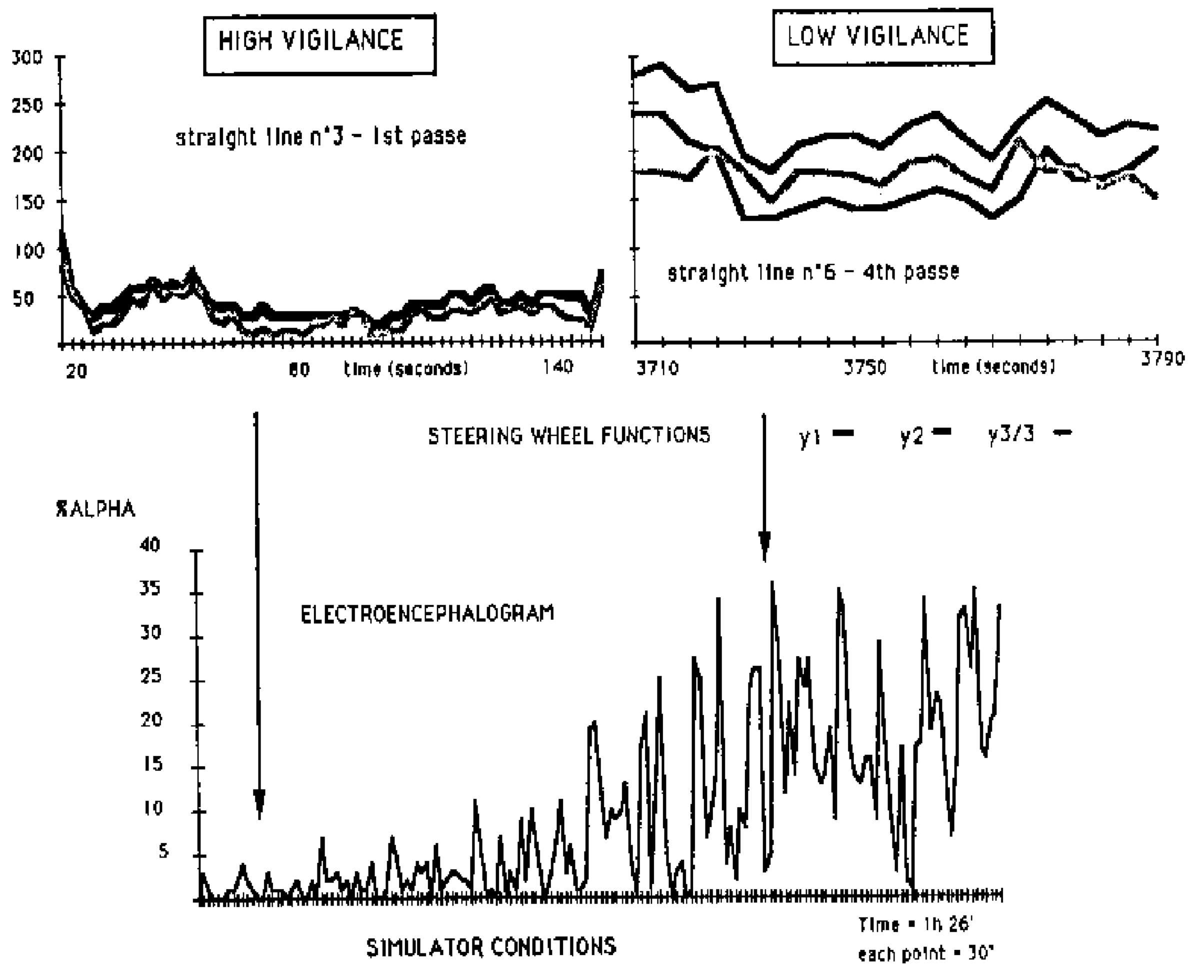

Figure 2.1: Steering wheel functions compared with the occurrence of alpha waves in the EEG (from Brookhuis et al., 1991)

More recently other EEG measures have been proposed as being more robust than alpha, in particular the **theta** and **delta** components of EEG, i.e. the so-called "slow-wave" EEG activities (Lal and Craig, 2001; Lal and Craig, 2002). However, Lal and Craig (2001a) state: "Even though the literature highlights the potential of using EEG in a fatigue detector, there are no tangible field trials on the efficacy of an EEG-based fatigue countermeasure."

2.3.4.3 EOG

With increasing fatigue, there is a general increase in blink frequency and the interval between blinks decreases. There is also a tendency for blink duration to increase as shown in Figure 2.2 (Galley and Schleicher, 2004), and this increase is held to be particularly related to the onset of fatigue.

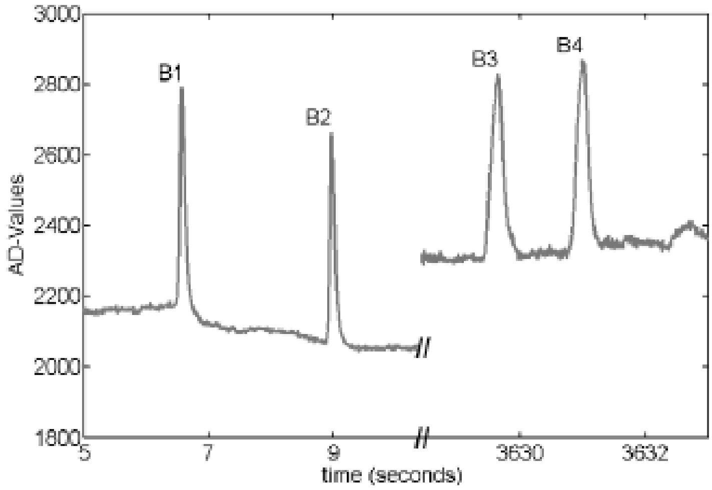

Figure 2.2: Vertical EOG (ElectroOculoGram) at the beginning and after an hour driving in a simulator course. Blinks are identifiable as peaks B1-B4 (source: Galley and Schleicher, 2004)

Lal and Craig (2001b) report that fast eye movement and conventional blinks in the alert state were replaced by no eye movement and small, fast rhythmic blinks during the transition to fatigue in a driving experiment. They also report a general finding that the disappearance of blinks and mini-blinks and relative quiescence in eye movement are the earliest reliable sign of drowsiness.

2.3.5 Operationalisation of fatigue for ITERATE experiments

For the simulator experiments, we want to observe both non-fatigued and fatigued operators. We have earlier distinguished between fatigue and sleepiness, and we do not want to be observing sleepy operators, since sleepiness (let alone actual sleep) might interfere with other aspects of our experiments.

Desmond and Matthews (1997) distinguish between two types of fatigue:

1. Sleepiness, which might result from say a long and monotonous journey
2. Task-induced fatigue, which might result from driving in heavy traffic

To induce task-type fatigue, Desmond and Matthews (1997) adopted the following procedure:

> [Subjects were required] to react to information presented on road-signs whilst driving at constant speed. Each sign presented a sequence of seven characters as the driver approached it, e.g. CU4KPIA. Subjects were instructed to ignore the letters and attend to the numbers. For each sequence, subjects were required to look for odd or even numbers and were instructed to press a button set into the steering wheel when they detected the "target" number. Each character was presented for 160 milliseconds. A coloured star was presented before each sequence which served to prime subjects to look for either odd (denoted by a red star) or even (denoted by a green star) numbers. The fatigue induction procedure is fatiguing for two reasons; first, it involves rapidly presented sequences of stimuli and, second, the driver is required to continuously change his or her "rule" for deciding which stimuli constitute targets, and so the measure demands attentional flexibility. A total of 528 signs were presented to subjects. Signs were presented at a distance of 40 m apart.

The fatigue and control conditions were *within subject,* which dealt with the problem of simulator experience. The fatigued condition was longer by approximately 15 km and involved following a lead vehicle which was driven at a constant 50 km/h, so that this element took 18 minutes,
This does suggest that we could induce fatigue via some task that does not involve vehicle operation, e.g. the vehicle (car/ train) could be driven automatically at a constant speed, while the participants are subjected to a strenuous observation task.

2.3.6 How to ensure fatigue

A large number of studies have used monotonous driving situations to induce fatigue. The fatigue condition has often been partially induced by:

1. Sleep deprivation, e.g. prior night's sleep no greater than four hours, or
2. Carrying out data collection during the post-lunch dip, or
3. Both

Thus Horne and Reyner (2001), in their investigation of the effects of energy drinks on sleepy drivers, used for the "sleepy" conditions a combination of sleep restriction in the prior night to 5 hours (the sleep was monitored by means of wrist-actimeters) plus afternoon driving (starting at 14.00 – 14.15) plus 30 minutes of monotonous motorway driving, which was followed by a 30 minute break of just sitting at the wheel and then a subsequent drive of 90 minutes. Dependent variables were crossing the lane lines when combined with eye movements associated with sleepiness and reaction time to an auditory bleep with the reaction being a button press. Lane excursions significantly increased in the 2nd 30 minutes of driving during the subsequent drive. Reaction time showed no significant time-on-task effects.

Thiffault and Bergeron (2003) studied the impact of monotonous driving on performance. The study was within-subjects with one condition being totally monotonous driving and the other monotonous driving with some visual stimulation in the scenery. All the participants drove during the post-lunch dip. They arrived at the lab at 13.00, had a 5-minute practice drive at 13.20 and then completed an initial 40-minute drive starting at 13.30. There was then a 15-minute break during which they were encouraged to take a walk, and they then drove for another 40 minutes in the other condition (the conditions were counter-balanced) starting at 14.25. Results showed that the mean amplitude of steering wheel movement increased steadily over time with observable increases being detected 15 to 20 minutes into each drive.

Merat and Jamson (2009) looked at the impact of various in-road treatments to moderate fatigue. Sixteen older drivers (aged over 45) and 17 shift workers under 35 were recruited. The shift workers drove in the morning, attending their sessions straight from work. The older drivers drove after lunch. All drivers did a baseline drive of approximately 26 minutes in a non-fatigued condition (i.e. after a normal night's sleep for the shift workers or in the morning for the older drivers) on a first day. They then performed three drives of approximately 26 minutes in the treatment conditions on a second day. They had a 10 minute break between each drive in which they asked to walk outside. One of the dependent variables was the Psychomotor Vigilance Task (PVT) which is a test of reaction time to a visual stimulus presented at a random interval between 2,000 and 10,000 ms. Fatigue is measured in terms of reaction time, response speed (1/RT) and missed responses (any response over 500 ms). The PVT was here administered before and after each drive over a 5-minute period using a laptop. Stimuli consisted of a 2 or 3-digit number in white on the centre of the screen and response was by press of the space bar. Results showed that PVT missed and reaction times were all greater following a treatment driver than before a drive, indicating increased fatigue after 26 minutes of driving. Fatigue was also observed to steadily increase over time, with average values significantly higher for Day 2 than for Day 1. Thus the breaks did not lead to full recovery, which could particularly be observed with the misses.

2.3.7 Alternatives for creating fatigue in the experiments

There are two possible alternatives for creating a fatigued group in the ITERATE experiments:

1. Administer a monotonous pre-drive to a group of participants who drive post-lunch. A 25-30 minute pre-drive should be sufficient. Arguably there would be a simulator practice contamination.
2. Follow the procedure of Desmond and Matthews (1997) and administer a tiring high-workload task. This could either not involve control of the simulator vehicle (in which case we would not have to worry about simulator experience) or could involve control in which case we might have to have two kinds of practice — one easy and one tiring but both the same in terms of vehicle control.

2.4 Experience: Hazard perception

2.4.1 Experience

Experience may be defined as the accumulation of knowledge or skills that result from direct participation in the driving activity. Experience can be operationalised in different manners of which age, exposure (mileage driven per week, year or lifetime), number of years driving and number of errors are the most frequently found in the literature studied.

For any given situation, drivers have to be able to quickly select the cues that are indicative of a hazard, integrate them into holistic patterns, comprehend their implications, project how the situation may evolve into a potential accident, and select the necessary action from his or her repertoire of driving behaviours. The more experienced drivers are, the greater their repertoire of situations and schemata in their long term memory. Thus, with experience the drivers learn to effectively select the cues to attend to, quickly perceive their meanings, and on the basis of these cues quickly identify the situation and project its implications into the immediate future. According to Maycock, Lockwood, and Lester (1991) the importance of experience is shown in accident statistics with a dramatic decrease in risk of traffic accident involvement during the first months after receiving the driving licence. Even though young novice drivers have a higher risk than older novice drivers of being involved in traffic accidents the decrease in risk is independent of age.

One reason to why novice drivers have a greater risk of traffic accident involvement then more experienced drivers might be the differences in capacity. Lansdown (2002) showed that novice drivers spend more time looking away from the road when performing in-vehicle tasks than more experienced drivers. Sagberg and Bjornskau (2006), on the other hand, found no evidence for additional capacities leading to a strong correlation between driving experience and hazard perception. Finally, Waylen et al. (2004) showed that the tendency to overestimate one’s own skill seems to be equally strong among novice drivers and more experienced drivers.

2.4.2 Hazard perception

According to OECD (2006), hazard perception includes *the process of discovering, recognising and reacting to potentially dangerous situations*. In addition, there are many other definitions of the term but most of them are fairly similar even though the level of specificity might differ.

Most of the methods for measuring, or rather testing, hazard perception use either pictures or videos where the most elaborate ones are PC-based. Sagberg and Bjornskau (2006) developed a hazard perception test. This test can be administered within a short period of time (15 minutes).

Reaction time to detect hazard in 13 videos sequences is measured. So far we have only found these tests for car drivers, not for train drivers, so further search is needed.

2.4.2.1 Response latency tests

In general, response latency is measured by using PC-based hazard perception programs (of which VTI has access to the program used by Sagberg and Bjornskau (2006) where the drivers' eye position and latency of reactions to predefined critical situations are recorded.

Using this technique researchers have been able to show that young drivers have longer hazard perception latencies than middle-aged drivers (Quimby and Watts, 1981; McKenna and Crick, 1991); hazard perception latencies are inversely correlated with total driving distance (Ahopalo, Lehikoinen, Summala, 1987); crash-involved drivers have longer hazard perception latencies than crash-free drivers (Currie, 1969; Pelz and Krupat, 1974; Quimby, Maycock, Carter, Dixon, Wall, 1986); hazard perception latencies are negatively influenced by additional mental load as imposed by a dual task paradigm (McKenna & Crick, 1997) and hazard perception latencies can be improved by hazard perception training (Crick & McKenna, 1992; McKenna & Crick, 1997; Mills, Hall, McDonald, Rolls, 1998; Deery, 1999).

2.4.2.2 Eye movement tests

Another way of measuring or testing hazard perception is by using eye movements and fixations. This method has shown promising results (e.g. Chapman et al., 2002) but it requires eye cameras and a substantial amount of analysis which makes it impossible to use for portable simulators. For stationary simulators it can be an option but it needs to be discussed whether it is worth the extra effort.

2.4.2.3 Questionnaires

Finally, questionnaires are a cost effective way to measure or test hazard perception. The relationship between questionnaire measures and response latency has, however, been questioned by, for example, Farrand and McKenna (2001) as well as Bjornskau (2006). Maybe the most fruitful approached would be to adopt several different measures within a single framework.

2.5 Workload

2.5.1 Definition

The definition of Workload was given by Sperandio as the rate of activity supplied by the operator in order to perform the task. It concerns the physical mental and sensori-motor activity level of a human operator performing a task (Sperandio, 1972).

2.5.2 Background

The "human operator performing a task" is a model proposed by Millot and shown in Figure 2.3. This model shows three interconnected loops (Millot, 1988). The first one deals with regulating performances by adjusting operating modes if needed. The second one is an interval one and deals with Workload regulation within the work capacity available for the task, which is the maximum capacity a given operator is willing to invest in the task. This work capacity is the remaining capacity after deducting this one due to disturbances. The principle results from the hypothesis of a limited capacity channel. By this loop, Millot shown that the assessment of Workload (output) cannot be conducted without *a definition of the task demands* (input) a priori. The third loop is related to the internal state which provides the maximal work capacity. Indeed the operator can decide to invest more or less work capacity in the task.

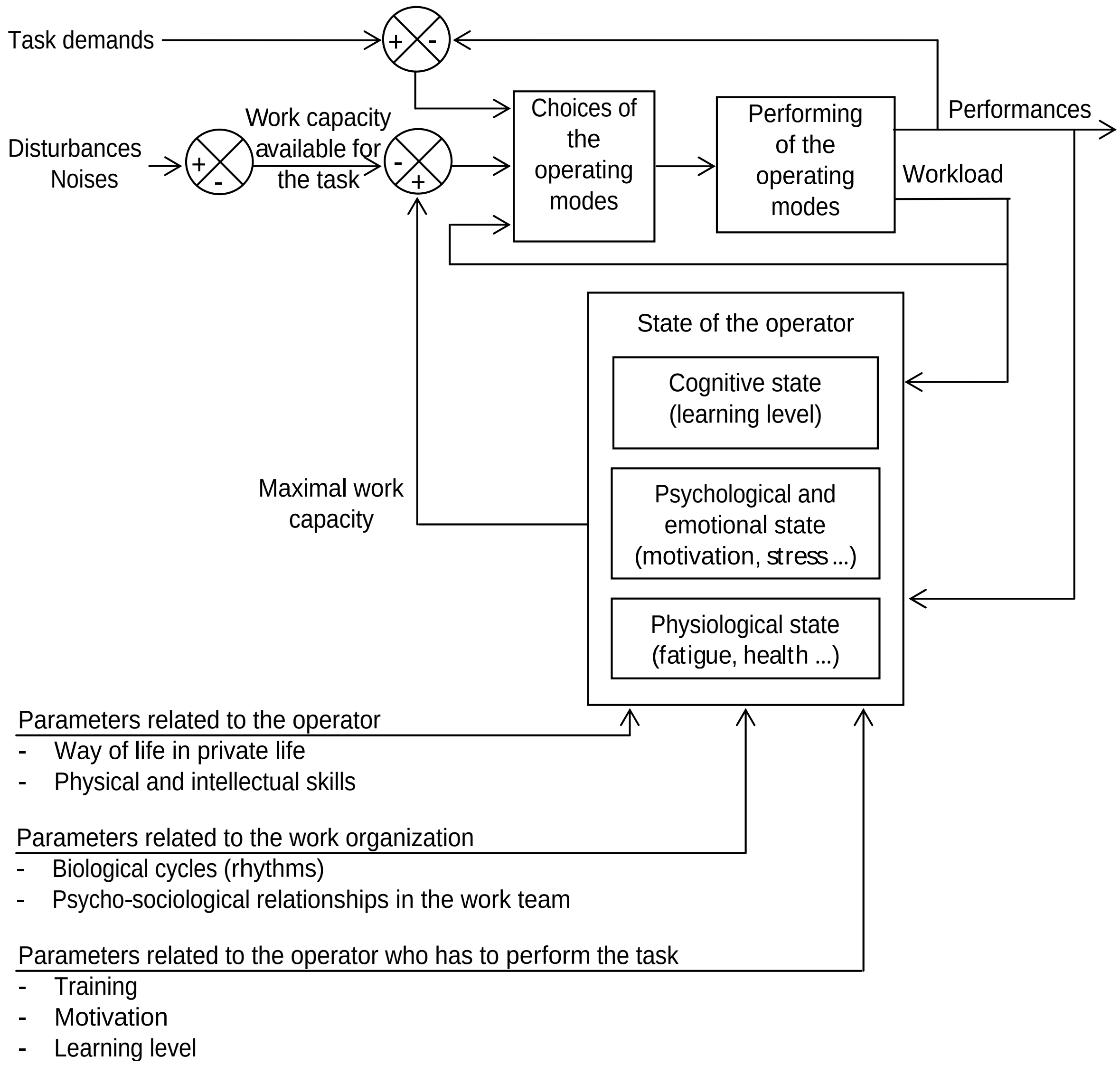

Figure 2.3. Model of the activity regulation of the "Human operator performing a task" system (adapted from Millot, 1988)

Workload assessment methods can be classified into three categories: self-report, performance and physiological measures. The methods that are the most relevant for the ITERATE experiments are self-reported measures.

2.5.3 The Subjective Workload Assessment Technique (SWAT)

The subjective workload assessment technique is a subjective rating technique developed by the US Air Force Armstrong Aerospace Medical Research Laboratory (Reid, Potter, Bressler, 1987). SWAT assumes that Workload is made of 3 dimensions; time load (temporal pressure), mental load (functional demands) and psychological stress load. Each dimension is quantified with 3 levels; Low (L), Medium (M) and High (H). The analyst builds 27 different cards each containing a point defined by the triple (levels of time load, levels of mental load, level of psychological stress load)and asks the operator to classify these cards from the lowest to the highest Workload value (see 2.1). This classification depends on the appreciation of the operator who evaluates her/his own Workload in general situation and remains constant according to experimental observations (Valot, Grau, Romans, Ferret, Gervais, & Imassa-Cerma, 1997).

Table 2.1: The 3 dimensions and 3 quantification levels of SWAT

	Low	Medium	High
Time load	• Often have spare time. • Interruptions or overlap among activities occur infrequently or not at all.	• Occasional have spare time. • Interruptions or overlap among activities occur frequently.	• Almost never have spare time. • Interruptions or overlap among activities are very frequent, or occur all the time
Mental Effort Load	• Very little conscious mental effort or concentration required. • Activity is almost automatic, requiring little or no attention	• Moderate conscious mental effort or concentration required. • Complexity of activity is moderately high due to uncertainty, unpredictability or unfamiliarity. • Considerable attention required	• Extensive mental effort and concentration are necessary. • Very complex activity requiring total attention
Psychological Stress Load	• Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.	• Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. • Significant compensation is required to maintain adequate performance.	• High to very intense stress due to confusion, frustration, or anxiety. • High to extreme determination and self-control required

Then the evaluation in specific situations can be done online by asking the operator to evaluate the level of time load, mental load and psychological stress load. The place of the corresponding card among the 27 cards allows estimation of operator's Workload (see Figure 2.4).

