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Final functional Human Factors recommendations

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AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

Document information //

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Revision and history chart //

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0.3	02.10.14	Adding HF Requirements from DLR
0.4	06.10.14	Consistency check of HF Requirements by DLR
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0.6	05.12.14	Reworking according the 4A structure by DLR
0.7	20.04.15	Pre-condensed homework done by partners comes together
1.0	30.04.15	First condensed version of already existing HFFuReqs
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1.2	13.05.15	Slightly improved and commented version after GA in Athens
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2.1	05.04.17	Preparation for internal review (restructuring the recommendation tables, annex, language check, review all chapters)
2.2	21.04.17	Including adjustments regarding reviewer comments
2.3	30.05.17	Final ediding after internal review

Glossary

AD = Automated driving

AFFP = Accelerator Force Feedback Pedal

DAVE = Driver-automation-vehicle-environment

HDD = Head-down display

HF = Human factors

HUD = Head-up display

IWI = Inform-warning-intervene

MRM = Minimum risk manoeuvre

SA = Situation awareness

SAE = Society of automotive engineers

UCD = User centered design

VSP = Vertical sub-project

Sim = Simulator

TOR = Take-over request

Rec = Recommendation

DAS = Driver alert system

BLIS = Blindsport Information System

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1 Introduction

This report documents the Human Factors (HF) recommendations developed and used for the design of demonstrator vehicles within the AdaptIVe project. The proposed HF-recommendations, therefore, mostly address the automation levels [61] (SAE) 1-3 [76], in highway, urban, and close-distance scenarios. The recommendations developed in this work were predominantly designed to meet AdaptIVe project requirements, and they should be carefully verified prior to use in further projects/applications. However, this report can provide general Human Factors guidelines for the User-Centred Design (UCD) of automated vehicles.

“Human Factors (…) is the practice of designing products, systems or processes to take proper account of the interaction between them and the people that use them.”[82] The product and system design traditionally benefits from well-established requirements analysis methods [15] defining functional and non-functional requirements[1] to continuously guide the complex development process. On the basis of this ‘traditional’ requirements analysis, within AdaptIVe we followed an iterative process to set up and refine several HF-recommendations that we see as most important for the design of automated vehicles.

In systems engineering practice [15], every requirement *must be followed* within the system development process. Compared to established technical approaches Human Factors considerations relating to vehicle automation design are still very much under investigation, and thus, the term ‘recommendation’ was chosen instead of ‘requirement’. Compared to requirements, HF-recommendations can be understood as a less stringent form of requirements analysis, contributing to the HF-related development of automated vehicles. HF-recommendations *can be followed* to improve the early technical development of automated systems by considering humans’ expectations and needs. This will enable efficient, safe, easy-to-understand, and well-accepted system design for different automation levels.

Similar to technical requirements, we distinguish between functional and non-functional HF-recommendations. Generally, a functional recommendation can be expressed in the form ‘system <u>should do</u> <recommendation>’; while non-functional recommendation is a ‘system <u>should be</u> < recommendation >’.

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[1] “A **functional requirement** defines a function of a system and its components. Functional requirements may be calculations, technical details, data manipulation and processing and other specific functionality that define what a system is supposed to accomplish. Functional requirements are supported by **non-functional requirements** (also known as quality requirements), which impose constraints on the design or implementation (such as performance recommendations, security, or reliability).” [81]

Given these definitions and explanations, the objectives of the AdaptIVe work on Human Factors recommendations are:

1. To provide a methodology for structuring HF-recommendations;
2. To present the HF-recommendations catalogue, including both previously existing recommendations, and those discovered through the AdaptIVe project;
3. To contribute to HMI development for the demonstrator vehicles within the project;
4. To provide HF-guidelines as a tool for future projects working on human-vehicle integration in the domain of automated vehicles.

This document consists of six sections. In chapter 2 we explain our approach to organising HF-related knowledge and the HF-recommendations for the driver-automation-vehicle-environment (DAVE) systems we are dealing with in the AdaptIVe project. Four main categories were identified as having relevance in the design of automated vehicles: a) Agent state, b) Awareness, c) Arbitration and d) Action, otherwise known as the 4A's. The chapter describes how we came up with the 4A-Structure, along with the methodology used for organizing the HF-recommendations according to that structure.

