D4.3 - Metrics and plan for V&V of the TeamMate HMI software in the 2nd cycle

Project Number:	690705
Classification	Public
Deliverable No.:	D4.3
Work Package(s):	WP4
Document Version:	Vs. 1.0
Issue Date:	31.01.2017
Document Timescale:	Project Start Date: September 1, 2016
Start of the Document:	Month 12
Final version due:	Month 14
Deliverable Overview:	**Main document:** D4.3
Compiled by:	Michael Falk, HMT
Authors:	Michael Falk, HMT Andrea Castellano, REL Elisa Landini, REL Jürgen Pichen, ULM Ebru Dogan, VED Adam Knapp, BIT
Technical Approval:	Fabio Tango, CRF
Issue Authorisation:	Andreas Lüdtke, OFF

DISTRIBUTION LIST		
Copy type[1]	Company and Location	Recipient
T	AutoMate Consortium	all AutoMate Partners

[1] Copy types: E=Email, C=Controlled copy (paper), D=electronic copy on Disk or other medium, T=Team site (Sharepoint)

RECORD OF REVISION		
Date	Status Description	Author
30.08.2017	First deliverable structure	Michael Falk, HMT
22.09.2017	Section 5 and 6 provided	Michael Falk, HMT
28.09.2017	Augmented HMI added	Michael Falk, HMT
17.10.2017	Contribution from the partner	All partner
26.10.2077	Conclusion added	Elisa Landini, REL

Table of Contents

1 Executive summary

The overall goal of the AutoMate project is to develop the TeamMate car as an enabler of highly automated vehicles. For the TeamMate car, the human driver and the automation are working together to achieve the goal of driving safely, efficiently and comfortably. In order to inform the driver, to cooperate and interact with the driver, a novel HMI implementation is required for the system.

The goal of WP4 is to develop this HMI. In the previous project cycle the *general HMI features*, the *hand-over strategy* and the *HMI modes* were defined. Furthermore, the first version of the *instrument clusters,* the *central stack display* and the *head-up display* were designed and implemented. Part of the HMI design is the process of verification and validation (V&V process) to ensure the adherence of the HMI implemented to the requirements introduced in D1.3. The general approach to TeamMate HMI verification and validation was described in the first cycle, in Deliverable 4.1, which covered the most suitable metrics, tools and methods that could be used for further experiments.

The current deliverable takes the results from the previous V&V cycle, the high-level requirements and the general metrics from D1.3, as a starting point to describe the plans and experiments on verification and validation of the HMI components developed in WP4.

2 Introduction

The key feature of the concept of a TeamMate car is the car's capability to act as team player or partner for the driver. That means that the car supports the driver as much as possible, as a real human partner would do, considering the current state of the driver, the current and upcoming demands of the traffic situation, and the current and upcoming state of the car and the automation itself. On the other hand, this means also that the driver acts as a partner for the TeamMate car and supports the car in situations where it is not able to perform the driving task on its own. For this purpose, a dynamic, situation adequate distribution of driving tasks between driver and TeamMate car must be provided to ensure that the joint driver-vehicle system performs the driving task optimally.

A necessary requirement for the realization of such a partnership is that the TeamMate car not only possesses the necessary functionality to carry out relevant driving functions, but also a high communication competence. This communication competence is required to create a shared situation representation between the driver and the TeamMate car. The TeamMate car must be able to communicate its current environment perception and situation classification, its planned actions and goals, and its current capabilities. This is necessary to allow the driver to detect possible mistakes, to provide adequate support to the TeamMate car in situations the car cannot handle alone, or to safely and efficiently modify the TeamMate car's plans to make it compatible with the driver's plans. At the same time the system must be able to understand the driver's goals and actions, the driver's current state and capabilities to provide proper and efficient support for the driver. This communication between driver and TeamMate car has to be realized in way that does not overload the driver, especially in situations where the driver has to take over control from the TeamMate car, that is, in situations where the driver needs to support the TeamMate car. Additionally, the design of this communication process also must take into account that the driver may not always pay attention to the driving task, the traffic environment, or the TeamMate car.