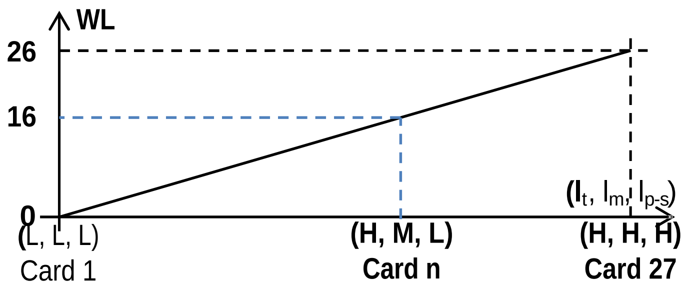

Figure 2.4: Workload assessment by SWAT (Reid & al., 1987)

The SWAT is among the best Workload assessment methods in terms of sensitivity, intrusiveness and usability (Casali & Wierwille, 1984).

2.5.4 The NASA Task Load indeX (NASA-TLX)

The NASA TLX (Hart & Staveland, 1988) is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of rating on six dimensions: mental demand (MD), physical demand (PD), temporal demand (TD), own performance (OP), effort (EF), and frustration (or stress, FR).

Each of the six dimensions is subjectively evaluated by the human operator her-/himself by making a mark to produce a rating on a continuous scale between 0 to 1; $R_i \in [0, 1]$. For quantifying Workload on a unique scale, we must aggregate each R_i by weighting each one in relation to the others through a weighting factor α_i, as shown in Equation 2.1.

$$WL=\sum_{i=1}^{6}\alpha_i.R_i \text{ , with } \sum_{i=1}^{6}\alpha_i=1$$

Equation 2.1: NASA-TLX Workload calculation

The operator is asked to evaluate each α_i. For that purpose the analyst builds a combination of two dimensions (pairs) and asks the operator to choose the most important one (see Figure 2.5). Therefore with the 6 dimensions 15 different pair-wise comparisons of the dimensions are obtained.

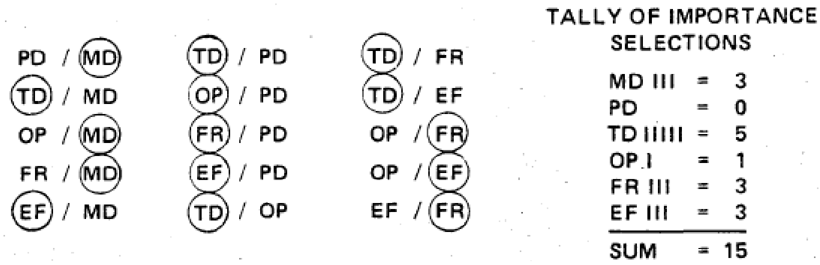

Figure 3.5: Pair-wise comparisons of dimensions

The analyst counts among the 15 answers the number N_i of times each dimension has been chosen by the operator. In order to obtain values normalised between 0 and 1, the N_i numbers are divided by 15. The result $N_i/15$ is the weighting factor α_i.

The R_i values are evaluated by a mark at distance f from the beginning of the scale, which is the maximal distance D longer. The quantity d/D corresponds to the value of R_i, as shown in Figure 2.6.

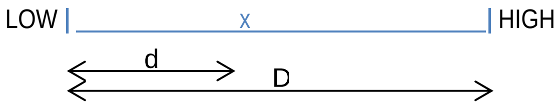

Figure 2.6: Rating scale R_i estimation

With the equation given above, workload can now be calculated (see Figure2.7).

DEMANDS	RATINGS FOR TASK 1:			RATING		WEIGHT		PRODUCT
MD	LOW	I __x__________I	HIGH	30	X	3	=	90
PD	LOW	I _x___________I	HIGH	15	X	0	=	0
TD	LOW	I ________x____I	HIGH	60	X	5	=	150
OP	EXCL	I ____x________I	POOR	40	X	1	=	40
FR	LOW	I ___x_________I	HIGH	30	X	3	=	90
EF	LOW	I _____x_______I	HIGH	40	X	3	=	120
				SUM			=	490

Figure 2.7: Workload assessment by NASA-TLX (Hart & Staveland, 1988)

The NASA-TLX is among the most commonly used Workload assessment methods because of its sensitivity, lack of intrusiveness and usability (Casali & Wierwille, 1984).

2.5.5 RSME, Rating Scale of Mental Effort

The RSME (Rating Scale of Mental Effort) method uses a one-dimensional scale. In using this method, the ratings of invested mental effort are indicated by the operator with a cross on a continuous line. The line runs from 0 to 150 mm, and every 10 mm is indicated. Along the line, at several anchor points, statements related to invested effort are given, e.g. "almost no effort"' or "extreme effort". The scale is scored by measurement of the distance from the origin to the mark in mm and is shown in Figure 2.8. It should be noted that scores above 100 are extremely rare.

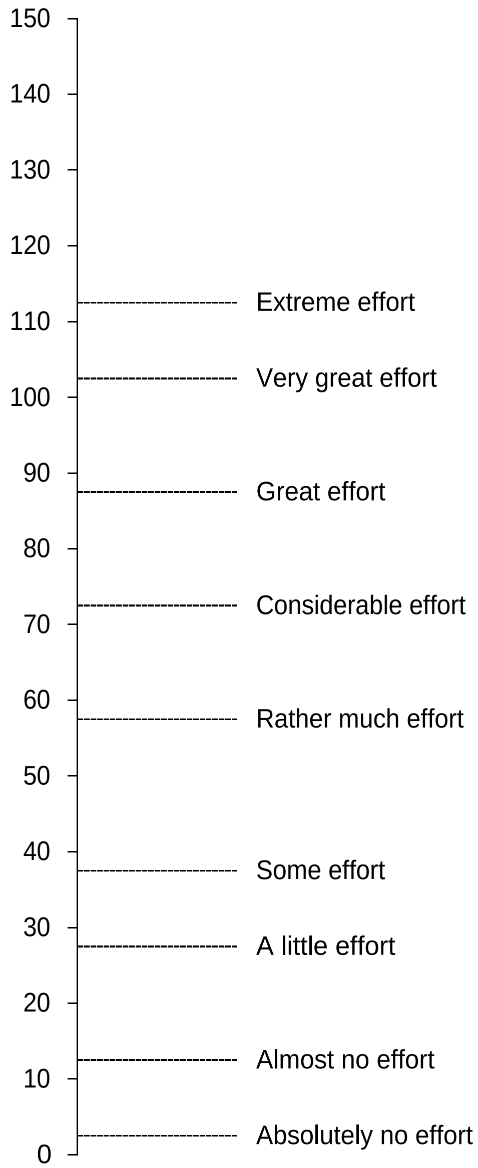

Figure 2.8: Questionnaire for Rating Scale of Mental Effort (RSME)

2.5.6 LAMIH's method (Millot, 1988), temporal measures

According to Sheridan, Workload, as it is defined by Sperandio, can be translated into temporal consideration, as shown in Equation 2.2 (Sheridan, 1979; Sperandio, 1972).

$$WL = \frac{TR}{TA}$$

Equation 2.2: Total Workload expression related to the temporal demands of the task (Sheridan & Stassen, 1979)

TA is the *time available* to perform the task and TR the *time required* by the human operator to perform the task. The quantity (1/TA) represents the temporal demand of the task and TR takes into account the difficulties that the operator has to face.

Millot added to the previous expression a parameter in order to take into account not only the temporal demand of the task but also the function of it, as proposed by the SWAT method (time load, mental effort load, and psychological stress load). This parameter is the *seriousness of the situation* S. The parameter S is included in Workload expression, as shown in Equation 2.3:

$$\frac{1}{TA_S(t)} = \frac{1}{TA(t)} \cdot S(t)$$

Equation 2.3: Subjective Time available as function of the Time Available and the Seriousness of the situation

Millot also included in his model of Workload a time parameter and a proposed expression of *instantaneous Workload* by analogy with power in physics. The task performed by an operator during duration equal to dt who supplies a "power" equal to $\frac{1}{TA_S(t)}$ has spent a workload dWL given by Equation 2.4.

$$dWL(t) = \frac{dt}{TA_S(t)}$$

Equation 2.4: Instantaneous workload expression (Millot, 1988)

The analogy with physics leads him to use the "energy" of workload (total workload) as the integral of the quantity dWL(t). This "energy" is the Workload supplied during the whole task performance and can serve as a value of fatigue, i.e. the resources which have been consumed.

Workload is assessed by a counter which is triggered when the human operator interfaces which the machine. The hypothesis is "the more the human acts on the machine, the more she/he is loaded". For example in the case of an emergency situation, the operator can push the button which makes the machine stop several times even if a unique activation would have been effective.

2.6 Culture

According to Leviäkangas (1998) traffic culture is defined as the sum of all factors that affect skills, attitudes and behaviour of drivers as well as equipment. Furthermore, it is suggested that traffic culture results from the large cultural element in heritage combined with the present environment including for example the economical and political climate. According to Özkan and Lajunen (in press), traffic culture is formed and maintained by formal and informal rules, norms, and values. Formal rules are mainly applied and enforced by authorities like the traffic police. Informal rules, norms, and values, on the other hand, are developed by the road users themselves as a result of exposure and interaction with each other. Every group (e.g. professional drivers working for different companies or drivers from different countries) has its own particular cultural characteristics that cause its members to interpret the interaction with other road users in a particular manner. Therefore, drivers who belong to different groups might interpret similar events in different ways and, consequently, make conflicting decisions, which increases their risk of being involved in an accident.

Traffic culture has repeatedly been mentioned in the literature and driver groups with different cultural characteristics have been compared by using, for example, the theory of planned behaviour (Ajzen, 1991). According to this theory people's attitude, subjective norm and perceived behavioural control determine their behaviour indirectly via intention. According to Özkan and Lajunen (in press), no attempts have, however, been made to measure the actual traffic culture empirically and therefore they developed the *traffic culture and climate scale*.

2.6.1 Traffic Culture and Climate Scale

When developing the scale, Özkan and Lajunen (in press) started with extracting terms assuming to describe traffic culture and climate using a Turkish dictionary. Three Turkish drivers then reviewed these items to maximize the content validity of the scale. Finally, non-Turkish experts added and reworded the items to prevent the view of one culture from dominating. The final set of 64 items was then tested by 307 private car drivers answering to what extent they thought that the items reflected the traffic in Turkey (1=strongly disagree; 5=strongly agree). Based on the results of this first study, the scale was further adjusted and a new set of 42 items was tested by 230 professional drivers and 94 private car drivers. In addition, the question was rephrased and this time the participants were asked to what extent the items reflect the traffic system, environment and atmosphere in Turkey (1=never reflects; 6=strongly reflects). Factor analysis revealed four factors which were named *functionality* (e.g. safe), *externality* (e.g. unpredictable), *internality* (e.g. requiring skilfulness), and *competitiveness* (e.g. stressful). Further analysis showed that both *functionality* and *internality* was negatively associated with traffic accident involvement. Özkan et al. (2006) then further adjusted the scale and used the new 44-item version of the scale to compare different traffic cultures by collecting data in four different countries — Turkey, Greece, Finland and Sweden. At the time being, these data have, however, not yet been completely analysed.

3. DEVELOPMENT OF SCENARIOS

3.1 Introduction

In order to be able to define the experiments and specifications for the simulators, we developed scenarios. These scenarios define what will happen when the experiment participants drive the simulated road or train track using the different support systems defined in WP2.

In the EuroFot project definitions (based on FESTA) of situations and scenarios are given (EUROFOT; Carsten & Barnard, in press). This gives a general idea about what we mean by these terms.

Situation: One specific level or a combination of specific levels of situational variables (Example: *rain+dark+motorway)*

Scenario: A use case in a specific situation (Example: *car following in rain+dark+motorway)*

For each of the systems we defined the prototypical situations in which the system is triggered and provides a warning. For example for the ISA system this is a situation in which the speed limit changes and the driver does not comply timely with an appropriate change in speed.

Scenarios are detailed descriptions of what we expect will happen in a certain situation and the characteristics of the environment in which the driving takes place.

3.2 Developing scenarios

Developing scenarios was a process in three steps:

1. A template was developed to describe scenarios. This template was tried out by several partners and adjusted according to the feedback.
2. For all hypotheses defined in D2.2, a template was filled in. For each hypothesis and each of the four systems 1-3 different scenarios were developed. During a workshop we defined a first set of scenarios in small groups, consisting of researchers from the car as well as the train domain. After the workshop each partner involved in this task developed more scenarios.
3. Scenarios were discussed, detailed and analysed for similarities. Several telephone and web-based conferences took place to discuss the scenarios.

3.3 Template for scenarios

We used the following template for scenario description (Table 3.1)

Table 3.1 Scenario template

Elements	Description	Example
Title	Mode plus number, Speed Management or Collision Avoidance, Hypothesis number	CAR12, SM, H6
Situation	Describe the situation and how the system operation is affected by the situation	Speed limit changes, driver does not adapt speed, ISA gives warning
Hypothesis	Specification of the hypothesis from D22	Fatigued operators will rely on the system to warn them about a critical situation
Operator	Description of the experiment participants	Car driver
Operator state/characteristic	Description of the characteristics of the operator related to the 5 variables selected (attitude, experience, task demand, culture)	Fatigued before the experiment starts
Operator manipulation	Description of manipulations of the operator during the experiment	Having to do a secondary task
Trigger	Description of the event that triggers an action from the system	VMS (Variable Message Sign) announces maximum speed reduction to 80km
Expected reactions from operator on the trigger	List of expected actions from the operator (these actions may be limited by the hypothesis)	Driver does not pay attention to sign
Expected reactions from the operator on the system warning	List of expected actions from the operator (these actions may be limited by the hypothesis)	1. Driver reduces speed after warning 2. Driver does not notice warning
Environment: road/track	Description of specific road/track characteristics	Long boring road
Environment: traffic conditions or other vehicles/objects	Description of the other elements than the vehicle itself that play a role in the scenario	Low traffic density, VMS at regular intervals
Environment: weather and light conditions	Description of weather conditions and time of day	Calm weather, daytime
Measures before experiment	Parameters and their measurement of participant characteristics	Questionnaire on job and mileage, subjective fatigue questionnaire
Measures during experiment	Parameters and their measurement of participant state and driving behaviour	Eye-movements to measure fatigue, speed
Measures after experiment	Parameters and their measurement of participant feedback	Structured interview, and subjective fatigue questionnaire
Notes		

Sometimes in the scenario it is necessary to split some of the cells in case of more than one operator characteristic or state. For example a scenario for a hypothesis stating that sensation seekers get more warnings, the cells have to be split for high and low sensation seeking drivers.

3.4 Example scenarios

Some examples of scenarios are given below in Tables 3.2 to 3.5; first two scenarios on speed management, next two scenarios on collision avoidance.

Table 3.2 Example scenario speed management for cars

Elements	**Scenario**	
Title	CAR13 SM H4	
Situation	Lower speed limit ahead	
Hypothesis	H4: Inexperienced drivers will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Experienced	Inexperienced
Operator manipulation	None	
Trigger	When the speed limit sign is in sight	
Expected reactions from operator on the trigger	Lift off accelerator to slowly reduce speed	Maintain driving speed
Expected reactions from the operator on the system warning	No warning given	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few curves "hiding" the sign.	
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage at the speed sign.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	Questionnaire on experience	
Measures during experiment	Speed, number of warnings, use of brake	
Measures after experiment		
Notes	Could apply to both experience of driving and of road	

Table 3.3 Example scenario speed management for trains

Elements	**Scenario**	
Title	TRAIN11 SM H9	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time	
Hypothesis	Under-load operator may drive without respecting the appropriate speed	
Operator	Train driver	
Operator state/characteristic	• Under-loaded driver in terms of temporal task demands (low / high time pressure). • Under-loaded driver in terms of functional task demand (low / high task complexity)	• Medium loaded driver in terms of temporal task demands (no time pressure). • Medium loaded driver in terms of functional task demand (no complex task)
Operator manipulation	Conditions for making the driver overloaded or non - overloaded, under-loaded, or non under-loaded	
Trigger	Strategies for managing workload	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment		
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Situation awareness indicators; Workload indicators; Warnings triggered	
Measures after experiment	Situation awareness indicators; Workload indicators	
Notes		

Table 3.4 Example scenario collision avoidance for cars

Elements	**Scenario**	
Title	CAR11 CA H6	
Situation	Unexpected event: obstacle on the road, broke down vehicle sticking out	
Hypothesis	Fatigued driver will notice an unexpected event later and gets more warnings	
Operator	Car driver	
Operator state/characteristic	Fatigue induced by experiment	Non-fatigued
Operator manipulation	Making drivers fatigued by high effort driving, followed by boring driving with cruise control, followed by an event	Only short pre-drive
Trigger	Vehicle broken down intruding into the driver's path on a two-lane road	
Expected reactions from operator on the trigger	Notices the broke-down vehicle too late	Notices the broke-down vehicle and brakes
Expected reactions from the operator on the system warning	Warning issued, brakes or goes to the other lane	No warning
Environment: road/track	Two lane road with small shoulder	
Environment: traffic conditions or other vehicles/objects	Normal traffic, in opposing lane either high or low density traffic to have a consistent reaction (brake or go to opposite lane)	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Pilot to verify whether drivers do get fatigued	
Measures during experiment	Eye-movements (perclos) to measure fatigue; KSS after pre-event intervals; Brake and lane change; Start of reaction; Standard driving measures including max deceleration; Number of warnings	
Measures after experiment		
Notes		

Table 3.5 Example scenario collision avoidance for trains

Elements	**Scenario**	
Title	TRAIN10 CA H6	
Situation	The Control Room sends information to the driver about an obstacle on the track, no placed in the direct sight of the driver. Drivers have to acknowledge this information.	
Hypothesis	Fatigued operators wait the AWS signal to start braking.	No-fatigued operators start braking as soon as she/he has received the message from the Control Room.
Operator	Professional train driver	
Operator state/characteristic	Fatigued driver	Non-fatigued driver
Trigger	Message from the Control Room	
Subject manipulation	No operator manipulation	
Expected reactions from operator on the trigger	Acknowledgement of the message from the Control Room	Acknowledgement of the message from the Control Room and start braking immediately
Expected reactions from the operator on the system warning	Acknowledgement of the AWS signal and activation of the brake pedal	Acknowledgement of the AWS signal
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	No obstacle at the driver sight on the railroad, need to be informed of the location of an obstacle by the Control Room	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Level of fatigue of the driver	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one) before braking; Speed curve of the train; Message from the Control Room moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment		
Notes		

3.5 Conclusion

In total, for the speed management systems 24 hypotheses were developed for cars and 12 for trains. For collision avoidance systems 21 hypotheses were developed for cars and 14 for trains. For trains fewer hypotheses were developed because the train driving task is much more restricted and regulated than the car driving task. This means that it is harder to come up with different situations in which the driver can act differently.

- In Appendix 1 the scenarios for cars and speed management are given.
- In Appendix 2 the scenarios for trains and speed management are given.
- In Appendix 3 the scenarios for cars and collision avoidance are given.
- In Appendix 1 the scenarios for trains and collision avoidance are given.

With his method we developed more scenarios than were needed for the experiments. This has several advantages:

- We were able to compare scenarios between the car and the train domain, searching for similarities and differences.
- It stimulated creativity to think about different situations and circumstances in which the systems would warn drivers and their possible reactions to potentially dangerous situations and the driving support.
- We had a large variety of scenarios to choose from and to combine (see Chapter 4).
- The scenarios that will not be used in the experiments can be used for validation purposes in WP7.

4. DEVELOPING EXPERIMENTAL SET-UPS

4.1 Introduction

After the development of multiple scenarios for the four car and train systems and for all 10 hypotheses, the subsequent phase was to define the experimental set-ups. For the experimental set-up the following items have to be specified:

- Overall experimental design
- Time-line of the experiments
- Scenarios encountered during the simulated drive
- Characteristics of participants
- Characteristics of the simulated environment

In order to be able to define experimental set-ups, a number of decisions had to be taken and scenarios selected to be included in the experiment.

The selection process had to answer the following questions:

1. Which operationalisation of independent parameters should be selected?
2. How are the parameters to be manipulated?
3. Which and how many hypotheses will be tested by the experiments?
4. Which and how many scenarios should be included in the experiments?

4.2 Selection criteria and considerations

We established the following list of selection criteria and considerations:

1. Comparability:

- the train and car experiments should have as much commonality as possible
- the scenarios should be viable for the different countries involved

2. Model validation:

- coverage of model parameters should be as complete as possible
- there should be the possibility of studying parameters in combination in order to study interactions

3. Practicalities:

- desk-top simulation
- only 30 subjects per study (per mode per country)
- the experiment should in principle last no longer than 2 hours (there is 30 euro available per participant)
- we should avoid the need to recruit operators with rare characteristics, who are difficult to find
- any special requirements for participant activities before the running of the actual experiments should be minimised
- additional equipment needed such as for physiological measures and/or eye-tracking should be avoided
- any programming of complex features would delay the experiments

4. **Experimental set-up:**
   - there should be the possibility to have more than one data point (if severity of incident is not too high) per scenario
   - the number of scenarios that could be handled in one experimental session needed consideration
   - we had to consider whether we should run the same experiment in the large simulators, perhaps with additional measures (e.g. eye-tracking)

4.3 Operator parameter selection

Because model validation is the most important objective of the experiments, we decided to use all five operator parameters in the experiments.

4.3.1 Attitude/personality: sensation seeking

Sensation seeking will be treated as a co-variant, so there is to be no selection of participants on sensation seeking. Selection on the basis of score on a sensation seeking test would mean testing a large number of potential participants before they are admitted to the experiment. For practical reasons we did not chose for this option. We will use a questionnaire to identify post-hoc how participants scored on a sensation seeking scale. In WP1 and 2 we have already identified the issue that train drivers will probably score low on sensation seeking tests because of the selection criteria and the nature of their work. However, we will still measure sensation seeking, to verify whether this is true and to be able to determine whether we still can find differences in the behaviour of drivers that have a higher or lower score. In addition the DBQ (Driver Behaviour Questionnaire) will used as a complement to the sensation seeking questionnaire. We will only use the violations part, and if train drivers do not drive or do not have a driving licence they will not have to fill it in. Alternatively it will be considered whether it is feasible to develop a train driver specific version.

4.3.2 Operator state: fatigue

In Chapter 2, we already gave an elaborate description of the different kinds of fatigue and the ways to induce and measure these. We want to study effects of mild fatigue on driving with a support system; we do not aim to have people who are extreme fatigued and are not able to stay awake.