In chapter 3 we summarize all existing HF-recommendations identified through literature research, as well as the new HF-recommendations discovered during the HF-experiments within the AdaptIVe project. Both types of recommendations (existing and new) are organized in tables based on the 4A-Structure. This catalogue of HF-recommendations in chapter 3 is considered a tool for future projects working on human-vehicle integration in the domain of automated vehicles. The catalogue was used by the demonstrator owners within AdaptIVe to aid with the development of the demonstrators. It was also used as a guideline for identifying outstanding research questions to be addressed in the HF-experiments in WP3.5 of the project.

Chapter 4 provides a section on lessons learned, and delivers an agenda for how the work on HF-recommendations can be continued.

Chapter 5 (not included in the public version of the document) is an annex providing additional information for better understanding our working process and underlining the contribution to the overall work from every participating partner. Chapter 5 describes how the demonstrator owners addressed the HF-recommendations within the AdaptIVe demonstrators.

2 Towards a structure for Human Factors recommendations

Both “Requirements Analysis” and “Human Factors” are complex domains, and thus, combining them is also a complex process. To avoid getting lost in this complexity, it is important to develop and maintain a clearly stated and structured approach for dealing with functional and non-functional HF-recommendations. Therefore, one of the main goals of this work was to document all HF-recommendations in a single catalogue to provide a useful tool for practitioners in the field of driver–vehicle integration, especially for the demonstrator owners in context of the automated vehicle functions they had in mind for the AdaptIVe project. An important question was how to bring together previously established HF-recommendations with the new ones emerging from experimental research, in order to address the specific issues of the AdaptIVe project? To address this question, for the AdaptIVe project we proposed a new three-stage approach towards developing a well-structured and usable HF-recommendations catalogue as a ‘final product’ of this work.

Firstly, we needed to establish a record of existing HF-recommendations within the available literature. These provided a good starting point for demonstrator owners to use the HF-recommendations catalogue as a tool during the initial development of the demonstrators in the early phase of the project. It also helped to guide the identification of research needs related to the driver-vehicle integration experiments in WP 3.5.

Secondly, we had to develop new and specific HF-recommendations with respect to the AdaptIVe functions, such as highway chauffeur, close-distance or intersection assistants etc., and the AdaptIVe use cases, such as switching the automation on and off, changing the automation level etc.. These had previously been defined in WP3.3 [20]. A closer analysis of the use cases provided the basis for the experiments executed in WP3.5 [21], which then informed the development of new HF-recommendations.

Thirdly, the continuous dialogue between SP3 partners and demonstrator owners in WP3.2 was another important source of information for the HF-recommendations catalogue. The use case analyses, the experimental results, and the corresponding dialogue with demonstrator owners, all enriched the HF-recommendations catalogue with AdaptIVe-specific examples (Annex).

With the three-stage approach, we have brought together ‘existing’ recommendations, ‘new’ recommendations, and implementation examples in a structured manner, documenting all of the HF-recommendations and corresponding examples into the same consistent catalogue.

To summarize the above information, the HF-recommendations catalogue brings together a series of recommendations based on the automated vehicle functions proposed by vertical-sup-project partners (VSP) partners, a thorough literature search of existing solutions, and the outcome of experimental research as part of AdaptIVe SP3.

2.1 Helpful concepts for developing appropriate structures

There are several different Human Factors aspects which need to be considered when designing for the interaction between humans and automated vehicles. Therefore, we developed a structuring methodology for documenting the existing and new HF-recommendations and implementation examples. This structure will be described in the following sections.

In general, the proposed structure is based on two key assumptions:

1. The information processing model within a cognitive system is taken as an appropriate basis by which to structure the HF-recommendations.
2. The driver, the automation, the vehicle and the environment are seen in this report as cognitive agents2 in a joint cognitive system [32], [45], [60].

Further, with respect to (human) cognition, early information processing models described a four stage process as follows: Sensory Processing, Perception, Decision Making, and Response Selection [6], Figure 2.1.