Therefore, the TeamMate HMI is at the core of the TeamMate car concept as these requirements on communication processes between TeamMate car and driver has to be realized by this HMI. In D4.2 an initial HMI concept has been developed and presented based on a deep analysis of the demands and characteristics of the different use cases and a qualitative approach of HMI design. Several stable states of the automation have been identified together with the expected driver behaviour in each of the states and the HMI information structure that integrates the different states and ensures that all use cases and defined scenarios can be addressed by the general TeamMate HMI. The essential HMI elements that were identified previously have been associated with different automation states. Furthermore, a wireframe for all the visual displays has been developed so that the visual components of HMI can be implemented.

The goal of the second cycle is now to verify and validate key aspects of the HMI concept. We plan to conduct experiments in controlled environments, such as driving simulators, in order to test the unique components of the TeamMate car concept. The approach to achieve this goal is to get a proof of concept not only in a qualitative but also in a quantitative way, demonstrated among a representative group of actual drivers.

The approach for the V&V process and the definition of metrics are described in chapter 3. In chapter 4, the requirements and metrics defined in D1.3 are referenced. New requirements and metrics were added and defined in chapter 5. The objectives of the experiments are described in chapter 6. The main part is the description of the different experiments in chapter 7.

3 Approach for verification, validation and metrics definition

Verification and validation are an important part in developing reliable and acceptable software. **Verification** can be seen as the task of determining whether the system is built according to its technical specifications and whether it satisfies "the standards, practices and conventions during life cycle processes" (IEEE, 2012). Verification, therefore, checks if the system is working correctly.

Validation, on the other hand, checks whether the system fulfils its intended purpose. The system has to meet the requirements, which has been defined to state the functionality of the system. In the validation process, a measurable threshold, which is related to the requirement, is taken to measure whether the quality of the system is acceptable for its intended use. Furthermore, the validation aims to satisfy the user needs in the operational environment (IEEE, 2012). For the TeamMate HMI this means that the validation is mainly focused on human factors aspects.

While the focus in the first cycle of the V&V process was more on the verification, in the second cycle the focus is on the validation with the goal to trace the implementation back to the requirements. To achieve this, there is a need to define the metrics and measure them in appropriate experiments. Our starting point is D1.3., where the high-level requirements of the HMI enabler have been defined. The high-level requirement can be redefined in order to test appropriate and specific functions and components of the system and new low-level requirements and specific metrics can be added when necessary.

The process for the definition of the metrics and the plan for future experiments is specified as follows:

1. Take the general requirements from D1.3 as a starting point
2. Redefine the requirements and/or add new requirements for V&V
3. Define specific metrics for the redefined/extended requirements
4. Define concrete experiments to verify or validate the requirements for the specific enabler

For this process, the results from the first cycle are also considered. In the first cycle, human factors methods and metrics for different performance indicators were investigated, which can be used for appropriate experiments. The methods explained in D4.1 can help to assess driver's situation awareness, mental workload, driving performance, reaction time, intervention, remaining action time, and trust and acceptance in the system.

4 Reference of requirements and metrics defined in D1.3

In the first cycle, the focus has been mostly on the design of the HMI concept and the strategy for a safe and smooth hand-over. During the V&V activities verification and validation requirements have been created and the results of the first cycle for the HMI concept was checked against these requirements. The requirements from R_EN6_tool1.1 to R_EN6_tool1.18 were already verified in D4.2.

The requirements that have not been verified and validated yet are listed in the table below to keep a reference to these requirements so that there can be used for the further V&V process (Table 1). The full list of requirements from the first cycle can be found in D1.3. The results of the verification and validation activities will be presented in D4.4.

Type of requirement	Enabler owner	Req ID	Description	Metric
Verification	ULM	R_EN6_tool1.19	The HMI must integrate all relevant information on traffic, driver and automation	Check: Y/N
Verification	HMT	R_EN6_tool1.20	The HMI must show safe driving corridors and constraints on these corridors using graphical means	Check: Y/N
Verification	ULM	R_EN6_tool1.21	NCDC must display when the automated driving mode is switched on/off	Check: Y/N
Verification	ULM	R_EN6_tool1.22	The HMI must clarify driver's and system's responsibility in order to prevent mode confusion	Check: Y/N
Verification	ULM	R_EN6_tool1.23	NCDC must display the information on lateral vehicle control and the longitudinal vehicle control	Check: Y/N