For practical reasons we have chosen not to work with people who come in already fatigued. This would have placed too large a burden on participant recruitment, and would have required additional measures to ensure their safe arrival and return home. Train drivers, but also car driving shift workers, should therefore not come in directly after night work. Instead we have chosen to use a combination of sleepiness induced by the environment and the task, manipulated during the experiment. Participants in the fatigued condition will drive a boring road in the simulator, in a relatively dark room and after lunch. This driving will be done with an automated system, which means that the drivers do not have to steer or use the pedals. The car drives itself and the driver only has to observe the road scene. The reason for using automated driving is to avoid drivers in the fatigued condition getting more experience with driving on the simulator. This automated driving with a car will also be used for train drivers. So both groups of participants will have the same treatment to induce fatigue. There was much discussion about how long they should be given a boring task, but, as the literature study reported in Chapter 2 shows, approximately 25 minutes will have an effect, and this is feasible within the time allocated for the experiments. In a pilot study before the real experiments start we will verify whether the task and environment will indeed lead to a sufficient increase in fatigue, using several measures as described in Chapter 2. If this is the case, there will be no need to measure the induced fatigue extensively during the experiments.

4.3.3 Experience

For experience, we will use driving experience, in terms of years after getting the driver license or starting the job as a train driver and amount of kilometres driven per year (not applicable for train drivers). Drivers will be selected on these criteria. We will only select drivers with a high and low experience, and not intermediate experience. Because we are studying the effects of experience, we assume that if we find a difference in driver behaviour based on experience, that there will be a natural progression from novice driver behaviour towards experienced driver behaviour as people continue driving. The norms that will be used are:

- Inexperienced car drivers: license held for a maximum of 1 year;
- Experienced car drivers: license for 5-10 years; drives a minimum of 10,000 km per year;
- Inexperienced train drivers: qualified drivers, but less than 2 years experience as an active train driver;
- Experienced train drivers: more than 4 year experience as an active train driver.

The differences in years between inexperienced and experienced train drivers is not large, but is taken for practical reasons, in order to avoid difficulties in the recruitment of a sufficient number.

For the experiments we planned to use the hazard perception test developed by Sagberg and Bjornskau (2006). This test can be administered within a short period of time (15 minutes) after the simulator experiments. Reaction time to detect a hazard in 13 video sequences will be measured. Results from this test will be used during the analysis phase to identify potential correlations between driving behaviour and the hazard perception test. Train drivers will not take this test because it is only related to car driving.

4.3.4 Workload

4.3.4.1 The three levels

It has been agreed that there will be three levels of task demand or workload in the experiments and that workload will be manipulated within a run. The three levels are:

1. A standard medium-level workload situation which will persist for much of the experiment
2. A low workload situation, which will occur for some of the time
3. A high workload situation which can be induced as needed

A further requirement is that the "dose" of task demand be administered for a period of time, i.e. not just be momentary.

4.3.4.2 Inducing the three levels

The low and medium levels of workload can be induced through manipulation of driving difficulty. While this could be done by means of varying traffic intensity and behaviour, such variation would be rather likely to induce direct behavioural response in terms of speed and headway choice which could interfere with the ADAS manipulations where speed and headway are the targets of the selected systems. For example erratic behaviour by a lead car is likely to result in increased time headway from the participants, which might well cause the FCW not to be triggered.

Thus using road and track layout is the sensible option. The chosen two-lane road can be varied in terms of curvature, with straight sections producing, it is hoped, low workload, and gentle curves requiring greater effort and hence producing medium workload. If the proposed medium workload situation is not sufficiently demanding, curvature can be increased somewhat and lane width can be reduced a bit. A rail counterpart will need to be found, though track curvature may also work in that mode.

Inducing high workload is more problematic. Erratic traffic is undesirable for reasons already discussed. So here secondary tasks are an attractive option. However, visual secondary tasks are likely to interfere directly with detection of road signs and in-vehicle information. So a sensible option would be presenting a cognitive load via an auditory or memory task. We will not have the luxury of an additional in-vehicle device for presenting such a task or collecting data from such as task, so that a purely auditory task is attractive. We also do not want presentation of the task to mask in-vehicle messages as might occur if we used a Paced Serial Addition Task (PASAT) where numbers to add to the last sum have to be announced regularly. An additional requirement is that the task can be started and stopped at chosen times, to produce high workload over a period of the drive.

A serial subtraction task meets our requirements. The task has been used extensively in the investigation of the impact of drugs and neurological deficit on driving performance (see e.g. Jones, Shinar and Walsh, 2003), the impact of fatigue on operator performance (e.g. Paul, Gray, Sardana and Pigeau, 2003), the impact of task load on situation awareness (Fletcher, 2006) and for evaluating a cognitive model (Ritter, 2009). PASAT, an analogous task, has been used to create a stressful (high workload) mobile phone task (De Waard, 1996).

Difficulty can be varied by changing the number to be subtracted (e.g. subtracting by 5s versus subtracting by 7s) and only the request to start and the initial seed number as well as the request to stop the task need to be announced. Subtraction by 7s is proposed as the high workload task. We will have to ensure that the verbalising of the numbers does not prevent participants from hearing ADAS system produced messages or sounds.

4.3.4.3 How to confirm that operators are experiencing workload at the three levels

Ideally, it would be advantageous to collect workload data during the experiments. However, there are a number of practical considerations:

- On-line collection of workload is difficult. Many of the techniques, such as NASA-TLX, SWAT or DALI require fairly elaborate score sheets that cannot be readily administered to operators while driving.
- Even more straightforward uni-dimensional techniques for reporting subjective workload such as RSME would require enunciation of a score which could (a) impose an extra workload and (b) interfere with response to an ADAS.

However it is necessary to confirm that operators do indeed experience three distinct levels of workload. It is proposed that this be achieved by means of pilot tests on the experimental routes with a small group of operators, specifically recruited for piloting. This needs to be done for both road and rail, but the test can be performed at a single site.

This validation can be performed by using the Rating Scale of Mental Effort (RSME; Zijlstra, 1993), see Chapter 2, Section 2.5.5. Target RSME score levels are:

Low workload: 25
Medium workload: 35
High workload: 70–80

Measuring during the experiments would interrupt the driving and interfere with other aspects of the experiments. After the experiment we may ask the participants to give a subjective rating of the workload they experienced.

4.3.5 Culture

Culture will be studied by comparing the outcomes of the experiments in the five different countries (Sweden, France, Italy, UK and Israel). As the experiments will be the same in all countries, we are able to see what differences there are in the behaviour of drivers from the different countries. Culture in this sense is not very well defined, and it will be hard to attribute differences found only to "culture". This parameter is thus treated in a more exploratory way. A questionnaire on the subjective perception of the traffic safety culture in the participants' country will be administered.

4.3.6 Summary of parameters operationalisation

- Sensation seeking will be measured post hoc. The scores on sensation seeking will only be known after the experiments.
- Experience will be used as a selection criterion. Only novices and experienced drivers will be used.
- Fatigue will be induced before the real experiment starts. The effectiveness of induction measures will be piloted. Fatigue is thus studied between subjects.
- High workload will be induced by a secondary task and low workload by an easy drive. Three levels of workload are used: medium workload for the main part of the experiment, and a high and a low workload situation. Workload can thus be studied within subjects.
- Culture will be investigated by comparing results from different countries.

4.4 Scenario merging and selection

During the experimental drive, several specific scenarios will occur. After having generated a large number of scenarios we analysed and compared them, and tried to merge similar scenarios.

We analysed the scenarios and grouped them together. Selection of scenarios used the following criteria:

- Possibility to share a road or track with similar properties, such as scenarios using a rural road;
- Possibility to share the same kind of environmental characteristics, such as scenarios requiring daylight;
- Scenarios that do not require too many resources for implementation;
- Scenarios that are familiar in all countries, such as two-lane motorways instead of three lanes;
- Scenarios that can be sequenced in such a way that the complete drive in the experiment appears as a logical one, and is not confusing for the participants and does not bring in too many surprises. In other words, the drivers should get the feeling that they are on a "normal" journey or work shift in which they encounter situations that one could (in principle) expect. Although the experiment is not a naturalistic driving situation, we aim to avoid scenarios that are too implausible or dangerous.

For cars we found that most scenarios for the speed management system can be run with a rural road with curves and villages, daylight and no specific weather conditions. This seems a good environment to study risk because (1) rural roads account for a large proportion of serious and fatal crashes and (2) experience in HASTE (Östlund et al., 2004)) showed that rural roads provided the

most powerful environment for the experiments. For the collision avoidance system, a two-lane motorway would be a good environment, as most of the scenarios were defined for such an environment and collision avoidance situations with warnings are easier to evoke in situations with a high speed.
In the car experiment, the driver could drive a rural road encountering different situations in which he/she should change the speed, such as sharp bends, village entries and speed signs. In these different scenarios the driver should either change speed in time or get a warning from the ISA system. The hypotheses on which the scenarios are based predict different behaviour for different driver groups. This behaviour can be measured in terms of reaction time, number of warnings, and change in speed, as specified in the different scenario. For the collision avoidance part of the experiment, a similar experimental layout can be defined. The driver drives on a two-lane motorway and encounters situations in which he/she should decelerate, brake or change lane in order to avoid a collision, such as road works, a lead car braking suddenly and sharply, or a parked truck sticking out into a lane. If the driver does not react timely, the FCW system will give a warning. The hypotheses predict differences in behaviour, or the moment of reacting to the potential danger or the amount of warnings.

For the train scenarios a similar procedure was followed. The type of train selected earlier in the project is a non-high-speed one. The scenarios play in a rural or urban environment. For the speed management scenarios, different situations imply speed adaptation. These situations are:

- Proximity with station: departure/arrival at station or moving in front of a station
- Change in lighting: moving through a tunnel
- Design of the track: curves or downhill
- Sharing of the track: crossing with cars and pedestrians

Several scenarios are related to a delay in the schedule. The driver has to find a manner to accelerate. Acceleration should in principle not be done in proximity with a station or at an intersection. Other scenarios required curves or downhill in the track. Finally stations play a role in many scenarios. Speed adaptation is necessary, both for arrival at a station and because level crossings are commonly placed in proximity of a station.

Most situations described above also demands the driver being aware of the possibility of a collision. In the scenarios, collisions can be avoided by a timely reaction of the driver to a warning from the AWS system, the timely detection of a restrictive signalling or a reaction to information from the Control Room. As with the car scenarios, the train drivers will drive along a track encountering different scenarios in which they have to change speed or brake to avoid collision. The hypotheses predict again different reactions or different reaction times for the different train driver groups.

4.5 Outline of the experiments and practical issues

The requirements for the experiments are as follows:

- Interactions between parameters need to be addressed
- All participants drive with two systems (for speed management and for collision avoidance), the order in which the systems are used will be counter-balanced
- All participants drive the same experimental road or track, encountering the same situations.
- Experiments should be set-up and run within available resources:
    - not too many different roads/tracks and environmental variations
    - experiments should be easy to run and not involve too much manipulation by the experimenter in order to ensure consistency over all test-sites

- We have planned 30 participants per experiment (30 car and 30 train drivers per site, and additionally 30 for the full-motion simulators in Leeds and at VTI).
- The scenarios in the full motion simulators will be the same as for the desktop simulators, but it will be possible to use additional measurement, like eye-tracking.
- Half of the participants should be male, although for train drivers it may be difficult to find 50% female participants in some countries.
- Analysis of the data will be done across all sites by road and rail.

The overall experimental design can be illustrated by Figure 4.1, where the within driver factor is shown inside the figures and between driver factors are shown outside.

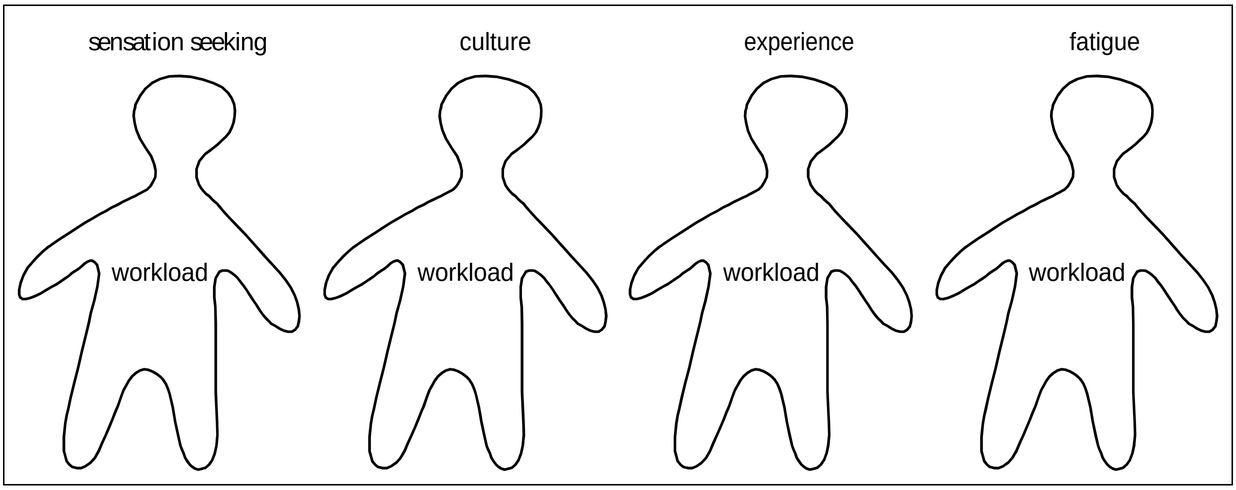

Figure 4.1: Overall experimental design

Given the considerations above, the experimental set-up will be as follows:

1. Introduction and questionnaires (10 mins)
2. Inducing fatigue for half of the participants (25 mins for half the participants only)
3. Explanation of and familiarisation drive with the first system (10 mins)
4. Experimental drive on road/track encountering several scenarios (25 mins, of which 15 with medium workload, 5 with low workload and 5 with high workload)
5. Break (10 mins for fatigued drivers, 20 mins for non-fatigued drivers)
6. Explanation of and familiarisation drive with second system (10 mins)
7. Experimental drive on road/track encountering several scenarios (25 mins, again with variation in workload)
8. Debriefing and questionnaires

5. SPECIFICATION OF EXPERIMENTS

5.1 Introduction

In this chapter we will describe the specification of the experiments based on the experimental set-up from Chapter 4, in which the justifications were given for the decisions that have been made.

The following elements are specified:

- Experimental procedures related to the participants (Section 5.2.)
- Specification of the experiments for cars (Section 5.3)
- The specification of the simulated road (Section 5.4)
- Specification of the experiments for trains (Section 5.5)
- The specification of the simulated train track (section 5.6)

The specifications described in this chapter are detailed to the level that programmers can implement the scenarios in the simulators and the experimenters can start to organise the experiments. However, during piloting and development work it might be possible that changes in the specifications are needed. We do not foresee major changes, but we aim to remain flexible and open-minded in order to arrive at experiments that are practically feasible given the available time and resources, and that answer our research questions. If necessary, decisions on changes will be made in consultation with the Workpackage 3 and 4 partners. In Workpackage 4 this development and piloting work will take place and if changes in the specifications have to be made they will be reported in the deliverable of the workpackage.

5.2 Experimental procedures related to the participants

5.2.1 The procedures for briefing and debriefing of the participants

In an experiment such as this that heavily relies on coordination between the experimental sites and that the experiments are carried out in the same way it is of importance that all the participants receive the same information. To make sure that is the case written instructions will be prepared in English and then translated to the native languages of the experimental sites. These documents will be prepared in WP4. Once a participant is scheduled for the experiment there will be information on time and place and some short information regarding the experiment, conditions to participate and cancel participation. Once they have arrived to the test site they will receive information on what they are supposed to do in the simulator, repeat the conditions to participate and what to do if they want to abort. After the experiment they will get the possibility to ask questions and they will receive their reimbursement. All this information and procedures will be the same for all experimental sites.

5.2.2 Hazard perception for ITERATE experiments

For the experiments we planned to use the hazard perception test developed by Sagberg and Bjornskau (2006). This test can be administered within a short period of time (15 minutes) either before or after simulator experiments. Reaction time to detect hazard in 13 videos sequences will be collected. Results from this test will not be used to design groups but rather during the analysis phase to identify potential correlations between driving behaviour and hazard perception test.

5.2.3 Attitude

For ITERATE experiments, part of the DBQ questionnaire will be used for car drivers and especially the part on violations. For train drivers the DBQ is not applicable in its current form so a version adapted to train drivers will be used. This version will not be validated before the experiments as is the case with DBQ, there will be some attempts to verify it retrospectively after the experiments.

The Sensation Seeking scale will also be used to survey the drivers' attitude but there will be some modifications since the scale is considered a bit outdated.

5.2.4 Culture

Depending on the length of the final experiment layout, we intend to use the traffic culture questions for car drivers. In order to fit train drivers also, some questions might be left apart.

5.2.5 Extra briefing for train drivers

As there is no "standard" train with the same controls as there is for cars (i.e. all have a steering wheel and pedals) and the systems for train drivers are rather complex and most train drivers are not used to these kinds of system, we will need another half hour to brief them. This will include a short presentation of the simulator (view, command, etc.) and a short presentation of the two systems (ATP and AWS) during 15 minutes. Familiarisation with the simulator lasts another 15 minutes. Total duration of this introduction for train drivers is 30 minutes.

5.2.6 The procedures for making participants fatigued

To induce fatigue, both car and train drivers will:

- drive with the **car** simulator for 25 minutes
- with an automated system, so they do not have to use the steering wheel or the pedals
- on a rather straight road
- with little other traffic
- in an environment with little variation
- participate in the experiment after lunch

Whether this procedure does indeed induce fatigue will be investigated in a pilot experiment. In this pilot some 10 participants will drive as described above and before and after the drive they will be questioned about their fatigue and sleepiness, using a subjective rating scale.

5.2.7 The secondary task used to induce high workload

To induce high workload, both car and train drivers will be asked to count backwards in sevens starting from a random number. For example starting from 1098: 1091, 1084, 1077.... In the experiments the participants will receive an automatic voice message telling them when to start and when to stop the task.

To verify whether the secondary task does indeed increase workload to a sufficient level a pilot experiment will be performed. In the pilot some 10 participants will be asked to perform this secondary task while driving on the experimental road or track. Before starting the task and some minutes after completion of the task participants will be asked to rate their workload on a RSME scale. Also during the task performance, the simulation will be frozen several times and the participants will be asked to rate their workload.

5.3 Specification of the experiments for cars

In Table 5.1 the time-schedule is given for the car experiments.

Table 5.1 Time-schedule experiment for cars

10 minutes:	**Briefing and questionnaires**	
Fatigued drivers		**Non-fatigued drivers**
10 minutes introduction drive first system		10 minutes introduction drive first system
25 minutes automated driving on boring road		
For both groups:		
15 minutes	**Drive with medium workload**	
5 minutes	**Drive with low workload**	
5 minutes	**Drive with high workload induced by secondary task**	
Fatigued drivers		**Non-fatigued drivers**
10 minutes break		20 minutes break
10 minutes introduction drive second system		10 minutes introduction drive second system
For both groups:		
15 minutes	**Drive with medium workload**	
5 minutes	**Drive with low workload**	
5 minutes	**Drive with high workload induced by secondary task**	
20 minutes	**Debriefing and questionnaires**	

In Table 5.2 the division of the participants over the different experimental conditions is given.

Table 5.2 Participants in the car experiment

32 participants per country per domain 8 experienced male + 8 experienced female + 8 novice male + 8 novice female			
16 Fatigued Participants 4 exp. male + 4 exp. female + 4 novice male + 4 novice female		16 Non Fatigued Participants 4 exp. male + 4 exp. female + 4 novice male + 4 novice female	
ISA → FCW 2 Exp. male +2 Exp. Female + 2 novice male + 2 novice female	FCW → ISA 2 Exp. male +2 Exp. Female + 2 novice male + 2 novice female	ISA → FCW 2 exp. male +2 exp. Female + 2 novice male + 2 novice female	FCW → ISA 2 exp. male +2 exp. female + 2 novice male + 2 novice female
Medium workload Low workload High workload		Medium workload Low workload High workload	

In Table 5.3 the specifications are given for the speed management system, describing the different situations and events the participants will encounter during their experimental drive, the specification of the road and environment and the measurements that will be made. In Table 5.4 the specifications are given for the collision avoidance system.

Table 5.3 Specification for the events in the speed management experiment for cars

Medium workload	
Duration	15 minutes
Road	Rural road with some gentle curves and 3 sharp curves
Traffic	Medium density
Signs	Generic speed signs (before and after villages) and curve warnings signs
Event	Need to change speed when encountering: 3 sharp bends, 3 villages and 1 school
Intervention	Secondary task to be performed when there is no event, as preparation for the high workload scenario
Measurements	• Number of warnings • Speed • Lateral position • Brake activation • Throttle position • Steering angle
Low Workload	
Duration	5 minutes
Road	Rural road with some gentle curves
Traffic	Low density
Signs	Curve warnings signs
Event	Need to change speed when encountering: 2 sharp bends
Intervention	None
Measurements	• Number of warnings • Speed • Lateral position • Brake activation • Throttle position • Steering angle
High Workload	
Duration	5 minutes
Road	Rural road with some gentle curves
Traffic	Medium density
Signs	Curve warnings signs
Event	Need to change speed when encountering: 2 sharp bends
Intervention	Secondary task
Measurements	• Number of warnings • Speed • Lateral position • Brake activation • Throttle position • Steering angle

Table 5.4 Specification for the events in the collision avoidance experiment for cars

Medium workload	
Duration	15 minutes
Road	2 lane motorway, with entry and exit ramps
Traffic	Medium density
Signs	None
Event	• Event 1: roadworks with vehicle sticking out (in the lane in which the driver is at that moment) • Event 2: short distance between entrance and exit, cars entering and exiting while a broken down truck blocks the fast lane
Intervention	Secondary task to be performed when there is no event, as preparation for the high workload scenario
Measurements	• Number of warnings • Time headway • Distance headway • Brake activation • Time to collision • Speed • Selection of lane
Low Workload	
Duration	5 minutes
Road	2 lane motorway
Traffic	Low density, but there will always be a lead car with >3 sec headway, independent of the lane in which the own car is driving
Signs	None
Event	Hard braking lead car towards the end of the drive
Intervention	None
Measurements	• Number of warnings • Time headway • Distance headway • Brake activation • Time to collision • Speed • Selection of lane
High Workload	
Duration	5 minutes
Road	2 lane motorway
Traffic	Moderate traffic
Signs	None
Event	Car cutting in (independent of lane)
Intervention	Secondary task
Measurements	• Number of warnings • Time headway • Distance headway • Brake activation • Time to collision • Speed • Selection of lane

5.4 Experimental road specification

5.4.1 Calculations of road length

In order to define the experimental road we calculated the length needed, given the speed limitations. Curves that play an important role in the scenarios for the ISA system were calculated.