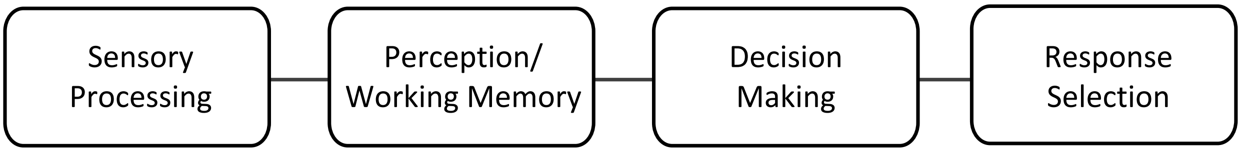


Figure 2.1: Linear four-stage human informational processing (after [6])

However, research suggests that humans use a less sequential and more interlaced informational processing model based on the concept of Situation Awareness (SA) [18]. SA suggests that in order to understand a particular situation, humans have to perceive, to comprehend, and to project the future states of that situation (Figure 2.2). This process occurs in a highly interlaced manner and is influenced by several more or less persistent preconditions or 'states' of agents, such as experience, abilities, goals, stress, etc., including the perceived state of the environment. Situation awareness is highly influenced by these agent states, and strongly influences the implementation of a decision, and the implementation of an action as described in the cognitive information processing model above (Figure 2.1).

[2] An agent is any entity able to act [9] and, in this context, the cognition can be seen as a capability of an agent to internally set, modify and follow own knowledge goals while acting. Systems consisting of at least one cognitive agent that can internally determine own knowledge, goals and behaviour can be defined as cognitive systems.

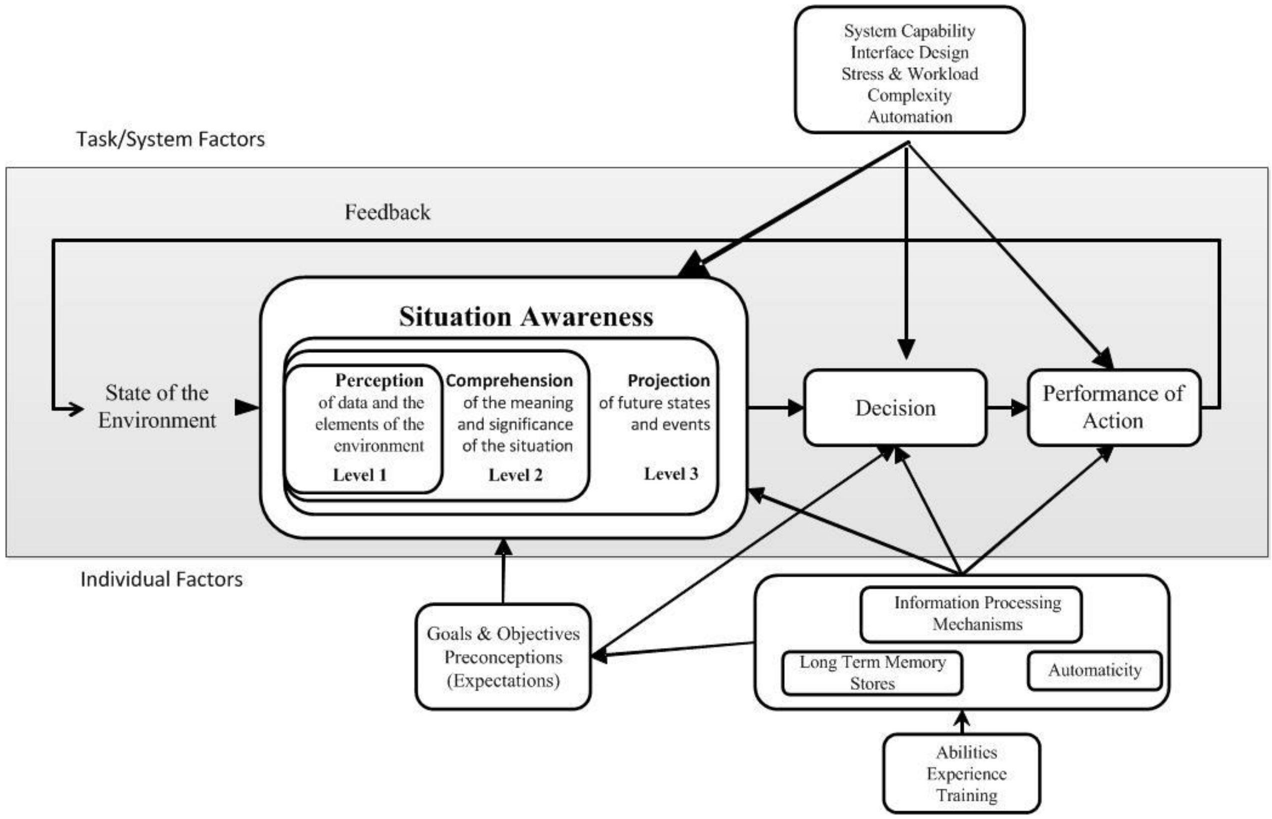


Figure 2.2: Concept of Situation Awareness in dynamic decision-making (after [18])