Validation	BIT	R_EN6_tool1.24	NCDC must display different map representations (short term as well as long term) to intuitively show imminent risks	Correct rate of recognition of imminent risks CR > 90% acceptable CR < 90% not acceptable
Verification	ULM	R_EN6_tool1.25	The HMI should offer different actions on a manoeuvre level to the driver	Check: Y/N
Validation	ULM	R_EN6_tool1.26	The HMI must be understood by the driver when it shows different actions at manoeuvre level	CR for understanding level < 90% not acceptable >90% acceptable
Verification	ULM	R_EN6_tool1.27	The HMI should select the right channel of communication at the right moment depending on the driver and the traffic situation	Check: Y/N

Verification	ULM	R_EN6_tool1.28	The HMI must at all times make sure that the driver is aware of how to intervene	Check: Y/N
Verification	ULM	R_EN6_tool1.29	Multiple communication channels additional to the visual user interface, such as acoustic feedback (i.e. speech recognition, microphones, cameras, speakers) and haptic feedback, should be provided to the driver	Check: Y/N
Verification	ULM	R_EN6_tool1.30	Driver must be alerted for possible dangers by using multi-modal stimuli	Check: Y/N
Validation	ULM	R_EN6_tool1.31	The performance of human-automation interaction must be evaluated with respect to: - attention allocation efficiency - mission effectiveness - driver physical comfort and fatigue - trust in the system - user acceptance - emotional experience	CR for mission effectiveness < 90% not acceptable >90% acceptable

Table 1. Requirements for verification and validation to be fulfilled in Cycle 2

5 Definition of additional requirements and metrics

The list of already defined high-level requirements is extended and separated into more low-level requirements and metrics (Table 2). Especially more validation requirements are added to serve as a base for the validation and the experiments in the second cycle. The plan for appropriate experiments to fulfill appropriate validation requirements, specific metrics to be used, and how they are measured are presented in chapter 8 "Description of the experiments".

Type of requirement	Enabler owner	Req ID	Description	Metric
Verification	HMT	R_EN6_tool1.33	In manual mode, augmented reality (AR) elements should be reduced to a minimum and not distract the driver.	Check: Y/N
Verification	HMT	R_EN6_tool1.34	In automated mode, augmented reality elements can be used to enhance the situation awareness.	Check: Y/N
Validation	HMT	R_EN6_tool1.35	In automated mode, the manoeuvres performed by the vehicle must be comprehensible for the driver through graphical visualizations.	CR for understanding level >90%

Validation	REL	R_EN6_tool1.36	The different HMI modes visualized in the driving cluster must be recognized by the driver.	CR for understanding level Situation Awareness
Validation	VED	R_EN6_tool1.37	The crucial ambient light modes must be understood by the driver (automated mode, emergency mode)	CR for understanding level < 90% not acceptable >90% acceptable
Validation	ULM	R_EN6_tool1.38	The takeover transition time from automated to manual mode must be long enough to rebuild attention of the driver and to bring him in the loop.	Take Over Success < 90% not acceptable >90% acceptable Driver Workload Reaction time
Verification	ULM	R_EN6_tool1.39	The system must provide a way of intervention by the driver in non-crucial situations.	Check: Y/N

Validation	ULM	R_EN6_tool1.40	The system must distinguish between intentional and unintentional intervention.	Threshold for steering wheel angle (e.g. 2 degrees) or braking pedal position
Validation	HMT	R_EN6_tool1.41	The HMI should communicate to the driver why the automation is acting in a certain manner in an understandable way.	Situation Awareness
Validation	HMT	R_EN6_tool1.42	The driver needs to understand the meaning of the overtaking corridor visualized through AR.	CR for understanding level
Validation	REL	R_EN6_tool1.43	The use of multimodal elements in the HMI must increase the level of situation awareness	SA >0 results from SAGAT
Validation	REL	R_EN6_tool1.44	The HMI must make the driver able to predict the relation among the HMI states (e.g. stable and transition)	Correct rate: > 90%

Table 2. Additional requirements for verification and validation of the TeamMate HMI

6 Objectives of the experiments

In the next cycle different features and functions of the HMI should be tested according to the requirements and the capabilities of the demonstrators. For each scenario there are specific features that assure the best possible way of communication between the driver and the car in a TeamMate matter. In this cycle the different scenarios will be tested by each scenario owner because the different scenarios have different demands on the interface, which only can be realized by certain features. These features will be integrated and tested in one joint interface – the TeamMate HMI.