Table 5.5 shows curve lengths for various curve radii and angles of turn. The design standards for 80 km/h roads typically set minimum horizontal curve radius in the range 240–260 m (O'Cinneide et al., 1993). For 100 km/h roads the values are generally in the 450–500 m and for 120 km/h roads in the range 650– 750 m. So for an 80 km/h road we can consider a 500 m or a 600 m radius curve to be gentle, with 600 m clearly indicating to drivers that there is no need to slow down. In terms of angular change, 30° is recommended as it will give drivers a relatively unobstructed view through the curve when they approach. Thus for the medium workload road with sweeping curves, initial values of curve radius 600 m and curve length 314 m are recommended.

Thus a medium workload road could be as follows:

Straight: 200 m
Curve R: 314 m
Straight: 200 m
Curve L: 314 m
etc.

Note that each straight and curve is approximately 0.5 km in length. The counterpart low workload road would be straight.

In terms of sharp curves for two-lane rural roads, the experiments in the MASTER project used curves with a radius of 100 m and 200 m (Comte, 1998). The 100 m curves were 75 m in length and the 200 m curves were 150 m in length. Thus both curves resulted in an angular turn of 43°. Both size curves were selected on the basis of the maximum safe speed calculated by Papacostas (1987) as shown in Table 5.5. However, it can also be seen from the Table that 200 m curves can, on dry roads, be safely negotiated at a speed close to 80 km/h. So it is recommended that for sharp bends we use curves of 100 m or 150 m radius with 100 m as the initial value to pilot. By making the curves have an angular change of 90°, we could ensure that drivers would not be able to see round the curve on approach. There are also indications in the accident data that such curves are problematic. Thus an initial sharp curve of 100 m radius and 157 m length is recommended. A curve radius of 150 m and length 236 m could also be tested.

Table 5.5: Curve radius and curve length

Curve Radius (m)	Length of 30° Angular Turn (m)	Length of 60° Angular Turn (m)	Length of 90° Angular Turn (m)
100	52	105	157
150	79	157	236
200	105	209	314
500	262	524	785
600	314	628	942

Table 5.6: Appropriate highest speeds (km/h) for negotiating curves with different friction values (superelevation *e* = 0.055)

Road Condition		Curve Radius	
		100 m	**200m**
Dry	*f*=0.5	57	78
Wet	*f*=0.4	53	73
	f=0.3	48	67
Slippery	*f*=0.2	43	59
	f=0.1	36	50

5.4.2 Road specification for speed management

Using these calculations, the following experimental road has been specified. During the implementation and piloting, adaptations may be needed.

In Table 5.7 the speed limits limit for different road segments, as well as the corresponding road length per second. Table 5.8 specifies in detail the rural road to be used in the speed management experiment for cars.

Table 5.7: Speed limits for different road segments in miles and kilometres per hour, and corresponding road length per second

	Speed limit			metre/sec
	miles per hour	kilometres per hour	kph, round figures	
school	20	32	30	8.33
village	30	48	50	13.89
rural road	50	80	80	22.22
motorway	70	112	110	30.56

Table 5.8: Detailed specification of the rural road to be used in the speed management experiment for cars

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	List (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	0	1	rural	80	straight	500	22				22	0.4
ISA Medium Work-load	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	List (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	B1	1	rural	80	straight	200	9			93		
	B1	2	rural	80	bend right	157	7	100				
	B1	3	rural	80	straight	200	9					
	B1	4	rural	80	curve left	314	14	600	39			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	V	1	rural	80	curve right	314	14	600				
	V	2	rural	80	straight	200	9			130		
	V	3	village	50	village entry	0	0					
	V	4	village	50	straight	200	14					
	V	5	rural	80	curve left	314	14	600	52			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	B2	1	rural	80	curve right	314	14	600				
	B2	2	rural	80	straight	200	9			135		
	B2	3	rural	80	bend left	157	7	100				
	B2	4	rural	80	straight	200	9		25			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	S	1	rural	80	curve right	314	14	600				
	S	2	rural	80	straight	200	9			116		
	S	3	village	50	village entry	0	0					
	S	4	village	50	straight	200	14					
	S	5	village	50	straight	200	14					
	S	6	village	30	school	100	12					
	S	7	village	50	straight	200	14					

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	List (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	S	8	rural	80	curve left	314	14	600	92			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	B1	1	rural	80	straight	200	9					
	B1	2	rural	80	bend right	157	7	100				
	B1	3	rural	80	straight	200	9					
	B1	4	rural	80	curve left	314	14	600	39			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	V	1	rural	80	curve right	314	14	600		130		
	V	2	rural	80	straight	200	9					
	V	3	village	50	village entry	0	0					
	V	4	village	50	straight	200	14					
	V	5	rural	80	curve left	314	14	600	52		814	13.6
ISA Low Work-load	A2	1	rural	80	curve right	250	11	1000				
	A2	2	rural	80	straight	200	9					
	A2	3	rural	80	curve left	250	11	1000				
	A2	4	rural	80	straight	200	9					
	A2	5	rural	80	curve right	250	11	1000				
	A2	6	rural	80	straight	200	9					
	A2	7	rural	80	curve left	250	11	1000	72			
	B3	1	rural	80	straight	200	9			81		
	B3	2	rural	80	bend right	157	7	100				
	B3	3	rural	80	straight	200	9					
	B3	4	rural	80	curve left	250	11	1000	36			
	A2	1	rural	80	curve right	250	11	1000				
	A2	2	rural	80	straight	200	9					
	A2	3	rural	80	curve left	250	11	1000				
	A2	4	rural	80	straight	200	9					
	A2	5	rural	80	curve right	250	11	1000				
	A2	6	rural	80	straight	200	9					

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	List (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	A2	7	rural	80	curve left	250	11	1000	72			
	B4	1	rural	80	curve right	314	14	600				
	B4	2	rural	80	straight	200	9			115		
	B4	3	rural	80	bend left	157	7	100				
	B4	4	rural	80	straight	200	9		39			
	A2	1	rural	80	curve right	250	11	1000				
	A2	2	rural	80	straight	200	9					
	A2	3	rural	80	curve left	250	11	1000				
	A2	4	rural	80	straight	200	9					
	A2	5	rural	80	curve right	250	11	1000				
	A2	6	rural	80	straight	200	9					
	A2	7	rural	80	curve left	250	11	1000	72		292	4.9
ISA High Work-load	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	B1	1	rural	80	straight	200	9			93		
	B1	2	rural	80	bend right	157	7	100				
	B1	3	rural	80	straight	200	9					
	B1	4	rural	80	curve left	314	14	600	39			
	A1	1	rural	80	curve right	314	14	600				
	A1	2	rural	80	straight	200	9					
	A1	3	rural	80	curve left	314	14	600				
	A1	4	rural	80	straight	200	9					
	A1	5	rural	80	curve right	314	14	600				
	A1	6	rural	80	straight	200	9					
	A1	7	rural	80	curve left	314	14	600	84			
	B2	1	rural	80	curve right	314	14	600				
	B2	2	rural	80	straight	200	9			130		
	B2	3	rural	80	bend left	157	7	100				
	B2	4	rural	80	straight	200	9		39		245	4.1
	0	1	rural	80	straight	500	22				22	0.4
											1396	**23.3**

5.4.3 Road specification for collision avoidance

Table 5.9 specifies in detail the rural road to be used in the collision avoidance experiment for cars.

Table 5.9: Detailed specification of the rural road to be used in the collision avoidance experiment for cars

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	Dist (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	0	1	M'way	110	straight	500	16.4					
FCW Medium Work-load	1	1	M'way	110	curve right	534	17.5	1020				
	1	2	M'way	110	straight	400	13.1					
	1	3	M'way	110	curve left	534	17.5	1020				
	1	4	M'way	110	straight	600	19.6					
	1	5	M'way	110	curve right	534	17.5	1020				
	1	6	M'way	110	straight	400	13.1					
	1	7	M'way	110	curve left	534	17.5	1020	115.7			
	2	1	M'way	110	curve right	534	17.5	1020				
	2	2	M'way	110	straight	400	13.1					
	2	3	M'way	110	curve left	534	17.5	1020				
	2	4	M'way	110	straight	600	19.6					
	2	5	M'way	110	curve right	534	17.5	1020				
	2	6	M'way	110	straight	400	13.1					
	2	7	M'way	110	curve left	534	17.5	1020	115.7			
	3	1	M'way	110	curve right	534	17.5	1020				
	3	2	M'way	110	straight	400	13.1					
	3	3	M'way	110	curve left	534	17.5	1020		295.9		
	3	4	M'way	110	Straight, roadworks with vehicle sticking out	600	19.6					
	3	5	M'way	110	curve right	534	17.5	1020				
	3	6	M'way	110	straight	400	13.1					
	3	7	M'way	110	curve left	534	17.5	1020	115.7			
	4	1	M'way	110	curve right	534	17.5	1020				
	4	2	M'way	110	straight	400	13.1					
	4	3	M'way	110	curve left	534	17.5	1020				
	4	4	M'way	110	straight	600	19.6					
	4	5	M'way	110	curve right	534	17.5	1020				
	4	6	M'way	110	straight	400	13.1					
	4	7	M'way	110	curve left	534	17.5	1020	115.7			
	5	1	M'way	110	curve right	534	17.5	1020				
	5	2	M'way	110	straight	400	13.1					

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	Dist (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	5	3	M'way	110	curve left	534	17.5	1020				
	5	4	M'way	110	straight	600	19.6					
	5	5	M'way	110	curve right	534	17.5	1020				
	5	6	M'way	110	straight	400	13.1					
	5	7	M'way	110	curve left	534	17.5	1020	115.7			
	6	1	M'way	110	curve right	534	17.5	1020				
	6	2	M'way	110	straight	400	13.1					
	6	3	M'way	110	curve left	534	17.5	1020		327.5		
	6	4	M'way	110	Straight, broken down truck	600	19.6					
	6	5	M'way	110	curve right	534	17.5	1020				
	6	6	M'way	110	straight	400	13.1					
	6	7	M'way	110	curve left	534	17.5	1020	115.7			
	7	1	M'way	110	curve right	534	17.5	1020				
	7	2	M'way	110	straight	400	13.1					
	7	3	M'way	110	curve left	534	17.5	1020				
	7	4	M'way	110	straight	600	19.6					
	7	5	M'way	110	curve right	534	17.5	1020				
	7	6	M'way	110	straight	400	13.1					
	7	7	M'way	110	curve left	534	17.5	1020	115.7			
FCW Low Work-load	8	1	M'way	110	curve right	534	17.5	1020				
	8	2	M'way	110	straight	400	13.1					
	8	3	M'way	110	curve left	534	17.5	1020				
	8	4	M'way	110	straight	600	19.6					
	8	5	M'way	110	curve right	534	17.5	1020				
	8	6	M'way	110	straight	400	13.1					
	8	7	M'way	110	curve left	534	17.5	1020	115.7			
	9	1	M'way	110	curve right	534	17.5	1020				
	9	2	M'way	110	straight	400	13.1					
	9	3	M'way	110	curve left	534	17.5	1020		327.5		
	9	4	M'way	110	Straight, hard braking lead car	600	19.6					
	9	5	M'way	110	curve right	534	17.5	1020				
	9	6	M'way	110	straight	400	13.1					
	9	7	M'way	110	curve left	534	17.5	1020	115.7			
	10	1	M'way	110	curve right	534	17.5	1020				
	10	2	M'way	110	straight	400	13.1					
	10	3	M'way	110	curve left	534	17.5	1020				
	10	4	M'way	110	straight	600	19.6					
	10	5	M'way	110	curve right	534	17.5	1020				

Con-dition	Tile	Sec-tion	Environ-ment	SL (kph)	Layout	Dist (m)	Time (sec)	Curve R	Tile du-ration	Time to event	Total sec	**Total min**
	10	6	M'way	110	straight	400	13.1					
	10	7	M'way	110	curve left	534	17.5	1020	115.7			
FCW High Work-load	11	1	M'way	110	curve right	534	17.5	1020				
	11	2	M'way	110	straight	400	13.1					
	11	3	M'way	110	curve left	534	17.5	1020				
	11	4	M'way	110	straight	600	19.6					
	11	5	M'way	110	curve right	534	17.5	1020				
	11	6	M'way	110	straight	400	13.1					
	11	7	M'way	110	curve left	534	17.5	1020	115.7			
	12	1	M'way	110	curve right	534	17.5	1020				
	12	2	M'way	110	straight	400	13.1					
	12	3	M'way	110	curve left	534	17.5	1020		327.5		
	12	4	M'way	110	Straight, car cutting in	600	19.6					
	12	5	M'way	110	curve right	534	17.5	1020				
	12	6	M'way	110	straight	400	13.1					
	12	7	M'way	110	curve left	534	17.5	1020	115.7			
	13	1	M'way	110	curve right	534	17.5	1020				
	13	2	M'way	110	straight	400	13.1					
	13	3	M'way	110	curve left	534	17.5	1020				
	13	4	M'way	110	straight	600	19.6					
	13	5	M'way	110	curve right	534	17.5	1020				
	13	6	M'way	110	straight	400	13.1					
	13	7	M'way	110	curve left	534	17.5	1020	115.7			
	0	1	M'way	110	straight	500	16.4				1537.1	**25.6**
						46,968						

5.5 Specification of the experiments for trains

In Table 5.10 the time-schedule is given for the car experiments.

Table 5.10 Time-schedule experiment trains

30 minutes:	**Introduction to train drivers on the simulator**	
10 minutes:	**Briefing and questionnaires**	
Fatigued drivers		**Non-fatigued drivers**
10 minutes introduction drive first system		10 minutes introduction drive first system
25 minutes automated **car** driving on boring road		
For both groups:		
15 minutes	**Drive with medium workload**	
5 minutes	**Drive with low workload**	
5 minutes	**Drive with high workload induced by secondary task**	
Fatigued drivers		**Non-fatigued drivers**
10 minutes break		20 minutes break
10 minutes introduction drive second system		10 minutes introduction drive second system
For both groups:		
15 minutes	**Drive with medium workload**	
5 minutes	**Drive with low workload**	
5 minutes	**Drive with high workload induced by secondary task**	
10 minutes	**Debriefing and questionnaires**	

In Table 5.11 the division of the participants over the different experimental conditions is given. As we expect difficulties to recruit sufficient female drivers, the gender is not specified for the train experiments.

For train drivers the workload issue is also a bit different. Actually, the usual train driving task induces low workload. We can make a difference between an extreme low workload situation and low workload situation (corresponding to medium workload for a car driver), according to the specifications given below:

- Low workload situation: straight track, rural landscape
- Medium workload situation: straight track and curves (sharp curves sometimes), crossing with car road and train stations; rural and urban landscapes

- The high workload is task induced based on the medium workload situation by adding a secondary task.

Table 5.11 Participants in the train experiment

32 participants per country per domain 16 experienced + 16 novice			
16 Fatigued Participants 8 exp. + 8 novice		16 Non Fatigued Participants 8 exp. + 8 novice	
ATP → AWS 4 Exp. + 4 novice	AWS → ATP 4 Exp. + 4 novice	ATP → AWS 4 Exp. + 4 novice	AWS → ATP 4 Exp. + 4 novice
Medium workload Low workload High workload		Medium workload Low workload High workload	

In Table 5.12 the specifications are given for the speed management system, describing the different situations and events the participants will encounter during their experimental drive, the specification of the road and environment and the measurements that will be made. The ATP functioning is linked with speed panels (events), imposing a decrease of the speed. However curves, station and crossing with road car are also protected by traffic light. In order to avoid interferences with scenarios related to collision avoidance, all traffic lights must be no restrictive, *i.e.* with a green colour.

In Table 5.13 the specifications are given for the collision avoidance system. The AWS functioning is linked with traffic light (events), imposing stopping or reducing speed of the train (red, orange or yellow light). However, a normal workload situation includes speed changes. Therefore speed panel must also be used.

Table 5.12 Specification for the events in the speed management experiment for trains

Medium workload	
Duration	15 minutes
Track	• Rural and urban landscape • Straight track and some gentle curves + 4 sharp curves or downhill • 1 Crossing with car road • 2 Stations
Traffic	Not relevant
Signs	• Speed panels (curve speed, crossing speed, station speed) + speed panels ("normal" speed) • All traffic lights with green colour
Event	• 4 curves (or downhill) (2 left and 2 rights), inducing speed decrease • 1 crossing, inducing speed decrease • 2 stations, inducing speed decrease
Intervention	• Information: the train is behind schedule, can be added to make drivers go faster • Secondary task to be performed when there is no event, as preparation for the high workload scenario
Measurements	• Speed • Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour
Low workload	
Duration	5 minutes
Track	• Rural landscape • Straight track and some gentle curves
Traffic	Not relevant
Signs	2 speed panels ("normal" speed)+ 1 speed panel (low speed)
Event	1 speed panel, inducing speed decrease
Intervention	None
Measurements	• Speed • Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour
High workload	
Duration	5 minutes
Track	Rural and urban landscape Straight track and 1 sharp curve
Traffic	Not relevant
Signs	2 speed panel ("normal" speed)+ 1 speed panel (curve speed)
Event	1 curve, inducing speed decrease
Intervention	Secondary task
Measurements	• Speed • Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour

Table 5.13 Specification for the events in the collision avoidance experiment for trains

Medium workload	
Duration	15 minutes
Track	• Rural and urban landscape • Straight track and some gentle curves + 4 sharp curves or downhill • 1 Crossing with car road • 2 Stations
Traffic	Not relevant
Signs	• Speed panels (curve speed, crossing speed, station speed) + speed panels ("normal" speed) • traffic lights + 6 restrictive light colours (orange for example)
Event	• 4 curves (or downhill) (2 left and 2 rights), inducing speed decrease • 1 crossing, inducing speed decrease • 2 stations, inducing speed decrease • Restrictive traffic lights (**on straight track**)
Intervention	• Information: obstacle on the railroad • Secondary task to be performed when there is no event, as preparation for the high workload scenario
Measurements	• Speed • Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour
Low workload	
Duration	5 minutes
Track	• Rural landscape • Straight track and some gentle curves
Traffic	Not relevant
Signs	• 2 speed panel ("normal" speed) • 2 traffic lights
Event	1 restrictive traffic lights **on straight track**
Intervention	None
Measurements	• Speed • Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour
High workload	
Duration	5 minutes
Track	• Rural and urban landscape • Straight track and 1 sharp curve
Traffic	Not relevant
Signs	Traffic lights and speed signs
Event	• 1 curve + restrictive traffic light • Restrictive traffic light (**on straight track**)
Intervention	• Information: obstacle on the railroad • Verbal secondary task
Measurements	• Speed

	• Number of warnings • Number of acknowledgements • Reaction time • Braking / deceleration behaviour

5.6 Experimental track specification

5.6.1 Selection of track

The experimental track used for trains is created somewhat differently than for cars since a real track is used. VTI has access to a database including all the coordinates for the entire Swedish rail network and by using this, a natural feel of the track can be created. When selecting the track to be used it was taken into account that it should include both straight, low workload sections and sections with both vertical and horizontal curves creating a higher workload. The selected section should also contain a number of stations which will give the possibilities to implement the scenarios.

A track section that fulfil these criteria is the track between the cities Falköping and Nässjö, a 112 kilometre long track with both straight fast sections, curvier sections with lower speed limit and sections with both curves and hills which is well suited for the three levels of workload we're trying to create in ITERATE. It also contains twelve stations which can be used for the scenarios. A map of the section can be found in Figure 5.1.

5.6.2 Calculation of track length

The track selected is 112 kilometres long with speed limits varying from 40 km/h at the stations up to 200 km/h. To allow for at least two hours of driving it was decided that the track needed to be repeated three times giving a total of 330 kilometres track. To repeat a road or a track is a method commonly used to get the exact length needed and is never or seldom discovered by the drivers. In the case of train drivers is also often the case that you travel the same track back and forth as a part of the daily routine.

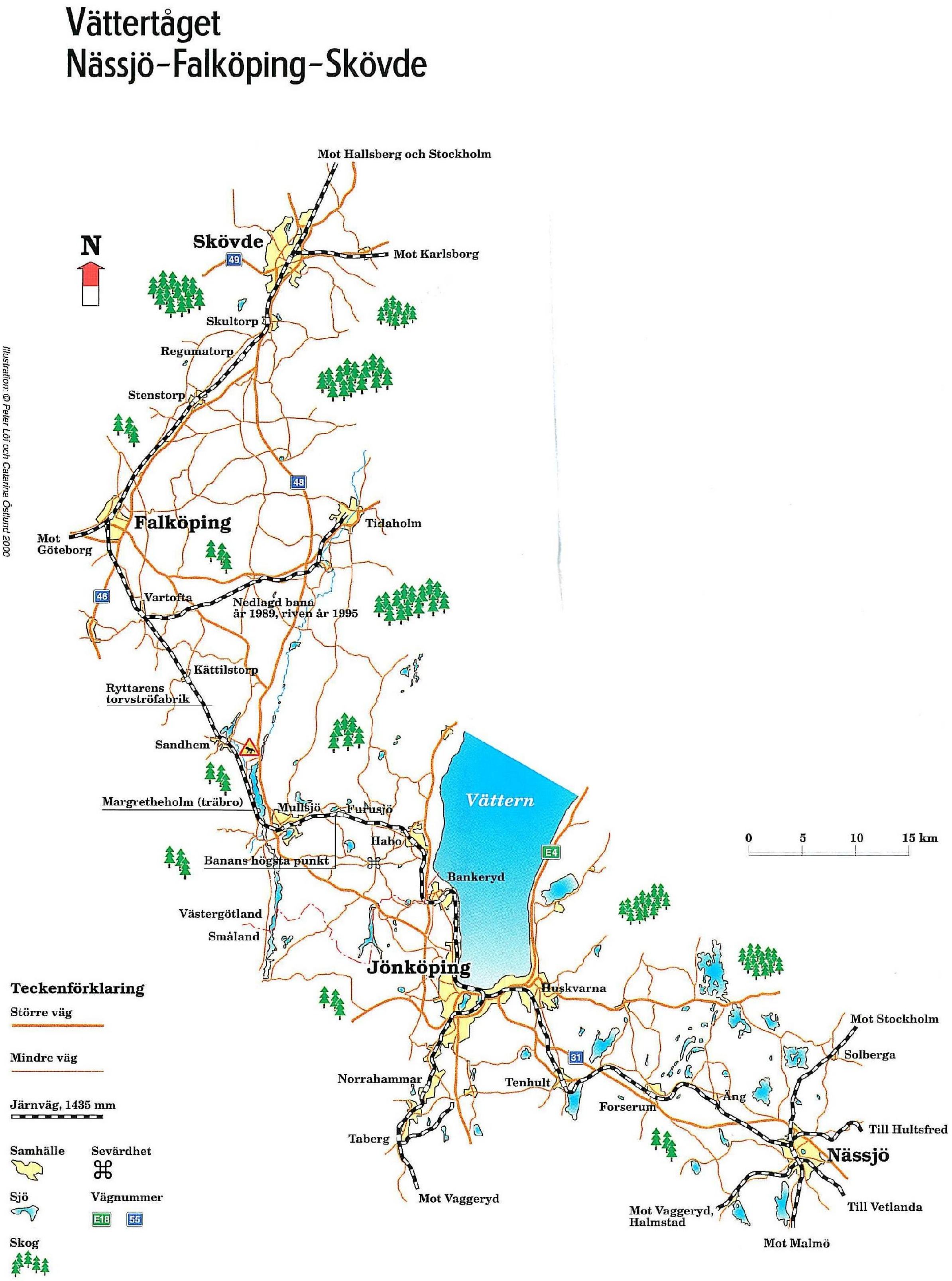

Figure 5.1: The track section to be implemented in the ITERATE train simulator.