Up until this point, we have talked about the information processing capacity of a single agent - the human (driver). Yet, a driver-automation-vehicle-environment (DAVE) system consists of several agents, such as the driver, automation, the vehicle itself, and the environment. It also can consist of further 'in-vehicle' and 'out-of-vehicle' agents, such as passengers, pedestrians, intelligent road infrastructure, etc. The cognitive system we are dealing with in AdaptIVe can therefore be more distributed in space than much of human cognition, and the structuring of the HF-recommendations should reflect this distribution.

In order to deal with the interaction, coordination and decision processes which occur within a distributed cognitive system, a concept named Arbitration [43] can be used. This concept describes at a high level the interaction and decision-making process in a distributed cognitive system. It also considers the interaction strategies between different agents for different modalities, such as haptic, acoustic, and visual; which consist of multimodal interaction signals and their meaning (semantics), order, and timing (syntax). Arbitration can be implicit, when the agents use the self-organisation process within the system [44], or it can be explicit, when the agents are externally organised by a particular design of an HMI-agent [1], i.e. an Arbiter [45] (Figure 2.3). The arbiter (blue rectangle in Figure 2.3) can moderate the interaction between the driver and automation through proper HMI-strategies, and signals supporting the self-organization within the system. When needed, the arbiter can make a decision with the highest benefit for all agents in the system.

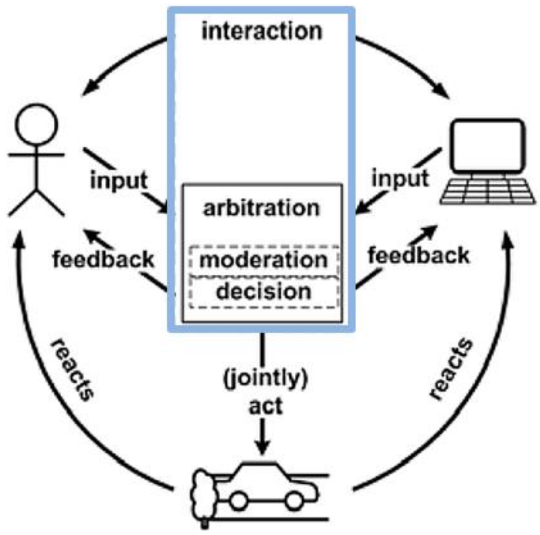


Figure 2.3: Particular arbitration model for automotive domain [after [43]]

2.2 4A-Structure

The HF-recommendations were structured according to the three concepts presented in the section above (sequential cognitive processing, situation awareness and arbitration). These concepts were amalgamated to provide the basis for the 4A structure as follows:

Step 1: Reducing the SA-concept from Figure 2.2, we can firstly extract four basic categories: Agent States, Situation Awareness, Decision and Action. For DAVE systems, the agent states category can be separated into additional sub-categories: driver, automation, vehicle, and environment states. Important sub-categories for the 'Action' category are ergonomics, usability, and controllability, as these can directly influence performance when the agents are acting.

Step 2: As we are dealing with distributed systems, the Decision aspect of information processing can be replaced by Arbitration, which can describe the complex distributed moderation and decision process within a DAVE system. Arbitration can subsume the sub-categories of interaction and decision, adaptivity, modes, and transitions for DAVE systems.

Step 3: As we are dealing with the specific domain of DAVE systems, situation awareness can be regarded as one sub-category with mode awareness, role and task awareness as further sub-categories under the roof of an overarching 'Awareness' category.

Through these very briefly described three steps of intensive work and long discussion, four main categories have been identified for informational processing within a (cognitive) DAVE system, with several sub-categories under each main category. The main categories are: 1. Agent state, 2. Awareness, 3. Arbitration, 4. Action (Figure 2.4). These are the four A's of the 4A-Structure.