Ulm will perform several studies on different HMI features like the different HMI-modes or the ambient light based on the PETER scenario. This scenario is implemented into the ULM driving simulator and can therefore be tested with a high immersion of the experimental users. Therefore, the experiments that will be conducted are expected to represent the new interface approaches in the safest way for the driver and other road users. The goal is to find an interface that can assure the situation representation of the car, so the driver can handle the use-cases of the PETER scenario with the help of the automation in the best possible way, thus assure a good TeamMate behaviour. It is important, that the communicative skills of the interface should be increased without decreasing the system's usability, so the driver does not have the feeling of a worse interaction while using the TeamMate approach.

REL will perform validation test in order to measure the level of comprehensibility of the HMI. This type of assessment will be done to make sure that the driver is aware about the current status (i.e. the level of automation) and the type of task that is required. To evaluate the real level of understanding of the TeamMate concept, the driver will be asked to define the relation among the modes: in this way it will be tested the identification of the transition (e.g. what happens after a transition mode) and the level of awareness of the driver. Furthermore, the use of another sensory channel, in addition to the visual one, will be tested during the cooperation phase.

VED will test the validation of the functionality of the TeamMate HMI, as ULM and REL do. The aim is to decipher drivers' understanding of the information communicated through the HMI, such as the current mode, future mode, the oncoming event, and the maneuver to be performed. User stories methodology (Cohn, 2004) will be employed in the validation experiments. The particular interest in the experiments is the kind of interaction with the system that drivers infer from the information communicated. The templates that he drivers' will be expected to express will follow Cohn's template, more precisely,

> "As a *<role>*, I can *<action with system>* so that *<why?/ external benefit>*".

For instance, an expression such as "As a driver, I can verify the current driving mode through the pictogram on the HMI so that I know who has control over the vehicle" would enable VED to validate driver's comprehension of the visual pictograms used to indicate driving mode on the HMI.

The functionalities on which we observe a discrepancy between the intended TeamMate HMI design and drivers' comprehension of the action expected from him/her will be evaluated for redesign in the next project cycle.

7 Description of the experiments

The section presents the most important experiments from HMI aspect and their related metrics. Each experiment description details its relevance in the AutoMate project. The aim of the experiments is to validate the earlier defined and above summarized requirements by defining the related metrics as well, which will be matched against the requirements after carrying out the experiments.

Hand-over and control sharing

VED investigates the handover process in a bimodal automated vehicle, that is, an automated vehicle which operates either in manual mode under driver's control or in automated mode under vehicle's control. In other words, VED does not treat the issues related to shared control, which will be covered by ULM.

The baseline VED vehicle issues unplanned takeover requests. That is, the driver is expected to take over manual control immediately after a takeover request. The TeamMate concept that will be integrated in the VED vehicle will enable planned takeover. Thus, the TeamMate HMI will be tested in situations where the driver can be warned in advance, such as approaching the end of an automated driving zone or a road work area. The objective of the TeamMate HMI is to provide the relevant information that would make sure that the driver is back in the control loop when s/he takes control. However, the timing of this communication is equally important. The information that is provided too early is likely to be forgotten while the one provided too late is not considered as useful by the driver (Winkler, Werneke, & Vollrath, 2016). The use cases in the Martha scenario will allow us to test the timing of the messages, drivers' understanding of them, their rebuilding of situation awareness, and the following takeover performance.

Metric 1

- ***Timing of the takeover request for planned takeover*** will be measured by driver's rating of usefulness and appropriateness of the timing of the takeover requests issued in advance of planned takeovers.
- It can be used to check whether requirement R_EN6_tool1.38 is fulfilled.

Metric 2

- ***Situation awareness*** will be measured by situation awareness rating (SART). This is a subjective measure of situation awareness originally developed for pilots. It consists of pilot's self-evaluation on ten dimensions. An adaptation for drivers will be carried out.
- It can be used to check whether requirements R_EN6_tool1.19, R_EN6_tool1.20, R_EN6_tool1.21, R_EN6_tool1.22, R_EN6_tool1.23, R_EN6_tool1.24, R_EN6_tool1.30 are fulfilled.