5.6.3 Track specification

In the track specification below the twelve stations and speed signs are displayed as they are in the existing track. This is the track that will be built as a starting point for the creation of the scenarios. During this process the track may be modified to accommodate for the correct timing of the scenarios. In addition to the speed signs there are also markers along the route where the ERTMS-system will provide the driver with information. These are not reported here since they as well will be changed during the construction of the track and the scenarios. The existing location of the signs will however be used as a starting point for the construction.

Table 5.14 Specification of the stations and the speed changes along the track

Distance (meters)	Highest Speed	Stations, signals etc
0	155	**Falköping station**
1 148	160	Speed sign
9 000	160	Speed sign
11 435	160	**Vartofta station**
24 785	160	Speed sign
25 881	160	**Sandhem station**
27 187	160	Speed sign
29 192	160	Speed sign
33 054	160	Speed sign
34 285	160	Speed sign
36 922	105	Speed sign
37 688	105	**Mullsjö station**
38 274	115	Speed sign
38 565	150	Speed sign
46 160	130	Speed sign
46 595	140	Speed sign
50 407	140	**Habo station**
50 970	160	Speed sign
56 060	140	Speed sign
56 860	130	Speed sign
58 000	105	Speed sign
58 748	105	**Bankeryd station**
59 080	90	Speed sign
60 430	130	Speed sign
68 283	80	Speed sign, curve
69 342	80	**Jönköping station**
70 920	65	Speed sign, bridge
71 161	90	Speed sign, curves
71 375	110	Speed sign
75 670	120	Speed sign
75 873	120	**Huskvarna station**
78 250	130	Speed sign
82 170	140	Speed sign
85 437	140	**Tenhult station**
85 680	95	Speed sign
88 080	130	Speed sign

90 430	115	Speed sign
91 560	130	Speed sign
96 510	130	**Forserum station**
96 760	90	Speed sign
97 120	120	Speed sign
98 970	130	Speed sign
101 190	140	Speed sign
103 793	140	**Äng station**
104 245	130	Speed sign
104 790	140	Speed sign
110 977	90	Speed sign, shunting yard
111 425	40	Speed sign, station area
112 731	40	**Nässjö station**

6. SPECIFICATION OF SIMULATORS

6.1 Portable simulator hardware

The hardware that is going to be used for both the train and the car simulator is as follows (see also Figure 6.1):

- HP Z400 workstation running Windows 7. This will generate the visual simulation imagery at 60Hz. It needs to be powerful enough to run all the components of the simulation. This is a brand that is available to both sites that are developing simulators, so we can have identical hardware.
- Samsung 40" wide-screen 1920x1080 monitor. This will display the main driver view.
- ViewSonic 15" wide-screen 1366x768 monitor. This will display the instrumentation for the dashboard or train cab, including any automated safety systems such as ISA.
- Logitech G27 steering wheel and pedals for the car. This is the market leader for low-cost steering solutions and we have experience with its predecessor, the G25.
- RailDriver for the train. A low-cost alternative to the 'professional' solution which would be too expensive.
- A GameRacer seat with mounting points for the wheel and train controller. This will provide support for the driver for long periods and helps us avoid modifying an existing seat in a workshop with associated problems of design and manufacture. It is compatible with the controllers we have chosen and folds compactly for shipping or storage purposes.

Figure 6.1: Seat, Primary display stand and Secondary monitor stand with shelf for rail controller

6.2 Full motion simulators

6.2.1 Car simulator

For the experiments with the full motion simulator the Leeds driving simulator will be used. The Leeds driving simulator (see Figure 6.2) incorporates a state-of-the-art motion base. Long duration lateral accelerations are simulated by sliding the whole vehicle cab and dome configuration along a railed gantry. Similarly, the whole gantry slides along tracks to create prolonged longitudinal acceleration cues. The 7m long rails and tracks allow 5m of effective travel in each direction. In addition, sustained cues are provided by a standard 2.5t payload, electrically-driven hexapod. The motion-base enhances the fidelity of the simulator by providing highly realistic inertial forces to the driver during braking and cornering. The simulator has the facility for automated driving, where lateral and longitudinal control of the car is maintained by an automated system.

Figure 6.2: the Leeds driving simulator

6.2.2 Train simulator

For the train experiments with the full motion base the VTI driving simulator II or III will be used. It will be used to create realistic sensations in a laboratory environment, including a:

- Train cabin with authentic controls
- Computerised vehicle model
- Large moving base system
- Vibration table
- PC-based visual system
- PC-based audio system

The driving simulator is shown in Figure 6.3. The main advantage of the full simulator for ITERATE is not the moving base as it is for cars, instead it is the use of an authentic cabin with authentic controls (as far as possible) that will provide the added value.

Figure 6.3: the VTI driving simulator III (left) and the interior of the train cabin (right)

6.3 Implementation of car driving

6.3.1 International Driving

The implementation addresses the following issues:

- Dashboard conventions
- Driving on the right or on the left
- Turning at a junction
- Road signs
- Curve radius for counterbalancing.

6.3.1.1 Dashboard

The University of Leeds Driving Simulator uses a Jaguar cab with its controls intact, so this was used as the basis of the dashboard representation. The portable simulator uses a secondary monitor to render its dashboard. A digital camera was used to capture a high resolution image of the physical dashboard. It was then processed using image manipulation software and turned into a texture map suitable for computer graphics display. The needles on the dials are animated separately using the speed and revs as input. The speedometer has dual display for kph and mph.

6.3.1.2 Driving on the right and the left

The lanes in the road network module have an associated direction of travel. When a road network is generated for a given scene, a so-called profile is set for each road, showing what lanes are present and their layout. Essentially, the direction for the lanes was swapped to make the traffic drive on the right. This means there can be two road networks for a given graphical scene database: one where the cars drive on the left and the other where they drive on the right.

6.3.1.3 Turning at a junction

There are a number of possible paths through a junction, with a particular direction of turning for each possible direction approach. The cars must be able to indicate correctly when approaching a junction, so a lookup table was used to map the approach road to an indicator direction. Given the direction of driving and type of junction, a particular lookup table can be used to make the cars indicate correctly when turning.

6.3.1.4 Road signs

Each road sign has an associated visual model, typically consisting of a cylinder for the pole and a texture-mapped polygon for the sign itself. If a sign is just visually different, the country can be used to index a particular version of the model at the start of the simulation.

6.3.1.5 Curve radius

A particular curved road will have a different radius in the inside from the outside, and this is potentially significant for the tight rural curves that are to be used in the scenarios. Therefore we intend to model two versions of the event curves and their associated scenery in order to counterbalance the experiment more effectively.

6.4 Implementation of train driving

For trains the scenario will be the same for all countries since they all drive on the left. In addition most of the route is single track. With regard to signs the ERTMS is an international standard where all signs are displayed in the ERTMS-system instead of in the environment. Thus there are no specific issues for changing between countries.

7. CONCLUSIONS

In this deliverable we have provided specifications of the experiments to be performed in Workpackage 4. We have taken a structured approach, starting from the theoretical driver behaviour model, defining hypotheses and scenarios and finally designing the experiments and specifying the small-scale simulators to be used as the common experimental platform.

7.1 Insight into parameters influencing driver behaviour and interaction with support systems

We are confident that with these experiments we will be able to provide new insights into the behaviour of operators driving with support systems. We have had extensive discussion of alternative experimental designs and investigated many options on what variables to include in the experiments and how to study these variables. A major decision was to include all the five parameters that influence driving behaviour according to the model: personality/attitude, experience, driver state, task demand and culture. In all five countries precisely the same experimental procedures will be followed. This means that we will have sufficient numbers of subjects for each value of the parameters, and that we will be able to investigate differences between countries as well. What is even more important is that we succeeded to design experiments in which the interactions between variables can be studied. As the literature study in Workpackage 1 showed (see the ITERATE deliverables 1.1 and 1.2), most previous research has been focussed on the behaviour of operators driving with support systems with respect to a single variable. For example, insights exist on how fatigue influences driver behaviour, but less is known about the differences in behaviour between experienced and novice drivers who are fatigued and who drive with a speed warning system.

7.2 Insight into driver behaviour in different transport modes

Not only does the interaction between model parameters provide a new research focus, but also the differences and commonalities between the different transport modes form an area about which little is known. The experiments have been designed with the aim of ensuring comparability between the train and the car experiments on issues such as experimental set-up, the systems and the support they bring, the events that will happen, and the characteristics and experimental manipulation of the participants. The experiments are not completely identical, and nor can they be due to task and environmental differences and differences in the driver populations. However, both types of driver will drive with a speed management and a collision avoidance system, they will encounter situations in which they have to adapt their speed or stop the vehicle, and they will get warnings from the systems if they do not do so in time. The way in which their fatigue and workload is to be manipulated in the experiments is exactly the same. We do expect that the train drivers will exhibit a lesser degree of sensation seeking and that it will be hard to recruit a sufficient number of female train drivers. Knowledge about the differences and commonalities between the behaviour of train and car drivers will give valuable insight into how task and driver characteristics affect the interaction with systems.

7.3 Future work

The next step in the ITERATE project is the realization of the experiments in the car and train simulators in Workpackage 4. Prior to the actual experiments, questionnaires, experimental manuals, and participant briefings will be prepared. After the implementation of the experimental scenarios and roads/tracks, and a piloting phase, the experiments will take place in the different countries. Two sets of identical hardware platforms have been purchased on which both the train and the car experiments can be run. Each country will perform the experiments with the simulators over a period of 2–3 months and then ship the simulators on to another country. In this way the experiments can be finished within a six-month period. The experiments on the two full motion simulators will take place during the same overall time period.

The data from the experiments will be analysed in Workpackage 5, and will be transferred to Workpackage 6 (Model Development and Tuning). In this workpackage, the theoretical architecture of the unified model of driver behaviour (UMD) will be implemented in a numerical simulation and software platform tool. The results from the experiments will be used for the tuning (calibration) of the model. Finally, the workpackage will adapt the software tool for exploitation in design processes and safety studies. Furthermore, an additional set of validation experiments will be performed in Workpackage 7 (Model Validation), where the ship domain will also be investigated. The model will then, if necessary, be adapted.

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Appendix 1: Car scenarios related to Speed Management

Operator support system: Intelligent speed adaptation (ISA)

ISA provides drivers with support on the speed-control task by constantly monitoring the vehicle speed and comparing it with the local speed limits. Appropriate speed limits are determined by pin-pointing the vehicle's location on the road network via GPS signals. An ISA system that provides warnings only reminds the driver of the appropriate speed limit and triggers visual and/or auditory warnings when the vehicle's speed exceeds the speed limit.

Twenty-three scenarios were made based the ISA system and the 10 common hypotheses. These scenarios are described as follows.

H1: Sensation-seeking operators adopt (or choose) shorter warning thresholds

Elements	**Scenario**	
Title	CAR1 SM H1	
Situation	Road with many changes in speed limit, and system re-enables at every sign. System is advisory (warning) ISA	
Hypothesis	Sensation-seeking operators turn advisory systems off	
Operator	Car drivers	
Operator state/characteristic	Sensation-seekers	Non-Sensation seekers
Operator manipulation	None	
Trigger	Speed signs with downward changes in limit	
Expected reactions from operator on the trigger	Less than full compliance	
Expected reactions from the operator on the system warning	Ignore and puts in standby	
Environment: road/track	Country road with numerous small villages	
Environment: traffic conditions or other vehicles/objects	Sparse traffic	
Environment: weather and light conditions	Normal	
Measures before experiment	Recruitment on SS (High and Low)	
Measures during experiment	Speed, warnings	
Measures after experiment	None	

Elements	Scenario
Title	CAR2 SM H1
Situation	Does not require a specific situation, the hypothesis relates to setting the system pre-drive.
Hypothesis	SS will select a warning threshold higher than the speed limit.
Operator	Car drivers
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.
Operator manipulation	None
Trigger	NA
Expected reactions from operator on the trigger	NA
Expected reactions from the operator on the system warning	NA
Environment: road/track	NA
Environment: traffic conditions or other vehicles/objects	NA
Environment: weather and light conditions	NA
Measures before experiment	Questionnaires on what threshold they would select.
Measures during experiment	NA
Measures after experiment	Could be interesting to ask again after system exposure
Notes	Requires a system where the operator can set the warning threshold themselves

H2: Sensation-seeking operators will behave in such a way that more warnings will be triggered

Elements	Scenario	
Title	CAR3 SM H2	
Situation	Road with many changes in speed limit, and advisory (warning) ISA cannot be disabled	
Hypothesis	Sensation-seeking operators will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Sensation-seekers	Non-SS
Operator manipulation	None	
Trigger	All changes in speed limit	
Expected reactions from operator on the trigger	Continue to exceed the limit	
Expected reactions from the operator on the system warning	Ignore	
Environment: road/track	Country road with numerous small villages	
Environment: traffic conditions or other vehicles/objects	Sparse traffic	
Environment: weather and light conditions	Normal	
Measures before experiment	Recruitment on SS (High and Low)	
Measures during experiment	Speed, warnings	
Measures after experiment	None	
Notes		

Elements	Scenario	
Title	CAR4 SM H2	
Situation	Road with fast straights and many sharp curves. Advisory (warning) ISA with curve speed warning feature that cannot be disabled	
Hypothesis	Sensation-seeking operators will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Sensation-seekers	Non-SS
Operator manipulation	None	
Trigger	Approach to curves	
Expected reactions from operator on the trigger	Drives too fast	
Expected reactions from the operator on the system warning	Ignore	
Environment: road/track	Country road with numerous sharp curves	
Environment: traffic conditions or other vehicles/objects	Sparse traffic and very few opposing vehicles	
Environment: weather and light conditions	Normal	
Measures before experiment	Recruitment on SS (High and Low)	
Measures during experiment	Speed around curves, warnings	
Measures after experiment	None	
Notes		

Elements	Scenario
Title	CAR5 SM H2
Situation	Rural road with free flow driving.
Hypothesis	SS will trigger more warnings
Operator	Car drivers
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.
Operator manipulation	None
Trigger	No trigger
Expected reactions from operator on the trigger	NA
Expected reactions from the operator on the system warning	Reduce speed
Environment: road/track	Rural road
Environment: traffic conditions or other vehicles/objects	Some traffic but good possibilities to reach the speed limit
Environment: weather and light conditions	Dry and sunny
Measures before experiment	SS-scale
Measures during experiment	Speed, no of warnings
Measures after experiment	
Notes	

Elements	**Scenario**
Title	CAR6 SM H2
Situation	Rural road with a few sharp bends, Curve speed warning system
Hypothesis	SS-drivers will trigger more warnings
Operator	Car drivers
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.
Operator manipulation	None
Trigger	Approach to curve, a few 100 metres before the system is activated
Expected reactions from operator on the trigger	The higher the SS score the higher the approach speed and/or the later the driver reduces speed.
Expected reactions from the operator on the system warning	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few sharp curves.
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage through the curve.
Environment: weather and light conditions	Dry and sunny
Measures before experiment	SS-scale
Measures during experiment	Speed, no of warnings, use of brakes
Measures after experiment	
Notes	

Elements	Scenario
Title	CAR7 SM H2
Situation	Roadwork with reduced speed limit
Hypothesis	SS-drivers will trigger more warnings
Operator	Car drivers
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.
Operator manipulation	None
Trigger	Approach to roadwork, a few 100 metres before the speed limit is lowered
Expected reactions from operator on the trigger	The higher the SS score the higher the speed and/or the later the driver reduces speed.
Expected reactions from the operator on the system warning	Reduce speed
Environment: road/track	Motorway where one lane is closed off due to roadwork
Environment: traffic conditions or other vehicles/objects	No cars in front obstructing the speed choice, cars in a queue behind.
Environment: weather and light conditions	Dry and sunny
Measures before experiment	SS-scale
Measures during experiment	Speed, no of warnings
Measures after experiment	
Notes	

H3: Sensation-seeking operators will seek stimulation to cope with monotonous situations

Elements	**Scenario**	
Title	CAR8 SM H3	
Situation	Monotonous road with roadside vehicle-activated signs or flashing posts	
Hypothesis	Sensation-seeking operators will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Sensation-seekers	Non-SS
Operator manipulation	None	
Trigger	Speed limit	
Expected reactions from operator on the trigger	Exceed the limit	
Expected reactions from the operator on the system warning	Encourages misbehaviour	
Environment: road/track	Boring motorway	
Environment: traffic conditions or other vehicles/objects	Sparse traffic	
Environment: weather and light conditions	Dusk or night	
Measures before experiment	Recruitment on SS (High and Low)	
Measures during experiment	Speed, warnings	
Measures after experiment	None	
Notes		

Elements	**Scenario**
Title	CAR9 SM H3
Situation	Motorway driving with light traffic. Mean speed of surrounding traffic slightly lower than the speed limit
Hypothesis	SS-drivers will overtake, undertake and change lanes more often
Operator	Car drivers
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.
Operator manipulation	None
Trigger	Start of motorway
Expected reactions from operator on the trigger	The higher the SS score the more vehicles will be overtaken. The higher the SS score the more lane changes will be performed.
Expected reactions from the operator on the system warning	No system warning
Environment: road/track	Motorway
Environment: traffic conditions or other vehicles/objects	Autonomous traffic with a mean speed slightly lower than the speed limit.
Environment: weather and light conditions	Dry and sunny
Measures before experiment	SS-scale
Measures during experiment	Speed, no of lane changes, no of overtakings
Measures after experiment	
Notes	Questionnaire on monotony in pilot

Elements	Scenario	
Title	CAR10 SM H3	
Situation	Boring rural road with curves of varying radius	
Hypothesis	SS-drivers will have a higher curve speed.	
Operator	Car drivers	
Operator state/characteristic	Two groups scoring high and low on the SS-scale alternatively we use the SS-score as a variable for each driver.	
Operator manipulation	None	
Trigger	Approach to curve(s)	
Expected reactions from operator on the trigger	The higher the SS score the higher the approach speed. The higher the SS score the higher the minimum speed through the curve. The higher the SS score the later will they slow down before the curve.	Low SS will have lower speeds
Expected reactions from the operator on the system warning	No system warning	
Environment: road/track	Rural road	
Environment: traffic conditions or other vehicles/objects	Autonomous traffic oncoming to add realism.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	SS-scale	
Measures during experiment	Approach speed, minimum speed, brake point, path through curve, TTC, TLC	
Measures after experiment		
Notes		

H4: Experienced operators will receive fewer warnings than inexperienced operators

Elements	**Scenario**	
Title	CAR11 SM H4	
Situation	Village at bottom of steep hill	
Hypothesis	Experienced drivers will slow down e.g. by gear change down (or shift of automatic into low) well in advance	
Operator	Car drivers	
Operator state/characteristic	Experienced in terms of lifetime experienced, more than 5 years	Recently qualified, less than 2 years of driving
Operator manipulation	None	
Trigger	Speed sign on village entry	
Expected reactions from operator on the trigger	Comply with limit	Brake after sign
Expected reactions from the operator on the system warning	No warning because has already slowed in advance	Gets warning because has not anticipated need to slow down in advance
Environment: road/track	Steep down grade on single carriageway 2-lane road. Village in valley.	
Environment: traffic conditions or other vehicles/objects	No other vehicles	
Environment: weather and light conditions	Daylight and dry	
Measures before experiment	None	
Measures during experiment	Speed, gear choice, deceleration on hill, speed at village entry, deceleration around village entry, number of warnings	
Measures after experiment	None	
Notes	May need to be precise about day and time, e.g. so that children could be expected on way to school	

Elements	Scenario	
Title	CAR12 SM H4	
Situation	Rural road with a few sharp bends. Curve speed warning system	
Hypothesis	Inexperienced drivers will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Experienced	Inexperienced
Operator manipulation	None	
Trigger	Approach to curve, a few 100 metres before the system is activated	
Expected reactions from operator on the trigger	Lift off accelerator to slowly reduce speed	Maintain driving speed and approach curve fast
Expected reactions from the operator on the system warning	No warning given	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few sharp curves.	
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage through the curve.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	Questionnaire on experience	
Measures during experiment	Speed, no of warnings, use of brake, use of gear	
Measures after experiment		
Notes		

Elements	Scenario	
Title	CAR13 SM H4	
Situation	Lower speed limit ahead	
Hypothesis	Inexperienced drivers will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Experienced	Inexperienced
Operator manipulation	None	
Trigger	When the speed limit sign is in sight	
Expected reactions from operator on the trigger	Lift off accelerator to slowly reduce speed	Maintain driving speed
Expected reactions from the operator on the system warning	No warning given	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few curves "hiding" the sign.	
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage at the speed sign.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	Questionnaire on experience	
Measures during experiment	Speed, no of warnings, use of brake	
Measures after experiment		
Notes	Could apply to both experience of driving and of road	

H5: Fatigued operators will rely on the system to warn them about a critical situation