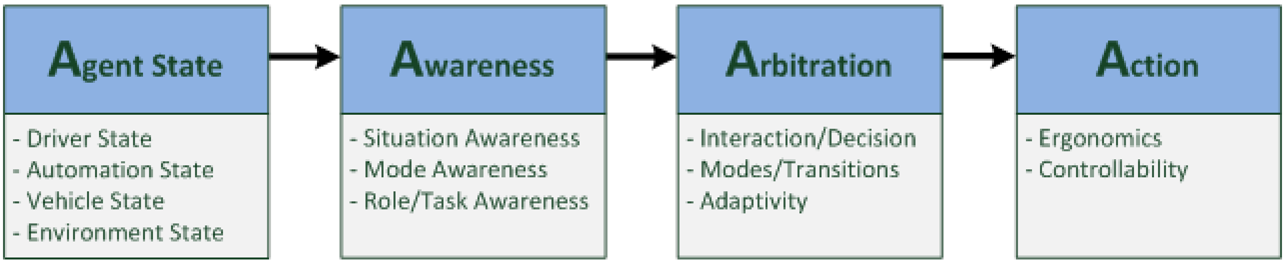


Figure 2.4: 4A-Structure with four main categories and with sub-categories describing the informational processing in a (cognitive) DAVE system. These categories and sub-categories are used to structure the HF-recommendations within the AdaptIVe project.

The 4A-Structure includes, in a reduced form, the concepts of cognitive information processing, situation awareness, and arbitration. It shows that information processing within a cognitive system, such as DAVE system, can occur on a high level described as follows: All agents in the system can determine or be in certain (cognitive) states, which strongly influence their awareness of the situation, modes, and role/tasks. Based on their specific awareness, the agents interact with each other, decide, and finally implement an action. The subcategories of the 4A's denote the main points of interest regarding the DAVE systems.

Using the 4A-Structure as means for documenting the HF-recommendations can bring advantages, as its categories are based on concepts of cognitive science and its sub-categories are based on the most important points from previous research of DAVE systems. This 4A-Structure provides an effective mechanism for documenting the HF-recommendations, and bringing them together in a coherent manner through the HF-recommendations catalogue. The users of that catalogue, such as the demonstrator owners within AdaptIVe, are also indirectly dealing with the 4A-Structure included in the catalogue they use. This theoretical basis can help the users of the HF-recommendations catalogue to comprehend the Human Factors perspective on the DAVE system, enabling more effective overall system and function development.

2.3 Using the 4A-Structure

Interaction between humans and technical parts of the system can induce Human Factors challenges that need solutions. Usually, these challenges are caused by the characteristics of the human cognition and the interaction with the human-machine interfaces (HMI). The challenges, therefore, arise as a result of the overall information processing within the cognitive system.

The 4A-Structure presented above can serve as structuring means to identify and to logically arrange those HF-challenges in a document. One can systematically go through the 4A categories and look for possible challenges in the particular cognitive information processing step with the sub-categories in mind, which provide further specification of the possible challenges to be addressed. The HF-challenges identified then need HF-solutions, which can be based on suitable system design recommendations, particularly in relation to HMI design. These HF-solutions can then be formulated as HF-recommendations, and written down next to the corresponding HF-challenge. This can be an iterative process to set up and refine several HF-recommendations in a catalogue.

In the catalogue we tried to use semi-formal language by using the same words for the same items or agents, e.g. automation refers to assistance, assistance system or support system etc. Humans, participants are named drivers. The overall joint cognitive system consisting of the driver, automation, vehicle, and environment is named system. We have used a limited number of verbs and adjectives, focusing on those, which are the most commonly used in the community regarding highly automated vehicle systems.

In summary, the 4A-Structure can serve as structuring methodology for discovering possible challenges around cognitive informational processing within a joint cognitive system such as DAVE systems. Solutions for the challenges can then be found, and explicitly formulated as HF-recommendations. The structure, therefore, provides the method we used for documenting already existing and new HF-recommendations, and examples of their implementation. This collection was compiled into the HF-recommendations catalogue (Chapter 3).

2.4 Deeper look into 4A's

In this section we provide a deeper explanation of the 4A-Structure to communicate the concept itself in more detail, as well as its usefulness as a structuring means during HF-recommendations analysis in the area of DAVE systems. In the next sections we systematically describe all 4A categories and sub-categories, and give examples of possible challenges and recommendations for each of these.