Ulm conducted an experiment to test shared control in one of the PETER use-cases where the driver has to confirm the overtaking manoeuvre. In manual driving mode, the driver would first check the oncoming traffic, then use the indicator and steer on the other lane. The two-step action sequence of using the indicator and turning the steering wheel a bit to the other lane initiates the overtaking manoeuvre. The automation then switches again.

Two interaction concepts of shared control were compared in this experiment. One of the interaction concepts was the interaction via the touch screen in the central stack, a method which is already in use by several car manufacturers (e.g. Tesla, Opel). The other interaction concept was one that was expected to give the driver a more natural way of interacting with the car in a shared control situation. The experiment showed, that there is no significant difference in the subjective rating of the usability of both interaction types.

In further experiments the shared control aspect of the TeamMate car will be tested against the baseline of handing over full control of the vehicle from the automation to the manual driver.

Multi-modal interaction

The TeamMate interaction concept is based on the overcoming of the warning-based paradigm and the exploitation of a negotiation-based approach. The core of the negotiation is represented by the sharing of decisions and actions between the driver and the vehicle. In the first cycle, we defined this state as "TeamMate Mode". In this state the car offers suggestions to the driver, acting as a team mate to achieve the best result, i.e. the safest driving behavior possible. The interaction in this mode is achieved mainly through the visual channel (e.g. dynamic representations of the suggested manoeuvre), but it should be reinforced using other sensory channels.

In scientific literature, but also in cars available on the market, there are a lot of example of the use of multimodal HMIs. In the last few years the awareness about the benefits of technologies such as gesture control (Roider et al., 2017), speech interfaces (Lo and Green, 2013) and in-vehicle touch-based displays (Colley et al., 2015) is increasing, and their gradual implementation by manufacturers is becoming more and more common.

The current, most widespread multimodal solutions are focused on two pillars:

- multimodal feedback to inputs (e.g. a sound to confirm the correctness of the input);
- multimodal messages to advise the driver of an incoming situation (e.g. the vibration on the seat or the steering wheel to inform the driver about a dangerous situation).

It seems clear that this approach contemplates the use of multimodal messages basically to warn the driver.

As stated in the first cycle of the HMI development, the core of the cooperation that inspires the AutoMate project is the negotiation. Since the negotiation requires a much more sophisticated communication of the typical warning-based approach, it appears essential to implement other modalities to improve the interaction between the driver and the vehicle. In particular in a safety-critical context, such as the automotive domain, this kind of interaction cannot rely only on the visual channel: information should be allocated on different channels as well, so that the driver can process them in the most effective way while tackling with the primary task. Following the AutoMate approach, the multimodality in the communication should not be used only in critical situation, but also to build trust in normal situations.

In the first cycle, the TeamMate HMI concept was focused mainly on visual interaction. In that cycle, the multimodal interaction concept was hypothesized, based on the model of the driver-state adaptive interaction. The most important driving tasks have been selected and then divided into subtasks, in order to address for each situation or behavior the best way to design the communication between the driver and the vehicle.

This kind of task analysis has allowed to create the information structure of the TeamMate HMI concept, i.e. to establish what kind of information should be presented in each moment and what is the right channel to convey this information (cfr. D4.2).

The variable selected to describe the driver state is the driver's level of attention. In this way, the interaction is optimized adapting the type of feedback to the state of the driver: if the driver is not attentive there is the demand to re-engage him/her into the monitoring task, and a more articulated system of feedback is needed; if he/she is attentive a simple visual feedback might be enough. It is important to highlight that in this document, when we talk about attention and distraction, we're referring to observable behaviors, i.e. driver's visual distraction.

The other variable used to classify the multimodal feedback is the type of the task, that is the relevance and the criticality of the human expected intervention.

In order to improve the communication between the vehicle and the driver, from the 2nd cycle multimodal elements will be added to the HMI. These improvements, in line with the cyclicity of the project, can be seen as part of the incremental approach used for the development and implementation of the HMI.

Metric 1

- How the use of another sensory channel in addition to the visual one affects the driver's **level of situation awareness**.
- The SAGAT technique (cfr. D4.1) will be used to assess the requirement is fulfilled. The positive rate of this tool represents the success criteria.
- It can be used to check that requirement R_EN6_tool1.43 is fulfilled

Metric 2

- How the HMI affects the **level of comprehension** of the driver about the automation state.
- It will be measured through a correct rate measure; the 90% of correct answers will be considered as success criteria.
- It can be used to check that requirement R_EN6_tool1.36 is fulfilled.