Elements	Scenario	
Title	CAR 14 SM H5	
Situation	Approaching sharp horizontal curve after fast straight. *Dynamic* system that only warns drivers when their approach speed is over a threshold.	
Hypothesis	Fatigued operators will rely on system to warn them about critical situations	
Operator	Young drivers may be preferable for both speed and fatigue reasons	
Operator state/characteristic	Fatigued – sleep deprived or disturbed (e.g. shift workers	Not sleep deprived or disturbed
Operator manipulation	Boring road in first part of the scenario	No boring road in first part of scenario
Trigger	Curve approach – warning location could be speed dependent. Will also need curves without the warning with identical geometry.	
Expected reactions from operator on the trigger	Not slow or delayed response	Slow down
Expected reactions from the operator on the system warning	Slow	None
Environment: road/track	2-lane rural. Slippery road could help.	
Environment: traffic conditions or other vehicles/objects	Opposing traffic. No shoulder.	
Environment: weather and light conditions	Not raining. Wet surface (puddles).	
Measures before experiment	Physiological measures for fatigue and/or KSS. Reaction time task.	
Measures during experiment	PERCLOS. KSS? (issue of interference), speed, braking behaviour, deceleration, lateral friction, TLC, ESC activation	
Measures after experiment	None	
Notes		

Elements	Scenario	
Title	CAR15 SM H5	
Situation	Approaching horizontal curve (not too sharp, not too gentle) after fast straight. Dynamic system that only warns drivers when their approach speed is over a threshold. System can be enabled/disabled at will.	
Hypothesis	Fatigued operators will rely more on the system to warn them about critical situations	
Operator	Car drivers	
Operator state/characteristic	Fatigued – sleep deprived or disturbed (e.g. shift workers	Not sleep deprived or disturbed
Operator manipulation	Boring road	No boring road
Trigger	Curve approach	
Expected reactions from operator on the trigger	Not slow down	Slow down
Expected reactions from the operator on the system warning	Slow down	None (no warning)
Environment: road/track	2-lane rural	
Environment: traffic conditions or other vehicles/objects	No opposing traffic. No shoulder.	
Environment: weather and light conditions	Misty, grey, maybe night-time	
Measures before experiment	Physiological measures for fatigue and/or KSS. Reaction time task.	
Measures during experiment	PERCLOS. KSS? (issue of interference), speed, enabling of system, warnings	
Measures after experiment	Debrief	
Note	Confirm monotony in piloting	

Elements	**Scenario**	
Title	CAR16 SM H5	
Situation	Rural road with a few sharp bends, Curve speed warning system	
Hypothesis	Fatigued drivers will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Alert	Fatigued
Operator manipulation	None	Shift workers in the morning
Trigger	Approach to curve, a few 100 meters before the system is activated	
Expected reactions from operator on the trigger	Lift off accelerator to slowly reduce speed	Maintain driving speed and approach curve fast
Expected reactions from the operator on the system warning	No warning given	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few sharp curves.	
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage through the curve.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	Questionnaire on hours awake, KSS	
Measures during experiment	Speed, no of warnings, use of brake, KSS	
Measures after experiment	KSS	
Notes		

H6: Operators will receive more warnings when fatigued than when alert

Elements	**Scenario**	
Title	CAR17 SM H6	
Situation	Village entry	
Hypothesis	Fatigued drivers will miss roadside speed sign and therefore subsequently get an alert from a warning ISA. Non-fatigued will be less prone to miss the sign.	
Operator	Car driver	
Operator state/characteristic	Fatigued – sleep deprived or disturbed (e.g. shift workers	Not sleep deprived or disturbed
Operator manipulation	Boring road in first part of the scenario	No boring road in first part of the scenario
Trigger	Speed sign on village entry	
Expected reactions from operator on the trigger	Misses sign	Pays attention, slows down
Expected reactions from the operator on the system warning	Realises error and slows down	NA (no warning)
Environment: road/track	Rural followed by village. Speed sign precedes village by some distance so that drivers cannot perceive the village ahead.	
Environment: traffic conditions or other vehicles/objects	No traffic **OR** preceding car does not slow down	
Environment: weather and light conditions	Sign not too conspicuous	
Measures before experiment	Physiological measures for fatigue and/or KSS. Reaction time task.	
Measures during experiment	PERCLOS; eye movements to confirm whether drivers have looked at the sign	
Measures after experiment	None	
Notes	Requires eye tracking	

Elements	Scenario	
Title	CAR18 SM H6	
Situation	Rural road with a few sharp bends, Curve speed warning system	
Hypothesis	Fatigued drivers will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Alert	Fatigued
Operator manipulation	None	Shift workers in the morning
Trigger	Approach to curve, a few 100 metres before the system is activated	
Expected reactions from operator on the trigger	Lift off accelerator to slowly reduce speed	Maintain driving speed and approach curve fast
Expected reactions from the operator on the system warning	No warning given	Reduce speed
Environment: road/track	Rural road, mainly straight fairly high speed sections with a few sharp curves.	
Environment: traffic conditions or other vehicles/objects	Some traffic for cosmetic purposes between curves but undisturbed passage through the curve.	
Environment: weather and light conditions	Dry and sunny	
Measures before experiment	Questionnaire on hours awake, KSS	
Measures during experiment	Speed, no of warnings, use of brake, KSS	
Measures after experiment	KSS	
Notes	Exactly the same as CAR16 SM H5	

H7: Fatigued operators will have less situational awareness than alert operators

Elements	**Scenario**	
Title	CAR19 SM H7	
Situation	School zone marked by roadside signs	
Hypothesis	Fatigued operators will have less situation awareness than alert operators	
Operator	Car drivers	
Operator state/characteristic	Fatigued — sleep deprived or disturbed (e.g. shift workers	Not sleep deprived or disturbed
Operator manipulation	Boring road in first part of scenario	No boring road in first part of scenario
Trigger	School sign and 30 km/h roundel on road	
Expected reactions from operator on the trigger	None	Slow down
Expected reactions from the operator on the system warning	Slow down	No warning
Environment: road/track	Urban road with buildings and children	
Environment: traffic conditions or other vehicles/objects	Light traffic	
Environment: weather and light conditions	Normal	
Measures before experiment	Physiological measures for fatigue and/or KSS. Reaction time task.	
Measures during experiment	PERCLOS. KSS? (issue of interference), speed, warnings	
Measures after experiment	None	
Notes		

H8: Fatigued operators may compensate for their fatigue by increasing the safety margin

Elements	**Scenario**	
Title	CAR20 SM H8	
Situation	Motorway roadworks with narrow lanes and 80 km/h (or even 90 km/h) speed limit. Some downhill sections so that cars tend to speed up.	
Hypothesis	Fatigued operators may compensate for their fatigue by increasing the safety margins.	
Operator	Car drivers	
Operator state/characteristic	Fatigued – sleep deprived or disturbed (e.g. shift workers	Not sleep deprived or disturbed
Operator manipulation	Boring road in first part of scenario	No boring road in first part of scenario
Trigger	Road works and speed limit	
Expected reactions from operator on the trigger	Slow down by extra amount	Slow down
Expected reactions from the operator on the system warning	Fewer warnings	More warnings
Environment: road/track	Motorway	
Environment: traffic conditions or other vehicles/objects	Medium traffic driving at speed limit	
Environment: weather and light conditions	Normal	
Measures before experiment	Physiological measures for fatigue and/or KSS. Reaction time task.	
Measures during experiment	PERCLOS. KSS? (issue of interference), speed, warnings	
Measures after experiment	None	
Notes		

H9: Operators will receive more warnings when under low workload

Elements	Scenario
Title	CAR21 SM H9
Situation	High quality urban arterial road (e.g. 4-lane dual carriageway or multilane one-way street)
Hypothesis	Low workload (few "threats") induces high speed
Operator	Car driver
Operator state/characteristic	
Operator manipulation	Low workload (perhaps after high workload more busy scene) e.g. leaving centre city. Medium workload too.
Trigger	Transition to easy stretch of road
Expected reactions from operator on the trigger	Speeds up
Expected reactions from the operator on the system warning	Slows down if speed compliant
Environment: road/track	Urban roads
Environment: traffic conditions or other vehicles/objects	Other vehicles ahead and in adjacent lanes speed up at trigger
Environment: weather and light conditions	Dry, sunny
Measures before experiment	Attitudes on speed. Workload by stretch of road is to be measured in piloting.
Measures during experiment	Speed, number of warnings
Measures after experiment	Debrief
Notes	

Elements	Scenario	
Title	CAR22 SM H9	
Situation	Rural road with vertical curves	
Hypothesis	Drivers with low workload will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	Low workload	Medium workload
Operator manipulation	None	None
Trigger	At the start of a descent	
Expected reactions from operator on the trigger	Not notice that the car increases speed downhill	Adjust their speed to prevent warnings.
Expected reactions from the operator on the system warning	Reduce speed	No warning
Environment: road/track	Rural road with vertical curves, boring.	
Environment: traffic conditions or other vehicles/objects	No, or little traffic	Medium traffic requiring the driver to actively regulate their speed
Environment: weather and light conditions	Dry and sunny	
Measures before experiment		
Measures during experiment	Speed, warnings issued (workload)	
Measures after experiment	Workload	
Notes	Workload obviously needs to be measured without creating some workload. Hard to do in simulator.	

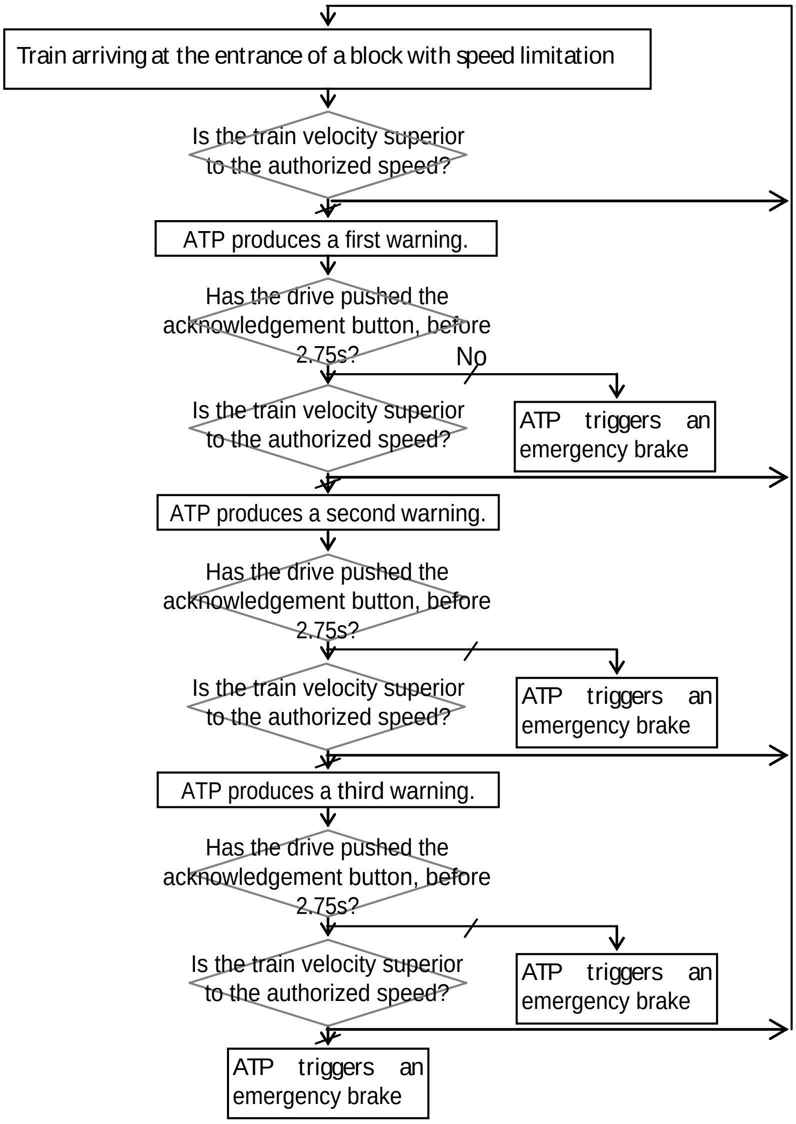
H10: Operators will receive more warnings when under high workload

Elements	Scenario	
Title	CAR23 SM H10	
Situation	Weaving section, lots of lane changes, speed signs on overhead gantry (so not masked by other vehicles)	
Hypothesis	High workload of maintaining sit awareness of surrounding traffic leads to missing change in limit and hence more warnings	
Operator	Car driver on unfamiliar route	
Operator state/characteristic		
Operator manipulation	High workload	
Trigger	Change to lower limit (e.g. 110km/h to 80 km/h)	
Expected reactions from operator on the trigger	Misses trigger	
Expected reactions from the operator on the system warning	Slows down	
Environment: road/track	Multi-lane road such a motorway which becomes urban motorway	
Environment: traffic conditions or other vehicles/objects	Lots of jumpy vehicles	Low density, non-aggressive traffic
Environment: weather and light conditions	Misty and sunny (different stretches)	
Measures before experiment	Verify workload in piloting	
Measures during experiment	Eye movements, speed, deceleration on warning	
Measures after experiment	None	
Notes		

Appendix 2: Train scenarios related to Speed Management

Operator support system: Automatic Train Protection (ATP)

The aim of ATP is to inform the train driver about over-speed. If the train velocity is superior to the speed limitation of the location where the train is arriving, the ATP produces a sound. The driver has to acknowledge the information given by the system by pushing the acknowledgement button, in 2,75s. If after 2,75s the driver has not pushed the acknowledgment button, an emergency brake is triggered. The driver who has acknowledged the information given by the ATP is supposed to brake. If the velocity of the train does not reduce after the acknowledgment by the driver, the ATP produces a sound again. The driver can make the ATP sound trigger three times. After these three times, the train is stopped by an emergency brake. Usually train drivers wait the third sound produced by the ATP to brake, particularly when they are behind schedule. This statement is used in several scenarios presented in this document. The diagram given in the figure below describes the ATP strategy. As sensation seeking is usually not a characteristic of train drivers, sensation seeking may be replaced by risk-taking.



Thirteen scenarios were made based the ATP system and the 10 common hypotheses. These scenarios are described as follows.

H1: Sensation-seeking operators adopt (or choose) shorter warning thresholds

Elements	**Scenario**
Title	TRAIN1 SM H1
Situation	The train is going to be behind schedule. The driver has to be on time. The ATP produced the signal in order to inform the driver about over-speed.
Hypothesis	A **risk taker driver** acknowledges the ATP signal and accelerates, while the ATP signal implies braking.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters
Operator state/characteristic	Risk taking driver
Operator manipulation	No manipulation
Trigger	Delay warning (Control Room warning?)
Expected reactions from operator on the trigger	Push the accelerator
Expected reactions from the operator on the system warning	Give up accelerating and brake
Environment: road/track	Straight track, allowing acceleration
Environment: traffic conditions or other vehicles/objects	No obstacle on the railroad, allowing acceleration
Environment: weather and light conditions	Good weather and daytime, with clear visibility
Measures before experiment	Degree of the driver sensation seeking
Measures during experiment	Stress on the acknowledgment button; Stress on the brake pedal; Stress on the accelerator pedal; View of the cabin, movements of the driver
Measures after experiment	
Notes	

H2: Sensation-seeking operators will behave in such a way that more warnings will be triggered

Elements	Scenario	
Title	TRAIN2 SM H2	
Situation	The train is going to be behind schedule. The driver has to be on time, otherwise she/he will be punished.	
Hypothesis	A sensation seeker accelerates instead of driving safely in order to decrease the delay. She/he evokes the maximal number of ATP signals before the occurring of the emergency brake.	A non-sensation seeker drives safely in order to decrease the delay. She/he evokes the minimal number of ATP signals.
Operator	Experienced, no fatigued, no under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Sensation seeker	No sensation seeker
Operator manipulation	No manipulation	
Trigger	Delay warning (Control Room warning?)	
Expected reactions from operator on the trigger	Push the accelerator	
Expected reactions from the operator on the system warning	Give up accelerating and brake	
Environment: road/track	Straight track, allowing acceleration	
Environment: traffic conditions or other vehicles/objects	No obstacle on the railroad, allowing acceleration	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Stress on the acknowledgment button; Stress on the brake pedal; Stress on the accelerator pedal; View of the cabin, movements of the driver	
Measures after experiment		
Notes		

H3: Sensation-seeking operators will seek stimulation to cope with monotonous situations

No scenarios

H4: Experienced operators will receive fewer warnings than inexperienced operators

Elements	**Scenario**
Title	TRAIN3 SM H4
Situation	Approaching vertical curve requiring managing (acceleration / deceleration) the speed limit, speed warning system, and perhaps the management of electrical energy device (pantograph state, not relevant for diesel engine)
Hypothesis	Experienced operators will moderate their speed in a timely manner and thereby receive fewer warnings than an inexperienced operator
Operator	Train driver
Operator state/characteristic	**Experienced** driver in terms of years of driving and annual distance driven. **Experienced** in terms of route knowledge
Operator manipulation	Training with and without the curve to gain experience of route Directives to make up for delays and unplanned stops into the curve (due to low speed and heavy train: impossible to join the top of the mountain)
Trigger	Strategies for managing the speed due to approaching curve
Expected reactions from operator on the trigger	The driver decelerates appropriately
Expected reactions from the operator on the system warning	Does not get warning
Environment: road/track	Track with mountains involving vertical curves, good possibility to reach the speed limit and management. Speed signs.
Environment: traffic conditions or other vehicles/objects	
Environment: weather and light conditions	Dry track, sunny day, good visibility
Measures before experiment	Years of driving
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Warnings triggered
Measures after experiment	
Notes	

Elements	Scenario	
Title	TRAIN4 SM H4	
Situation	Approaching vertical and horizontal curve requiring a management of the speed limit, speed warning system, and the electrical energy device (pantograph state, no relevant for diesel engine)	
Hypothesis	Experienced operators will moderate their speed in a timely manner and thereby receive fewer warnings than an inexperienced operator	
Operator	Train driver	
Operator state/characteristic	**Experienced** driver in terms of years of driving and annual distance driven. **Experienced** in terms of route knowledge	**Inexperienced** driver in terms of years of driving and annual distance driven. **Inexperienced** in terms of route knowledge
Operator manipulation	Training with and without the curves to gain experience of route Directives to make up for delays and unplanned stops into the curve (due to low speed and heavy train: impossible to join the top of the mountain...)	
Trigger	Strategies for managing the speed due to approaching curve	
Expected reactions from operator on the trigger	The driver decelerates appropriately	The driver decelerates too late or not at all
Expected reactions from the operator on the system warning	Does not get warning	Brakes after being warned
Environment: road/track	Track with tangents and horizontal curves, good possibility to reach the speed limit. Speed sign.	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility	
Measures before experiment	Years of driving	
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Warnings triggered	
Measures after experiment		
Notes		

H5: Fatigued operators will rely on the system to warn them about a critical situation

Elements	**Scenario**	
Title	TRAIN5 SM H5	
Situation	Approaching vertical and/or horizontal curve requiring a management of the speed limit, the speed warning system, and the electrical energy device (pantograph state, no relevant for diesel engine) Presence of an obstacle of the tracks	
Hypothesis	Fatigued operators will use frequently the system to manage critical and surprising situations	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission.	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned or system braking system activation	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects	Presence of an obstacle of the tracks	
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment	Fatigue and alert indicators	
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Measures after experiment	Fatigue and alert indicators	
Notes		

Elements	Scenario	
Title	TRAIN6 SM H5	
Situation	Approaching vertical and/or horizontal curve requiring a management of the speed limit, the speed warning system, and the electrical energy device (pantograph stat, not relevant for diesel engine) Electrical energy device problem due to climate conditions (snow or frost)	
Hypothesis	Fatigued operators will use frequently the system to manage critical and surprising situations	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned or system braking system activation	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects	Presence of an obstacle of the tracks	
Environment: weather and light conditions	Snow and frost	
Measures before experiment	Fatigue and alert indicators	
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Measures after experiment	Fatigue and alert indicators	
Notes		

Elements	**Scenario**	
Title	TRAIN7 SM H5	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time and presence of an obstacle on the track	
Hypothesis	Fatigued operators will use frequently the system to manage critical and surprising situations	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned or system braking system activation	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects	Presence of an obstacle on the track	
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment	Fatigue and alert indicators	
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Measures after experiment	Fatigue and alert indicators	
Notes		

H6: Operators will receive more warnings when fatigued than when alert

Elements	Scenario	
Title	TRAIN8 SM H6	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time	
Hypothesis	Alert operators will moderate their speed in a timely manner and thereby receive fewer warnings than a fatigued operator	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment	Fatigue and alert indicators	
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Notes		

H7: Fatigued operators will have less situational awareness than alert operators

Elements	Scenario	
Title	TRAIN9 SM H7	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time	
Hypothesis	Alert operators will moderate their speed in a timely manner and thereby receive fewer warnings than a fatigued operator	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment		
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Measures after experiment	Fatigue and alert indicators; Situation awareness indicators	
Notes		

H8: Fatigued operators may compensate for their fatigue by increasing the safety margin

Elements	**Scenario**	
Title	TRAIN10 SM H8	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time	
Hypothesis	Fatigued operator may drive with lower speed than required and alert operator may drive with higher speed than required	
Operator	Train driver	
Operator state/characteristic	• Fatigued driver in terms of monotonous and repetitive task. • Fatigued driver at the beginning of the mission • Fatigued driver provoked by a long-term mission of driving	• Alert driver in terms of non monotonous and non repetitive task. • Alert driver at the beginning of the mission • Alert driver provoked by a short-term mission of driving
Operator manipulation	Training with or without repetitive and monotonous activity. Conditions for making the driver fatigued or alert before the mission. Definition of a short-term and a long-term mission	
Trigger	Strategies for managing fatigue	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment		
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Fatigue and alert indicators evolution; Warnings triggered	
Measures after experiment	Fatigue and alert indicators; Situation awareness indicators	
Notes		

H9: Operators will receive more warnings when under low workload

Elements	Scenario	
Title	TRAIN11 SM H9	
Situation	Approaching a station requiring a reduction of the speed limit to stop at time	
Hypothesis	Under-load operator may drive without respecting the appropriate speed	
Operator	Train driver	
Operator state/characteristic	• Under-loaded driver in terms of temporal task demands (low / high time pressure). • Under-loaded driver in terms of functional task demand (low / high task complexity)	• Normal loaded driver in terms of temporal task demands (no time pressure). • Normal loaded driver in terms of functional task demand (no complex task)
Operator manipulation	Conditions for making the driver overloaded or non - overloaded, under-loaded, or non under-loaded	
Trigger	Strategies for managing workload	
Expected reactions from operator on the trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from the operator on the system warning	Brakes after being warned	Does not get warning
Environment: road/track	Track with stations and planned stops	
Environment: traffic conditions or other vehicles/objects		
Environment: weather and light conditions	Dry track, sunny day, good visibility.	
Measures before experiment		
Measures during experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Situation awareness indicators; Workload indicators; Warnings triggered	
Measures after experiment	Situation awareness indicators; Workload indicators	
Notes		

H10: Operators will receive more warnings when under high workload

Elements	**Scenario**	
Title	TRAIN12 SM H10	
Situation	Overloaded operator may drive without respecting the appropriate speed	
Hypothesis	Train driver	
Operator	• Overloaded driver in terms of temporal task demands (low / high time pressure). • Overloaded driver in terms of functional task demand (low / high task complexity)	• Normal loaded driver in terms of temporal task demands (no time pressure). • Normal loaded driver in terms of functional task demand (no complex task)
Operator state/characteristic	Conditions for making the driver overloaded or non -overloaded, under-loaded, or non under-loaded	
Operator manipulation	Strategies for managing Workload	
Trigger	The driver decelerates and stops too late or not at all	The driver decelerates and stops appropriately
Expected reactions from operator on the trigger	Brakes after being warned	Does not get warning
Expected reactions from the operator on the system warning	Track with stations and planned stops	
Environment: road/track		
Environment: traffic conditions or other vehicles/objects	Dry track, sunny day, good visibility.	
Environment: weather and light conditions		
Measures before experiment	Vehicle speed (at various points); Jerks (Brake); Maximum braking; Acceleration/Deceleration management; Situation awareness indicators; Workload indicators; Warnings triggered	
Measures during experiment	Situation awareness indicators; Workload indicators	
Measures after experiment		
Notes		

Elements	**Scenario**	
Title	CAR 24 SM H10	
Situation	Rural road with vertical curves	
Hypothesis	Drivers with high workload will trigger more warnings	
Operator	Car drivers	
Operator state/characteristic	High workload	Medium workload
Operator manipulation	Arrows task, difficult	Arrows task, medium
Trigger	At the start of a descent	
Expected reactions from operator on the trigger	Not notice that the car increases speed downhill	Adjust their speed to prevent warnings.
Expected reactions from the operator on the system warning	Reduce speed	No warning
Environment: road/track	Rural road with vertical curves, boring.	
Environment: traffic conditions or other vehicles/objects	Little traffic	Little traffic
Environment: weather and light conditions	Dry and sunny	
Measures before experiment		
Measures during experiment	Speed, warnings issued (workload), arrows task performance	
Measures after experiment	Workload (maybe not needed because arrows task already validated)	
Notes	Workload obviously needs to be measured without creating some workload.	