2.4.1 Agent State

'Agent State' category refers on a high level to a precondition within the DAVE system for further informational processing. Driver, automation, vehicle, and environment, are defined as agents of a DAVE system, and can be in certain (long-term) states during the informational processing. These agent states can refer to human's state e.g. level of knowledge or fatigue, as well as to the states of the technical parts of the system (the automation and the vehicle) e.g. system limitations; or environmental states, such as traffic density levels, or weather.

2.4.1.1 Driver State

'Driver State' refers to states, such as drowsiness, knowledge levels, mental models, attention, etc. These types of states are constraints, and may induce driver-state related HF-challenges. An example of a driver state challenge is: The driver is not aware of upcoming automation limits. The HF-recommendation could be: The automation should inform in advance about an upcoming automation limit, and if possible, about upcoming automation failures.

2.4.1.2 Automation State

'Automation State' refers to states, such as automation level, failure state, uncertainty, etc. All these types of states are constraints and subject to automation state-related HF-challenges. An example of an automation state HF-challenge is: The automation does not check if the driver has taken over the driving task. The HF-recommendation could be: The automation should be able to detect that the driver has taken over the driving task.

2.4.1.3 Vehicle State

'Vehicle State' refers to states, such as physical limits, mechanical or electrical failures etc. These types of states are constraints and subject to vehicle state HF-challenges. An example of a vehicle state HF-challenge is: In particular situations, a vehicle can reach its physical limits. The HF-recommendation could be: The vehicle should avoid the physical limits.

2.4.1.4 Environment State

'Environment State' refers to states, such as rain, snow, dangerous objects on the expected trajectory, speed limits, legal restrictions etc. These types of states are constraints and subject to environment State HF-challenges. An example of an environment State HF-challenge is: There is an obligation to drive 50 km/h at maximum in urban areas. The HF-recommendation could be: The environment agent should inform the automation and the driver about the obligation to drive 50 km/h at maximum in urban areas.

2.4.2 Awareness

'Awareness' refers to the next step of cognitive informational processing within the DAVE system. In this step, HF-challenges are related to (short-term) perception, comprehension, and projection of the situation, as well as to the awareness of current system modes, such as current automation level, and awareness of role and task distribution between agents.

2.4.2.1 Situation Awareness'

'Situation Awareness' "refers to the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their statuses after a variable has been changed, such as time, or a predetermined event." [83] Humans in particular, can lose situation awareness, e.g. being out of the vehicle control loop for too long, which can lead to skill degradation, or having to process too much information at once (informational overload). Drivers can also fail to comprehend information due to its novelty. They can fail to anticipate information due to missing mental models of the dynamics of the scenario, e.g. during an unexpected situation. An example of a SA-related HF-challenge: A distracted driver overlooks visual information on the display. The HF-recommendation could be: Use effective HMI modalities or images to ensure that information can easily be recognized by the driver.

2.4.2.2 Mode Awareness

'Mode Awareness' refers to current and future system modes, such as automation levels. Human agents, in particular, can lose mode awareness when receiving information too suddenly, too unexpectedly, or not regularly enough. An example of a mode awareness HF-challenge: The driver does not know if the automation is available or not. The HF-recommendation could be: The automation should display its availability for activation to the driver.

2.4.2.3 Role & Task awareness

'Role & Task awareness' refers to current and future roles of the agents, and the corresponding tasks within these roles. The driver and automation agents can lose their role and task awareness in circumstances when they do not receive information about the current role distribution between the agents. An example of a role and task awareness HF-challenge is: The driver can fail to check the surrounding traffic situation while performing a lane change. The HF-recommendation could be: The automation agent shall keep the driver aware of tasks while performing a lane change.

2.4.3 Arbitration

'Arbitration' category is about interaction and decision strategies between the agents. It covers signal understanding and scheduling challenges, such as delays, bursts, or deadlocks during the communication or coordination of the agents, including the modalities of the dialogue, e.g. the channels (haptic, acoustic, visual) over which information shall be communicated. Interaction design matters are also considered in the arbitration category, such as how many modes are needed, and the type of transitions required, e.g. escalation schemes or prioritisation in the mode transitions. Adaptivity matters of the agents are also addressed in the arbitration category, e.g. if the automation can adapt itself to the driver or be adaptable by the driver.