Metric 3

- How the HMI affects the ability of the driver to predict the relation among the HMI modes, e.g. recognizing the relationships between the transition states and the stable states.
- This metric will be measured through a correct rate in order to understand if the driver will be able to distinguish among the states: the 90% of correct rate will be considered as success criteria.
- It can be used to check that requirement R_EN6_tool1.44 is fulfilled.

Upcoming Experiment/Study/Test (2nd Cycle)

The sample of drivers will be chosen in order to ensure a sufficient heterogeneity. The participants will be asked to assess the level of comprehension of the HMI and the relation among the states: one of the possible answers will be correct, and will be used to measure the correct rate.

Concurred Abbreviation

Concurred abbreviation (CA) is a recently arising concept in the field of HMI usability (Koo et al., 2014). CA is a voice alert that aims at remedying one of the bottlenecks of the automated driving, namely, lack of feedback to let the driver know what actions will take place, ahead of the event. Thus, CA is rather a feedforward information in order to ensure trust in the system and driver situation awareness.

CA can provide information about how or why the upcoming action will occur, or the combination of how and why information. A how-message primarily focuses on the operational behavior of the car, whereas a why-message focuses on the driving environment where the event will be taking place. Koo and colleagues (2014) indeed demonstrated that drivers felt more positive about a why-message without how-message and that the system acceptance was higher with why-message regardless of the presence of how-message. Safe driving behavior, however, was more frequently performed when why and how messages were combined.

The above results are indeed in line with the analyses of Beggiato and colleagues (2015) on drivers' needs of information in an automated vehicle. Among the primary information needs were: current and planned maneuvers, oncoming critical events, and degree of certainty that the vehicle can handle the situation.

Feedforward CA is especially important in the case of a mode transition and in case the driver is expected to handle the upcoming event.

We will employ two attitudinal measures, namely, emotional valence and acceptance (Koo et al., 2014), and two behavioral measures, namely, safe driving behavior and glance behavior (Koo et al., 2014; Beggiato et al., 2015), in order to study the efficiency of CA in the context of TeamMate system. These metrics will serve to validate whether the indicators in R_EN6_tool1.31 are fulfilled.

In the next cycle, concurred abbreviations as an additional TeamMate feature will be tested. The current status of the driving mode will be shown by different ambient light colours. Therefore, the driver does not need to focus on a specific symbol or location to find out about the driving mode.

Metric 1

- ***Emotional valence*** refers to positive or negative emotions regarding driver's experience with the CA that is communicated via TeamMate interface.
- It is an aggregate score to in response to the question "How well do the following words describe how you felt while driving?" The specific emotions are: anxious, annoyed, and frustrated.
- It can be used to check whether the "emotional experience" component of the R_EN6_tool1.31 is fulfilled.

Metric 2

- ***Acceptance*** refers to driver's acceptance of the CA that is communicated via TeamMate interface after its use.
- It is an aggregate score to in response to "How well do the following adjectives describe the car?" The specific adjectives are: intelligent, helpful, dominant, and reliable.
- It can be used to check whether the "user acceptance" component of the R_EN6_tool1.31 is fulfilled.

Metric 3

- ***Safe driving behavior*** will be analyzed based on the behavioral data in response to CA that is communicated via TeamMate interface obtained from the driving simulator.
- Precise behavioral indicators are collisions, time exposed time to collision, time headway, and lateral acceleration.

- It can be used to check whether the “mission effectiveness” component of the R_EN6_tool1.31 is fulfilled.

Metric 4

- ***Glance behavior*** refers to the percentage of time spent with control glances and attention allocation towards different zones in the TeamMate system, such as interface, roadway, side mirrors.
- Precise indicators are fixations and saccades.
- It can be used to check whether the “attention allocation strategy” component of the requirement R_EN6_tool1.31 is fulfilled

Augmented HMI

To follow the TeamMate approach, it is necessary that the system provides a shared understanding of the current situation between the driver and the automation. The driver should understand the current situation and the automation’s behavior. The idea of the augmented reality part is to provide a better situation understanding and to understand the behavior of the automation. Using an Ecological Interface Design (EID) approach, relevant model information is visualized through augmented reality to understand what the automation is actually “seeing”. Though current HUD only display information, next generation HUD will make use of Augmented Reality to project information in such a way that it looks like it is part of the real environment.