Appendix 3: Car scenarios related to Collision Avoidance

Operator support system: Forward Collision Warning (FCW)

FCW can help avoid rear-end impacts or minimise the effects of these type of collisions. A radar continuously scans the area in front of a vehicle. If the vehicle approaches a lead vehicle too quickly or is too close to the lead vehicle, the driver is alerted via auditory and/or visual warnings.

Twenty-one scenarios were made based the FCW system and the 10 common hypotheses. These scenarios are described as follows.

H1: Sensation-seeking operators adopt (or choose) shorter warning thresholds

Elements	Scenario	
Title	CAR1 CA H1	
Situation	Car following on a single carriageway road, one lane in each direction, constant oncoming traffic	
Hypothesis	Risk Taking drivers will follow closer to a slow moving lead vehicle (e.g. seeking opportunity for overtaking) and would choose to set a shorter distance or time threshold for warning in order to avoid frequent warnings.	
Operator	Car driver	
Operator state/characteristic	Risk Taking drivers	Non risk taking drivers
Operator manipulation	N/A	
Trigger	Slow-moving lead vehicle	
Expected reactions from operator on the trigger	Close following	Keep a good following distance
Expected reactions from the operator on the system warning	Reset warning threshold	None (no warnings triggered)
Environment: road/track	Single carriageway road	
Environment: traffic conditions or other vehicles/objects	Not heavy traffic but the gaps of oncoming traffic would prevent safe overtaking	
Environment: weather and light conditions	Normal	
Measures before experiment	SS scale	
Measures during experiment	Warning thresholds, number of warnings, headway, throttle position, brake activation, attempts of overtaking (vehicle position in lane as well as vehicle cross the centre line)	
Measures after experiment		
Notes		

Elements	**Scenario**	
Title	CAR2 CA H1	
Situation	Target car is overtaking and then braking very hard in front of own vehicle	
Hypothesis	Sensation-seeking operators adopt (or chose) shorter warning thresholds	
Operator	Car driver	
Operator state/characteristic	High Sensation seeking = adopt short warning threshold	Low sensation seeking= adopt default warning threshold
Operator manipulation	N/A	
Trigger	Braking light on the lead vehicle (which just overtake)	
Expected reactions from operator on the trigger	The driver will receive a warning	The driver will receive a warning
Expected reactions from the operator on the system warning	React to the warning by braking	React to the warning by braking
Environment: road/track	Two lane motorway with a lot of traffic ahead	
Environment: traffic conditions or other vehicles/objects	Small truck ahead and other vehicle	
Environment: weather and light conditions	Foggy weather, daytime light	
Measures before experiment	Hazard perception test (before or after)	
Measures during experiment	TTC, Time headway, braking RT,	
Measures after experiment	Acceptance questionnaire about the warning (ex. timing)	
Notes	Requires a FCW where the warning threshold can be adjusted. Maybe the procedure for finding each driver preferred threshold is part of scenario to?	

H2: Sensation-seeking operators will behave in such a way that more warnings will be triggered

Elements	**Scenario**	
Title	CAR3 CA H2	
Situation	Car following on single carriageway, two lane road	
Hypothesis	Sensation-seeking drivers will have short headways to a slow lead car and trigger more warnings	
Operator	Car driver	
Operator state/characteristic	Sensation seeker	Non-sensation seeker
Operator manipulation	N/A	
Trigger	Slow car (non-sexy car) as a lead car Possibility: car speeds up if pushed then slows down again	
Expected reactions from operator on the trigger	Sensation seeker adopts shorter headway	
Expected reactions from the operator on the system warning	Ignore warning Create warning by pushing lead car	
Environment: road/track	Single carriageway, two lane road	
Environment: traffic conditions or other vehicles/objects	Sunday, no trucks, normal density, enough opposing traffic to avoid overtaking Slow car as a lead car	
Environment: weather and light conditions	Normal	
Measures before experiment	Sensation-seeking scale	
Measures during experiment	Standard driving behaviour; Headway; Number of warnings; Define and measure “pushing behaviour”	
Measures after experiment		
Notes		

Elements	Scenario	
Title	CAR4 CA H2	
Situation	Motorway driving, high density traffic, own car cutting in into a gap or pulling out (might be difficult to control in an experiment)	Motorway driving, high density traffic
Hypothesis	Sensation-seeking drivers in heavy and semi-chaotic traffic will receive more warnings	
Operator	Car driver	
Operator state/characteristic	High sensation-seeking	Non-sensation seeking
Operator manipulation	Missing	
Trigger	Own behaviour, cutting in on other traffic and accelerating towards the lead car before a lane change	
Expected reactions from operator on the trigger	See above	
Expected reactions from the operator on the system warning	Ignore warning	No warning
Environment: road/track	Motorway, with entrance ramp to vary the traffic flow	
Environment: traffic conditions or other vehicles/objects	High traffic density Speed variation between lanes	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Sensation seeking test, for selecting participants	
Measures during experiment	Speed adjustment; Number of warnings; Reaction time to warnings; Lane changing behaviour; Standard driving behaviour measures	
Measures after experiment		
Notes		

H3: Sensation-seeking operators will seek stimulation to cope with monotonous situations

Elements	**Scenario**	
Title	CAR5 CA H3	
Situation	Slow lead car on long narrow rural road	
Hypothesis	*Sensation-seeking operators will seek stimulation to cope with monotonous situations.*	
Operator	Car driver	
Operator state/characteristic	Sensation seeker	Non sensation seeker
Operator manipulation		
Trigger	Sensation seeker will come too close to lead car and warning will be given	Non-sensation seeker will maintain safe distance, no warning
Expected reactions from operator on the trigger		
Expected reactions from the operator on the system warning	Ignore warning	No reaction to warning or switch off the system
Environment: road/track	Long narrow rural road, no possibility to overtake lead car	
Environment: traffic conditions or other vehicles/objects	No other traffic	
Environment: weather and light conditions	Normal	
Measures before experiment	Sensation seeking scale for participant selection	
Measures during experiment	Speed, number of warnings, TTC	
Measures after experiment	Debriefing	
Notes		

Elements	Scenario	
Title	CAR6 CA H3	
Situation	Car following task on a monotonous 2 lane motorway with light traffic	
Hypothesis	Sensation seeking operator will seek stimulation to cope with monotonous situations	
Operator	Car driver	
Operator state/characteristic	High Sensation seeking = adopt short warning threshold	Low sensation seeking= adopt default warning threshold
Operator manipulation	Braking light on from the leading vehicle, in this case a small truck	
Trigger	Secondary task?	Secondary task
Expected reactions from operator on the trigger	The driver receives several warnings	The driver receives the warning once
Expected reactions from the operator on the system warning	Reacts to the warning by braking	No warning
Environment: road/track	Two lane motorway with light traffic	
Environment: traffic conditions or other vehicles/objects	Vehicle ahead	
Environment: weather and light conditions	good weather, daytime light	
Measures before experiment	Hazard perception test (before or after)	
Measures during experiment	TTC, Time headway, braking RT, performance on the secondary/distraction task	
Measures after experiment	Acceptance questionnaire about the warning (ex. timing)	
Notes		

H4: Experienced operators will receive fewer warnings than inexperienced operators

Elements	Scenario	
Title	CAR7 CA H4	
Situation	Roadworks, single lane traffic, construction vehicle pulls out, cars in front have to brake to let it in	
Hypothesis	Experienced drivers will anticipate potential hazards, and get fewer warnings	
Operator	Car drivers	
Operator state/characteristic	Experienced drivers: 10.000 km a year and more than 5 years after driving license	Inexperienced drivers, less than 2 years after license
Operator manipulation		
Trigger	construction vehicle pulls out, cars in front have to brake to let it in	
Expected reactions from operator on the trigger	Experienced driver anticipates by slowing down	Inexperienced driver is surprised, does not anticipate by braking
Expected reactions from the operator on the system warning	No warning	Inexperienced driver gets warning slows down
Environment: road/track	Two lane road going to one lane with roadworks Slightly curvy	
Environment: traffic conditions or other vehicles/objects	High traffic density Construction vehicle 3 cars ahead own car, braking lights of cars ahead should be visible	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Experience Hazard perception test	
Measures during experiment	Standard driving behaviour, braking, speed etc. Number of warnings	
Measures after experiment	Debriefing afterwards, asking when did you perceive a potential problem?	
Notes		

Elements	**Scenario**	
Title	CAR8 CA H4	
Situation	Driving behind a long queue of cars, heavy traffic in both lanes	
Hypothesis	Experienced drivers will anticipate potential hazards, and get fewer warnings	
Operator	Car drivers	
Operator state/characteristic	Experienced drivers: 10.000 km a year and more than 5 years after driving license	Inexperienced drivers, less than 2 years after license
Operator manipulation		
Trigger	Car in front barking even if others car in the front are not braking	
Expected reactions from operator on the trigger	Experienced driver anticipates by slowing down	Inexperienced driver does not brake
Expected reactions from the operator on the system warning	No warning	Warning issued
Environment: road/track	Two lane motorway	
Environment: traffic conditions or other vehicles/objects	Heavy traffic in both lanes, long queue of cars in front of own car	
Environment: weather and light conditions	good weather, daytime light	
Measures before experiment	Hazard perception test (before or after)	
Measures during experiment	TTC, Time headway, braking RT	
Measures after experiment	Acceptance questionnaire about the warning (ex. timing)	
Notes		

H5: Fatigued operators will rely on the system to warn them about a critical situation

Elements	**Scenario**	
Title	CAR9 CA H5	
Situation	Motorway, light traffic	
Hypothesis	Fatigued drivers would rely on the FCW to warning them of the events when a lead car is close	
Operator	Professional drivers	
Operator state/characteristic	Fatigue due to completing a shift prior to commending the experiment	Non-fatigued drivers; no sign of fatigue prior to commencing the experiment
Operator manipulation	Experiment starts with a 10-min boring drive	
Trigger	Presence of a lead vehicle (either the host vehicle gradually closes up the gap, or a car cutting in)	
Expected reactions from operator on the trigger	Receive warnings	Increase headway promptly
Expected reactions from the operator on the system warning	Increase headway upon warnings	None (because no warnings)
Environment: road/track	Motorway	
Environment: traffic conditions or other vehicles/objects	Light traffic	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	History of driving activities prior to attending the experiment; Sleepiness	
Measures during experiment	Headway; Number of warnings; Speed variation	
Measures after experiment		
Notes		

Elements	**Scenario**	
Title	CAR10 CA H5	
Situation	A small truck is braking very fast due to congestion in the front	
Hypothesis	Fatigue operator swill rely on the system to warn them about a critical situation	
Operator	Car driver	
Operator state/characteristic	Fatigue operator	Alert operator
Operator manipulation	Fatigue: sleep deprivation the night before the experiment	none
Trigger	Braking light on from the leading vehicle, in this case a small truck	
Expected reactions from operator on the trigger	React to the warning	React to the warning
Expected reactions from the operator on the system warning	Longer reaction time to the warning by braking	Faster reaction time to the warning by braking
Environment: road/track	Two lane motorway with a lot of traffic ahead	
Environment: traffic conditions or other vehicles/objects	Small truck ahead and other vehicle	
Environment: weather and light conditions	Foggy weather, daytime light	
Measures before experiment	KSS	
Measures during experiment	KSS, TTC, Time headway, braking RT, number of warnings received,	
Measures after experiment	Acceptance scale	
Notes		

H6: Operators will receive more warnings when fatigued than when alert

Elements	Scenario	
Title	CAR11 CA H6	
Situation	Unexpected event: obstacle on the road, broke down vehicle sticking out	
Hypothesis	Fatigued driver will notice an unexpected event later and gets more warnings	
Operator	Car driver	
Operator state/characteristic	Fatigue induced by experiment	Non-fatigued
Operator manipulation	Making drivers fatigued by high effort driving, followed by boring driving with cruise control, followed by an event	Only short pre-drive
Trigger	Vehicle broken down intruding into the driver's path on a two-lane road	
Expected reactions from operator on the trigger	Notices the broke-down vehicle too late	Notices the broke-down vehicle and brakes
Expected reactions from the operator on the system warning	Warning issued, brakes or goes to the other lane	No warning
Environment: road/track	Two lane road with small shoulder	
Environment: traffic conditions or other vehicles/objects	Normal traffic, in opposing lane either high or low density traffic to have a consistent reaction (brake or go to opposite lane)	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Pilot to verify whether drivers do get fatigued	
Measures during experiment	Eye-movements (perclos) to measure fatigue; KSS after pre-event intervals; Brake and lane change; Start of reaction; Standard driving measures including max deceleration; Number of warnings	
Measures after experiment		
Notes		

Elements	Scenario	
Title	CAR12 CA H6	
Situation	Parked bus not using turning signal will drive in front of own vehicle	
Hypothesis	Fatigued driver will notice an unexpected event later and gets more warnings	
Operator	Car drivers	
Operator state/characteristic	Fatigue driver	Non fatigued driver
Operator manipulation	Shift workers coming after work	N/A
Trigger	Bus coming from parking spot in front of own vehicle	
Expected reactions from operator on the trigger	Warning issued	No warning
Expected reactions from the operator on the system warning	Brake late	Slow down before being close to the bus
Environment: road/track	Two lane road	
Environment: traffic conditions or other vehicles/objects	Normal traffic	
Environment: weather and light conditions	good weather, daytime light	
Measures before experiment	KSS	
Measures during experiment	KSS, TTC, Time headway, braking RT, number of warning received,	
Measures after experiment	Acceptance scale	
Notes		

H7: Fatigued operators will have less situational awareness than alert operators

Elements	Scenario	
Title	CAR13 CA H7	
Situation	Car following on motorway, high density traffic	
Hypothesis	Fatigued driver will be less situational aware and get more warnings	
Operator	Professional drivers, maybe taxi drivers, shift-workers	
Operator state/characteristic	Fatigued drivers who had a long drive before the experiment	Non-fatigued drivers
Operator manipulation	Long pre-experimental drive, to make fatigued drivers more sleepy	Making drivers fatigued by high effort driving, followed by boring driving with cruise control, followed by an event
Trigger	Obstacle on road, such as car broken down	
Expected reactions from operator on the trigger	Driver is aware too late, does not react in times	Timely awareness and reaction, slowing down or braking
Expected reactions from the operator on the system warning	Warning issued, after warning, slowing down or braking	No warning
Environment: road/track	Motorway	
Environment: traffic conditions or other vehicles/objects	Busy but orderly traffic Car broken down, several cars in the lead	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Questionnaire on driving before experiment Subjective scale of sleepiness, KSS	
Measures during experiment	Headway; KSS; Number of warnings; Speed; Coherence	
Measures after experiment		
Notes		

Elements	Scenario	
Title	CAR14 CA H7	
Situation	Busy two-lane motorway, a platoon of cars is overtaking and at least one car is in front of own car	
Hypothesis	Fatigued operators will have less situational awareness than alert operators	
Operator	Car operator	
Operator state/characteristic	Fatigue operator	Alert operator
Trigger	Lead car braking (since heavy traffic there is car in the adjacent lane too)	
Subject manipulation	Fatigue by sleep deprivation and start of the experiment late at night + secondary task (ex. Arrows task)	Secondary task (ex. Arrows task)
Expected reactions from operator on the trigger	Operator will receive several warnings	Operator will receive fewer warnings
Expected reactions from the operator on the system warning	Late response to warning by braking	Shorter response to warning by braking
Environment: road/track	Two lane motorway	
Environment: traffic conditions or other vehicles/objects	Heavy traffic in both lanes	
Environment: weather and light conditions	Good weather condition and day time light	
Measures before experiment	KSS	
Measures during experiment	Speed variation, TTC, braking RT, number of warnings issued, performance to the secondary task	
Measures after experiment		
Notes		

H8: Fatigued operators may compensate for their fatigue by increasing the safety margin

Elements	**Scenario**	
Title	CAR15 CA H8	
Situation	Car following on motorway, low density traffic	
Hypothesis	Fatigued drivers who are aware of their fatigue adopt a longer headway threshold	
Operator	Professional drivers, maybe taxi drivers, shift-workers	
Operator state/characteristic	Fatigued drivers who had a long drive before the experiment	Non-fatigued drivers
Operator manipulation	Begin experiment with boring drive	
Trigger	Roadworks, lane drop, higher traffic density, mini shockwave	
Expected reactions from operator on the trigger	Slow down, adopting longer headway	Maintaining headway or shorter headway?
Expected reactions from the operator on the system warning	No warning	Warning, slow down
Environment: road/track	Road with roadworks and lane drop	
Environment: traffic conditions or other vehicles/objects	Starting with low density, gradually building up Mini shockwave	
Environment: weather and light conditions	Night time conditions, or at least dull and grey, poor lighting	
Measures before experiment	Questionnaire on driving before experiment Subjective scale of sleepiness KSS	
Measures during experiment	Headway KSS; Number of warnings ; Speed; Coherence	
Measures after experiment		
Notes		

Elements	**Scenario**	
Title	CAR16 CA H8	
Situation	School transport bus using turning indictor to stop at the next bus stop	
Hypothesis	Fatigued drivers who are aware of their fatigue adopt a longer headway threshold	
Operator	Car drivers	
Operator state/characteristic	Fatigued drivers	Non fatigued drivers
Operator manipulation	Use shift workers already tired when they start the experiment	None
Trigger	School transport bus using turning indicator	
Expected reactions from operator on the trigger	Warning issued	No warning since headway very long
Expected reactions from the operator on the system warning	Braking suddenly	
Environment: road/track	One lane road in a rural area	
Environment: traffic conditions or other vehicles/objects	Traffic in the opposite lane School transport bus in front on own vehicle	
Environment: weather and light conditions	Good weather and day light condition	
Measures before experiment	KSS	
Measures during experiment	Speed variation, TTC, braking RT, number of warnings issued	
Measures after experiment		
Notes		

H9: Operators will receive more warnings when under low workload

Elements	Scenario	
Title	CAR17 CA H9	
Situation	After a long boring drive the driver encounters a broken down vehicle which sticks out into the lane	
Hypothesis	Operators will receive more warnings when under low workload because they are not paying attention to possibly dangerous situations	
Operator	Car driver	
Operator state/characteristic	Under loaded driver	Driver with medium workload
Operator manipulation	Drive for 15 minutes on boring road without traffic	Drive for 15 minutes on normal road with normal traffic
Trigger	Broken down car (or other object)	
Expected reactions from operator on the trigger	Does not notice object	Notices object and brakes in time
Expected reactions from the operator on the system warning	Brakes after warning	No warning
Environment: road/track	Rural road,	Rural road
Environment: traffic conditions or other vehicles/objects	no traffic broken down car (or other object)	normal traffic
Environment: weather and light conditions	Normal	
Measures before experiment		
Measures during experiment	Subjective workload scale after 10 minutes of driving Number of warnings, TTC	
Measures after experiment		
Notes		

Elements	Example	
Title	CAR18 CA H9	
Situation	Straight monotonous rural road with no traffic under a long period of time, i.e. 15 minutes	
Hypothesis	Operator will receive more warning when under low workload (since she distracting herself to not fall asleep)	
Operator	Car driver	
Operator state/characteristic	Low workload= long driving without other traffic during 15 minutes	
Operator manipulation	Secondary task (ex. texting)	No secondary task
Trigger	A parked bus is driving in front the own car	
Expected reactions from operator on the trigger	More warnings received	Fewer warnings received
Expected reactions from the operator on the system warning	Longer reaction time to warning by braking	Shorter reaction time to the warning by braking
Environment: road/track	Rural road one lane, with bus stop on the road	
Environment: traffic conditions or other vehicles/objects	Bus at a bus stop + other buses and parked vehicles (dummies) distributed along the road to avoid suspicion	
Environment: weather and light conditions	Foggy weather, day time	
Measures before experiment	Workload measure TBD	
Measures during experiment	Workload measure TBD, TTC, Time headway, braking RT, number of warnings issued, duration of eyes off road?	
Measures after experiment	Acceptance	
Notes		