2.4.3.1 Interaction & Decision

'Interaction & Decision' sub-category is about the interaction and decision strategies to coordinate the agents. Matters addressed in this sub-category include, for example, how decisions are made: when, and by whom, and what role and task allocation shall be implemented in order to execute a decision? An example of an interaction and decision HF-challenge is: The driver wants to override the automation. The HF-recommendation could be: All assisting functions should be designed in a way that the driver can always override them.

2.4.3.2 Modality

'Modality' is about the channels through which the agents are communicating and interacting. Matters addressed in this sub-category include, for example, how to communicate a lane departure warning, e.g. visually on the instrument cluster, or with haptic output on the steering wheel, or both. An example of a modality HF-challenge is: The driver can oversee the visual information on the instrument cluster display while performing a complex manoeuvre. The HF-recommendation could be: The automation should provide means to support the drivers while performing a complex manoeuvre.

2.4.3.3 Meaning & Scheduling

'Meaning & Scheduling' sub-category is about challenges and recommendations regarding the meaning and scheduling of interaction signals, e.g. shall we use an escalation scheme, a handshake, how will priorities be applied etc., along with the meaning of interaction signals. An example of a meaning and scheduling HF-challenge is: Drivers cannot react instantaneously to a situation and usually require some processing time. The HF-recommendation could be: The Automation should schedule the interaction signals with respect to the drivers' reaction time.

2.4.3.4 Modes & Transitions

'Modes & Transitions' sub-category is about challenges and recommendations regarding the system modes and the transitions between the modes, e.g. how many modes are needed, how should automation look and behave when in these modes, and what sorts of transitions are required between the modes. An example of a modes and transitions HF-challenge is: The automation cannot handle all driving situations. The HF-recommendation could be: The automation should provide different automation levels in order to involve the driver in vehicle control when needed.

2.4.3.5 Adaptivity

‘Adaptivity’ sub-category is about challenges and recommendations regarding the effects of interactions on the system design. For example, how the driver and the automation agent can adapt to complex situations and interactions, and to each other. An example of an adaptivity HF-challenge is: The driver can’t adapt to the counter-torque on the steering wheel, which can induce instability of control while changing the direction of the counter-torque. The adaptivity HF-recommendation could be: The automation should provide a continuous blending of counter-torque when changing its direction.

2.4.4 Action

‘Action’ category refers to the immediate action performance and action support of the agents. It mostly deals with ‘classical’ ergonomic challenges, such as reachability, ability and inability to act, lack of skills, and inappropriate or incompatible form and function of the automation support, such as the screen is ‘too dark’, a button is too small etc. This category is closely related to usability and controllability challenges, such as observability and directability [10], which have an immediate impact on the vehicle control.

2.4.4.1 Ergonomics

‘Ergonomics’ sub-category refers to challenges and recommendations that can affect system design due to the physiological and psychophysical properties of the driver. For example, agents can vary in their particular abilities connected to action performance and issues such as reachability distance, actors’ mobility etc. should be considered. An example of an ergonomics HF-challenge is: The driver cannot interpret an acoustic signal. The HF-recommendation could be: Sounds should be used appropriately and made distinguishable from other sounds in the vehicle.

2.4.4.2 Controllability

The ‘Controllability’ sub-category refers to challenges and recommendations, which can appear in the system design as a result of vehicle control requirements. It belongs to the Action category, since the vehicle control is mostly performed through direct actions on vehicle's input devices. The controllability of the vehicle depends on the execution of correct (micro-) actions at correct points of time. An example of a controllability related HF-challenge is: The driver is surprised by an unexpected minimum risk manoeuvre. The controllability HF-recommendation could be: The driver should be informed about an imminent or ongoing minimum risk manoeuvre.

2.5 Remarks on Human Factors recommendations catalogue

All AdaptIVe Human Factors recommendations are documented in the form of a catalogue and presented in the next section. The HF-recommendations catalogue consists of several pages. Each page is about one HF-challenge, one corresponding functional HF-recommendation, and several non-functional HF-recommendations. The header of each page contains information about the unique identification code of the recommendation, the name of the recommendation derived from its related topic, the SAE Level(s) addressed, the related 4A sub-category, and the application scenario (highway, urban, close-distance) (Figure 2.5).

Further, there is a description of the HF-challenge and recommendation followed by an example of already existing implementation. At the very end, there are acronyms for references.