For this HMI component the online risk assessment, which is developed in WP3, serves as a base to help the driver to understand overtaking situations. Figure 1 shows how an overtake corridor is augmented in the view of the driver to inform the driver about potential risks with the use of an overtake corridor and different colors.

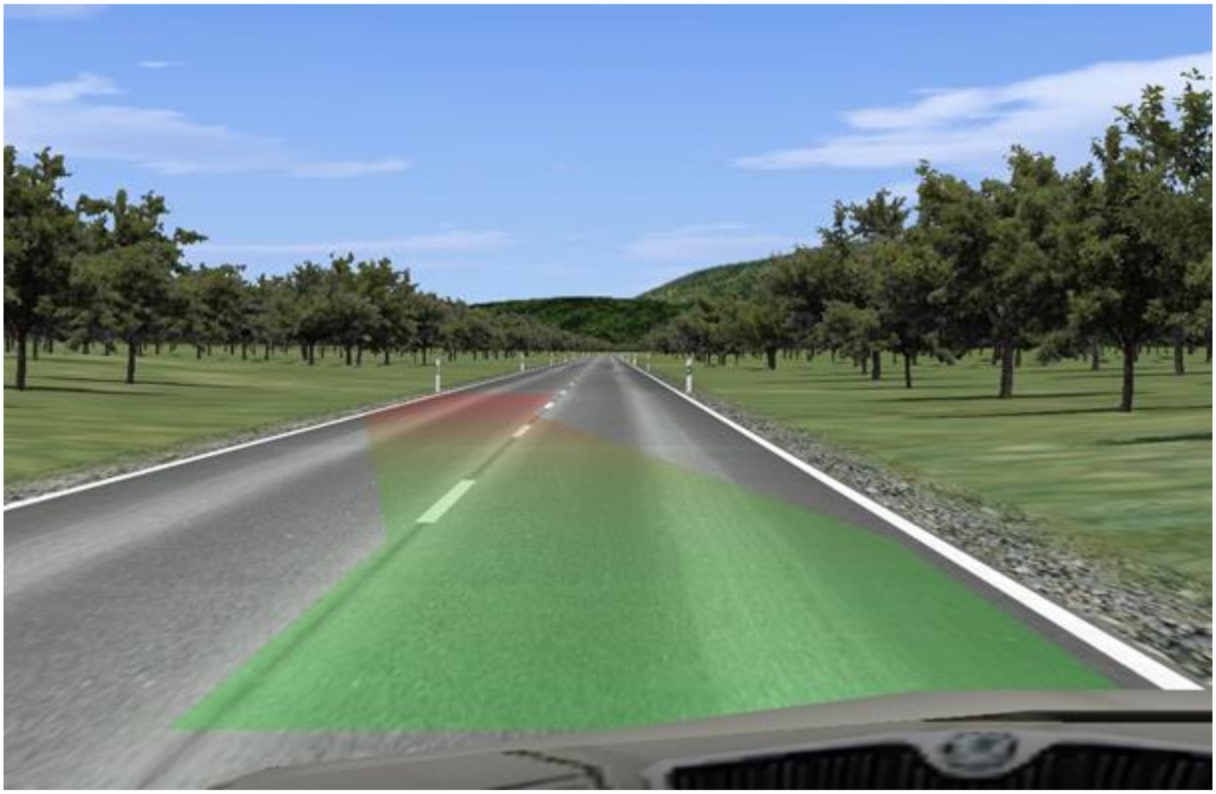

Figure 1. Overtake Corridor from the Augmented HMI

The augmented information coming from the risk assessment will help the driver to predict and understand the overtaking behavior of the automation. Though the Augmented HMI could assist the driver in manual mode to assess the risk of a situation as well, the focus is on understanding the actions taken by the automation.

The automation should also take the driver model from WP3 into account to react according to the driver's preference, so that the driver is not surprised of the actions taken by the automation. Different situations have been identified in overtaking situations which need to be validated. Taking the preference of the driver into account, there are three different scenarios: (1) TeamMate knows from the driver model that the driver wouldn't overtake and will hold the lane, (2) TeamMate knows from the driver model that the driver would overtake and will start overtaking because the overtaking is considered as safe, (3) TeamMate knows from the driver model that the driver would overtake, but won't overtake because overtaking is considered as not safe.