H10: Operators will receive more warnings when under high workload

Elements	Scenario	
Title	CAR19 CA H10	
Situation	Motorway driving, high density traffic, vehicle cutting in into the gap before own vehicle	Motorway driving, normal density traffic, vehicle cutting in into the gap before own vehicle
Hypothesis	Drivers in heavy and semi-chaotic traffic will receive more warnings	
Operator	Car driver	
Operator state/characteristic	High workload externally induced	Medium workload
Operator manipulation	Inducing high workload by traffic situation	
Trigger	Car cutting in	
Expected reactions from operator on the trigger	Do nothing	Adjust speed
Expected reactions from the operator on the system warning	Adjust speed after warning	No warning
Environment: road/track	Urban motorway, with entrance ramp to vary the traffic flow	
Environment: traffic conditions or other vehicles/objects	High traffic density and semi-chaotic behaviour of other vehicles	Car following
Environment: weather and light conditions	Normal	
Measures before experiment	Pilot study measuring workload under different traffic conditions, using subjective scale (RSME), as a benchmark	
Measures during experiment	Speed adjustment; Number of warnings; Reaction time to warnings (No measure of workload because of interference problems, except by physiological measures)	
Measures after experiment	Play-back of a critical scene and ask about subjective workload	
Notes		

Elements	**Scenario**	
Title	CAR20 CA H10	
Situation	Urban driving, vehicle ahead decelerates rapidly to stop at red traffic light. Driver receives complex traffic information just before lead vehicle deceleration.	Urban driving, vehicle ahead decelerates rapidly to stop at red traffic light. No traffic information.
Hypothesis	Drivers distracted by external information will receive more warnings	
Operator	Car driver	
Operator state/characteristic	High workload induced by secondary task	Medium workload
Operator manipulation	Secondary task	
Trigger	Lead vehicle decelerates suddenly	
Expected reactions from operator on the trigger	Late reaction	Reacts in time
Expected reactions from the operator on the system warning	Brakes after warning	
Environment: road/track	Urban arterial with one lane in each direction	
Environment: traffic conditions or other vehicles/objects	Car following	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Pilot study measuring workload with and without secondary task, using subjective scale (RSME), as a benchmark	
Measures during experiment	TTC; Brake reaction time; Jerk; Max deceleration; Number of warnings; Reaction time to warnings (No measure of workload because of interference problems, except by physiological measures)	
Measures after experiment	Play-back of a critical scene and ask about subjective workload	
Notes		

Elements	**Scenario**	
Title	CAR21 CA H10	
Situation	Urban driving, vehicle ahead decelerates rapidly to stop at red traffic light. Driver is engaged in hands-free phone conversation when lead vehicle decelerates.	Urban driving, vehicle ahead decelerates rapidly to stop at red traffic light. No phone conversation.
Hypothesis	Drivers distracted by secondary task will receive more warnings	
Operator	Car driver	
Operator state/characteristic	High workload induced by secondary	Medium workload
Operator manipulation	Secondary task	
Trigger	Lead vehicle decelerates suddenly	
Expected reactions from operator on the trigger	React late	React in time
Expected reactions from the operator on the system warning	Brake after warning	No warning
Environment: road/track	Urban arterial with one lane in each direction	
Environment: traffic conditions or other vehicles/objects	Car following	
Environment: weather and light conditions	Normal conditions	
Measures before experiment	Pilot study measuring workload with and without secondary task, using subjective scale (RSME), as a benchmark	
Measures during experiment	TTC; Brake reaction time; Jerk; Max deceleration; Number of warnings; Reaction time to warnings (No measure of workload because of interference problems, except by physiological measures)	
Measures after experiment	Play-back of a critical scene and ask about subjective workload	
Notes		

Appendix 4 Train scenarios related to Collision Avoidance

Operator support system: Automatic Warning System (AWS)

The AWS produces sounds to inform the driver about a restrictive signalling on the side of the track, e.g. red, orange, yellow traffic light. Then the driver, who has noticed the restrictive signalling with or without the sound given by the AWS, has to inform the AWS that she/he is aware of the restrictive signalling. Pushing a button linked to the AWS before 2,75s, allows the driver to acknowledge the informative signal given by the AWS. After the 2,75s, an emergency break is triggered by the AWS.

Therefore the term "warning" used in the different hypotheses is not the sound produced by the AWS which is an informative signal. Moreover, no warning occurs during the use of AWS. A non-acknowledgement is immediately followed by "the punishment", the emergency break. An idea could be to study the behaviour of the driver before the informative signal. Has she/he already decreased the speed of the vehicle or not? Thus the sound produced by the AWS becomes a warning. The number of warnings (one or no warning) has to be counted during the period between the earliest moment when the restrictive signalling can be seen (the driver can miss the signalling) and the use of the breaking pedal by the train driver (Figure 3).

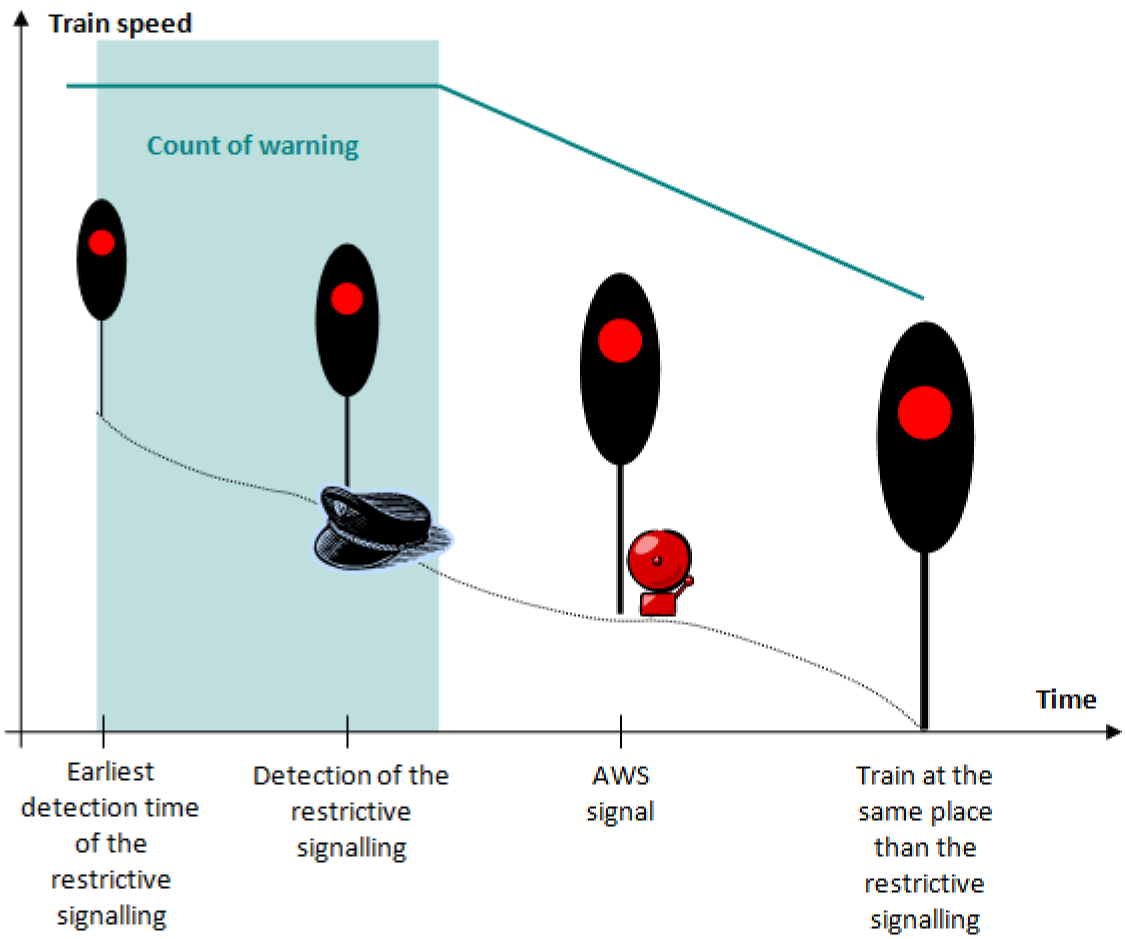


Figure 3 Time specifications during scenarios

Fourteen scenarios were made based the AWS and the 10 common hypotheses. These scenarios are described as follows.

H1: Sensation-seeking operators adopt (or choose) shorter warning thresholds

Elements	**Scenario**	
Title	Train1 CA H1	
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light). The driver, who has seen the signalling, has the choice between decreasing the train velocity as soon as she/he sees the restrictive signalling and waiting for the informative signal produced by the AWS.	
Hypothesis	A train driver, who seeks sensation, does not brake before hearing the sound produced by the AWS.	A train driver, who does not seek sensation, brakes as soon as she/he sees the restrictive signalling.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Sensation seeker	No sensation seeker
Operator manipulation	No operator manipulation	
Trigger	Detection of a restrictive signalling	
Expected reactions from operator on the trigger	No activation of the brake pedal	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and activate the brake pedal	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered before braking (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment	Detection of the signalling (questionnaire?)	
Notes		

Elements	Scenario	
Title	Train2, CA, H1	
Situation	A sound was produced by the AWS which implies the driver pushing the button of acknowledgement. The driver has to acknowledge before the time limit (2,75s).	
Hypothesis	A train driver, who seeks sensation, acknowledges the informative signal given by the AWS, as later as possible.	A train driver, who does not seek sensation, acknowledges the informative signal given by the AWS, as soon as the sound is produced.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Sensation seeker	No sensation seeker
Operator manipulation	No operator manipulation	
Trigger	AWS signal	
Expected reactions from operator on the trigger	Wait before pushing the acknowledgement button	Push the acknowledgment button immediately
Expected reactions from the operator on the system warning	Wait before pushing the acknowledgement button	Push the acknowledgment button immediately
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Stress on the acknowledgement button; View of the cabin, movements of the driver	
Measures after experiment		
Notes		

Elements	**Scenario**	
Title	TRAIN3 CA H1	
Situation	A sound was produced by the AWS which implies the driver pushing the button of acknowledgement. The driver has to acknowledge before the time limit (2,75s). In the same time, the Control Room calls the train driver.	
Hypothesis	A train driver who seeks sensation, picks up the phone first and then pushes the acknowledge button.	A train driver who does not seek sensation, pushes the acknowledge button first, and then picks up the phone.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Sensation seeker	No sensation seeker
Operator manipulation	No operator manipulation	
Trigger	AWS signal + the Control Room call	
Expected reactions from operator on the trigger	Pick up the phone and immediately push the acknowledgement button and the brake pedal	Push the acknowledgement button, brake and can pick up the phone
Expected reactions from the operator on the system warning	Push the acknowledgement button and the brake pedal	Push the acknowledgement button
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Stress on the acknowledgement button; View of the cabin, movements of the driver	
Measures after experiment		
Notes		

H2: Sensation-seeking operators will behave in such a way that more warnings will be triggered

Elements	**Scenario**	
Title	TRAIN4 CA H2	
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light). The driver, who has seen the signalling, has the choice between decreasing the train velocity as soon as she/he sees the restrictive signalling and waiting for the informative signal produced by the AWS.	
Hypothesis	A train driver, who seeks sensation, does not brake before hearing the sound produced by the AWS.	A train driver, who does not seek sensation, brakes as soon as she/he sees the restrictive signalling.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Sensation seeker	No sensation seeker
Operator manipulation	No operator manipulation	
Trigger	Detection of a restrictive signalling	
Expected reactions from operator on the trigger	No activation of the brake pedal	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and activating the brake pedal	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered before braking (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment	Detection of the signalling (questionnaire?)	
Notes		

Elements	Scenario	
Title	TRAIN5 CA H2	
Situation	The Control Room sends information to the driver about an obstacle on the track, not placed in the direct sight of the driver. Drivers have to acknowledge this information.	
Hypothesis	Sensation-seeking operators will wait for AWS signal to start braking	Non sensation-seeking operators start braking as soon as they receive information about an obstacle on the track.
Operator	Professional train driver	
Operator state/characteristic	Sensation seeker	No sensation seeker
Trigger	Message from the Control Room	
Subject manipulation	No operator manipulation	
Expected reactions from operator on the trigger	Acknowledgement of the message from the Control Room	Acknowledgement of the message from the Control Room and activation of the brake pedal
Expected reactions from the operator on the system warning	Acknowledgement of the AWS signal and activation of the brake pedal	Acknowledgement of the AWS signal
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	The obstacle on the railroad cannot be seen by the operator, he/she needs to be informed of the location of an obstacle by the Control Room	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Degree of the driver sensation seeking	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one) before braking; Speed curve of the train; Message from the Control Room moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment		
Notes		

H3: Sensation-seeking operators will seek stimulation to cope with monotonous situations

Elements	**Scenario**
Title	TRAIN6 CA H3
Situation	The train moves on the tracks. A restrictive signalling could appear.
Hypothesis	A train driver, who seeks sensation, decreases the train velocity before the AWS signal. The game is to be quicker than the system.
Operator	Experienced, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters
Operator state/characteristic	Sensation seeker
Operator manipulation	No operator manipulation
Trigger	Detection of a restrictive signalling
Expected reactions from operator on the trigger	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)
Environment: weather and light conditions	Good weather and daytime, with clear visibility
Measures before experiment	Degree of the driver sensation seeking
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment
Measures after experiment	Detection of the signalling (questionnaire?)
Notes	

H4: Experienced operators will receive fewer warnings than inexperienced operators

Elements	Scenario
Title	TRAIN7 CA H4
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light). The driver, who has seen the signalling, has the choice between decreasing the train velocity as soon as she/he sees the restrictive signalling and waiting for the informative signal produced by the AWS.
Hypothesis	An inexperienced train driver decreases the train velocity before the AWS informative signal, in order to prove that she/he is able to drive by her-/himself.
Operator	No sensation seeker, non-fatigued, not under-/overloaded train driver, in order to avoid interaction with other parameters
Operator state/characteristic	Inexperienced driver
Operator manipulation	No operator manipulation
Trigger	Detection of a restrictive signalling
Expected reactions from operator on the trigger	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)
Environment: weather and light conditions	Good weather and daytime, with clear visibility
Measures before experiment	Experience of the driver
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment
Measures after experiment	Detection of the signalling (questionnaire?)
Notes	

Elements	**Scenario**	
Title	TRAIN8 CA H4	
Situation	The Control Room sends information to the driver about an obstacle on the track, no placed in the direct sight of the driver. Drivers have to acknowledge this information.	
Hypothesis	Experienced operators start braking as soon as she/he receives information about an obstacle on the track.	Inexperienced operators start braking later than the moment she/he has received the message from the Control Room.
Operator	Professional train driver	
Operator state/characteristic	Experience of the situation	Lack of experience of the situation
Trigger	Message from the Control Room	
Subject manipulation	No operator manipulation	
Expected reactions from operator on the trigger	Acknowledgement of the message from the Control Room and start braking immediately	Acknowledgement of the message from the Control Room and activation of the brake pedal after her/his reaction time (memory work)
Expected reactions from the operator on the system warning	Acknowledgement of the AWS signal	Acknowledgement of the AWS signal and activation of the brake pedal, if she/he did not brake before
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	No obstacle at the driver sight on the railroad, need to be informed of the location of an obstacle by the Control Room	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Experience of the driver	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one) before braking; Speed curve of the train; Message from the Control Room moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment		
Notes		

H5: Fatigued operators will rely on the system to warn them about a critical situation

No scenario

H6: Operators will receive more warnings when fatigued than when alert

Elements	Scenario	
Title	TRAIN9 CA H6	
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light).	
Hypothesis	A fatigued train driver does not detect the restrictive signalling by her-/himself. She/he need to hear AWS signal.	A non-fatigued train driver detects the restrictive signalling before the AWS signal.
Operator	Experienced, no sensation seeker, not under-/overloaded train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Fatigued driver	Non-fatigued driver
Operator manipulation	Bring the driver in a fatigue state	
Trigger	Detection of a restrictive signalling	
Expected reactions from operator on the trigger	No activation of the brake pedal	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and activate the brake pedal	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Level of fatigue of the driver	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment	Detection of the signalling (questionnaire?)	
Notes		

Elements	**Scenario**	
Title	TRAIN10 CA H6	
Situation	The Control Room sends information to the driver about an obstacle on the track, no placed in the direct sight of the driver. Drivers have to acknowledge this information.	
Hypothesis	Fatigued operators wait the AWS signal to start braking.	No-fatigued operators start braking as soon as she/he has received the message from the Control Room.
Operator	Professional train driver	
Operator state/characteristic	Fatigued driver	Non-fatigued driver
Trigger	Message from the Control Room	
Subject manipulation	No operator manipulation	
Expected reactions from operator on the trigger	Acknowledgement of the message from the Control Room	Acknowledgement of the message from the Control Room and start braking immediately
Expected reactions from the operator on the system warning	Acknowledgement of the AWS signal and activation of the brake pedal	Acknowledgement of the AWS signal
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	No obstacle at the driver sight on the railroad, need to be informed of the location of an obstacle by the Control Room	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	Level of fatigue of the driver	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one) before braking; Speed curve of the train; Message from the Control Room moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment		
Notes		

H7: Fatigued operators will have less situational awareness than alert operators

No scenarios

H8: Fatigued operators may compensate for their fatigue by increasing the safety margin

Elements	**Scenario**
Title	TRAIN11 CA H8
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light).
Hypothesis	A fatigued driver, who has missed the restrictive signalling, pushes immediately the acknowledgement button when the signal from the AWS is heard. She/He is surprised and stressed because she/he has missed the signalling previously.
Operator	Experienced, no sensation seeker, not under-/overloaded train driver, in order to avoid interaction with other parameters
Operator state/characteristic	Fatigued train driver
Operator manipulation	Bring the driver in a fatigue state
Trigger	AWS signal
Expected reactions from operator on the trigger	Pushing the acknowledgment button and active the brake pedal in a short time
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and active the brake pedal in a short time
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)
Environment: weather and light conditions	Good weather and daytime, with clear visibility
Measures before experiment	Level of fatigue of the driver
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment
Measures after experiment	Detection of the signalling (questionnaire?)
Notes	

H9: Operators will receive more warnings when under low workload

Elements	Scenario	
Title	TRAIN12 CA H9	
Situation	The driver drives the train on approach of a restrictive signalling (red, orange or yellow traffic light). No acts on the train commands and no communications with the Control Room were needed since 30 min.	
Hypothesis	A driver, who is under-loaded, does not detect the restrictive signalling, before the AWS signal triggering. She/he never brakes before the AWS signal.	A driver, who is not under-loaded detects the restrictive signalling before the AWS signal. The braking begins before the AWS signal triggering.
Operator	Experienced, no sensation seeker, non-fatigued train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Under-loaded driver	Not under-loaded driver
Operator manipulation	Bring the driver in an under-load state, *e.g.* without disturbance during 30 min	
Trigger	Detection of a restrictive signalling	
Expected reactions from operator on the trigger	No activation of the brake pedal	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and activate the brake pedal	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	"Stress" level of the driver, level of workload	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment ; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment	Detection of the signalling (questionnaire?)	
Notes		

H10: Operators will receive more warnings when under high workload

Elements	Scenario	
Title	TRAIN13 CA H10	
Situation	The Control Room is calling the driver because they need to obtain information which demands the driver to use his/her memory. At the same time moment, the driver drives the train approaching a restrictive signalling (red, orange or yellow traffic light).	
Hypothesis	A driver, who is over-loaded, does not detect the signalling before the AWS signal triggering.	A driver, who is not over-loaded, detects the signalling before the AWS signal triggering.
Operator	Experienced, no sensation seeker, non-fatigued train driver, in order to avoid interaction with other parameters	
Operator state/characteristic	Over-loaded driver	Not over-loaded driver
Operator manipulation	Make the driver in an over-load state, *e.g.* by the occurrence of a phone call from the Control Room	
Trigger	Detection of a restrictive signalling	
Expected reactions from operator on the trigger	No activation of the brake pedal	Activation of the brake pedal
Expected reactions from the operator on the system warning	Pushing the acknowledgment button and activate the brake pedal	Pushing the acknowledgment button
Environment: road/track	Track with traffic light placed at 500m in front of the initial place of the train	
Environment: traffic conditions or other vehicles/objects	"Clean" track (no obstacle on the railroad)	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	"Stress" level of the driver, level of workload	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one); Speed curve of the train; Temporal Detection moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment	Detection of the signalling (questionnaire?)	
Notes		

Elements	Scenario	
Title	TRAIN14 CA H10	
Situation	The Control Room sends information to the driver about an obstacle on the track, no placed in the direct sight of the driver. Drivers have to acknowledge this information.	
Hypothesis	Over-loaded operators wait the AWS signal to start braking.	No-overloaded operators start braking as soon as she/he has received the message from the Control Room.
Operator	Professional train driver	
Operator state/characteristic	Overloaded driver	Non-overloaded driver
Trigger	Message from the Control Room	
Subject manipulation	No operator manipulation	
Expected reactions from operator on the trigger	Acknowledgement of the message from the Control Room	Acknowledgement of the message from the Control Room and start braking immediately
Expected reactions from the operator on the system warning	Acknowledgement of the AWS signal and activation of the brake pedal	Acknowledgement of the AWS signal
Environment: road/track	Track with traffic light	
Environment: traffic conditions or other vehicles/objects	No obstacle at the driver sight on the railroad, need to be informed of the location of an obstacle by the Control Room	
Environment: weather and light conditions	Good weather and daytime, with clear visibility	
Measures before experiment	"Stress" level of the driver, level of workload	
Measures during experiment	Detection of the signalling (push a button?); Count of AWS signal triggered (no one or one) before braking; Speed curve of the train; Message from the Control Room moment; AWS signal triggering moment; Beginning of braking moment	
Measures after experiment		
Notes		