Therefore, there is the possibility that the distances or the difference speed to alter cars is acceptable for the automation, but not from the driver's point of view. In order to build trust and acceptance, the automation adapts to the driver's behavior. The challenge for the HMI is to visualize the current situation, so that the driver is not surprised of the actions by the system.

Metric

- The HMI will be validated by inspecting the **Correct Rate (CR)** for the driver to recognize and understand given overtaking situations visualized through the AR part of the HMI.
- It can be used to check that the requirements R_EN6_tool1.35 and R_EN6_tool1.42 are fulfilled.
- An acceptable ratio of correctly assessed situations by the subject of the test should be in the range of over 90%.

Upcoming Experiment/Study/Test (2nd Cycle)

The subject of the test should be able to recognize and understand the meaning of different overtaking situations. Different scenarios based on the description above and a setup where the subject of the test can step through different scenarios must be prepared. For each scenario questions are asked to determine the understanding level at that particular situation. To obtain the answers the SAGAT method which is described in D1.3 can be used (Endsley, 1988). The subjects' answers are compared with the correct answers. If more than 90% of situations are recognized correctly, the requirements can be considered met.

To gain insights about future improvements they will be different variants of the Augmented HMI which can be tested independently as described here and compared against each other.

8 Conclusions

The aim of the HMI developed in WP4 is to facilitate the cooperation and the creation of the solid team between the driver and the automation.

While the V&V in the Cycle 1 was focused on verifying the correctness of the preliminary set of HMI modules, in the Cycle 2, the V&V tests will mainly focus on validating the ability of the HMI modules to concretely act as enablers to reach the overall project objectives, i.e. to allow the driver and the automation to cooperate safely as a solid team to drive from A to B.

Several HMI enablers have been developed in WP4 to achieve this objective.

The current deliverable takes the development and verification results from the Cycle 1, the high-level requirements and the general metrics from D1.3 as a starting point to describe the plans and experiments that will be conducted in this cycle (2nd) for the validation of the HMI components developed in WP4.

Experiments has been planned to be conducted in controlled environments (such as driving simulators) with real drivers, in order to test the role and added value of the HMI for the implementation of the TeamMate car concept. The outcome of these experiments will feed forward to the fine tuning of the HMI in Cycle 3.

9 References

Beggiato, M., Hartwich, F., Schleinitz, K., Krems, J., Othersen, I., & Petermann-Stock, I. (2015). *What would drivers like to know during automated driving? Information needs at different levels of automation*. Proceedings of 7th Conference on Driver Assistance, Munich, 25-26 Nov 2015.

Cohn, M. (2004). *User stories applied: for agile software development.* Addison-Wesley: Boston.

Colley, A., Vayrynen, J., & Hakkila, J., (2015). *In-Car Touch Screen Interaction: Comparing Standard, Finger-Specific and Multi-Finger Interaction*, PerDis '15 Proceedings of the 4th International Symposium on Pervasive Displays, Pages 131-137.

Endsley, M. R. (1988). *Situation awareness global assessment technique (SAGAT)*. Presented at the National Aerospace and Electronic Conference (NAECON).

IEEE Std. 1012, (2012), Standard for system and Software Verification and Validation.

Koo, J., Kwac, J., Ju, W., Steinert, M., Leifer, L., & Nass, C. (2014). Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust, and performance. *International Journal on Interactive Design and Manufacturing, 9,* 269-275. doi: 10.1007/s12008-014-0227-2

Lo, V. E. & Green, P. (2013). Development and Evaluation of Automotive Speech Interfaces: Useful Information from the Human Factors and the Related Literature. *International Journal of Vehicular Technology, 2013*, http://dx.doi.org/10.1155/2013/924170

Roider, F., Rumelin, S., Pfleging, B., Gross, T., (2017), *The effects of Situational Demands on Gaze, Speech and Gesture Input in Vehicle*, AutoUI '17 Proceedings of The 9th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications

Winkler, S., Werneke, J., & Vollrath, M. (2016). Timing of early warning stages in a multi stage collision warning system: Drivers' evaluation depending on situational influences. *Transportation Research Part F, 36*, 57-68.