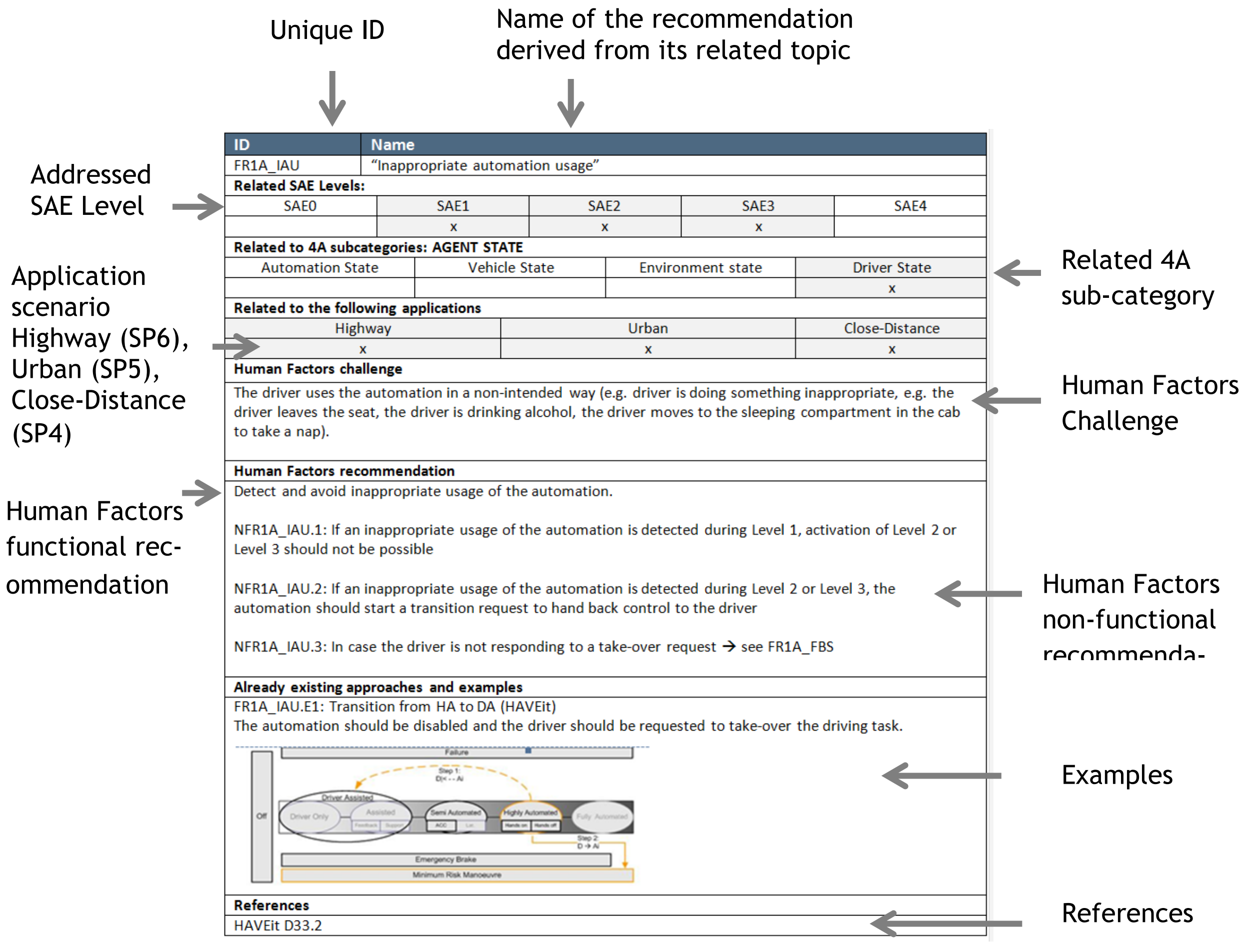


Figure 2.5: Explanation of the HF-catalogue

The acronym 'FR' in the unique ID stands for Functional Recommendations; 'NFR' stands for Non-Functional Recommendations. The acronyms are followed by the number of the 4A category (1=Agent state, 2= Awareness, 3= Arbitration, 4= Action). This is followed by an acronym of the recommendation, e.g. AUL = Automation Limits (Figure 2.6), and a number if necessary for enumeration of the examples.

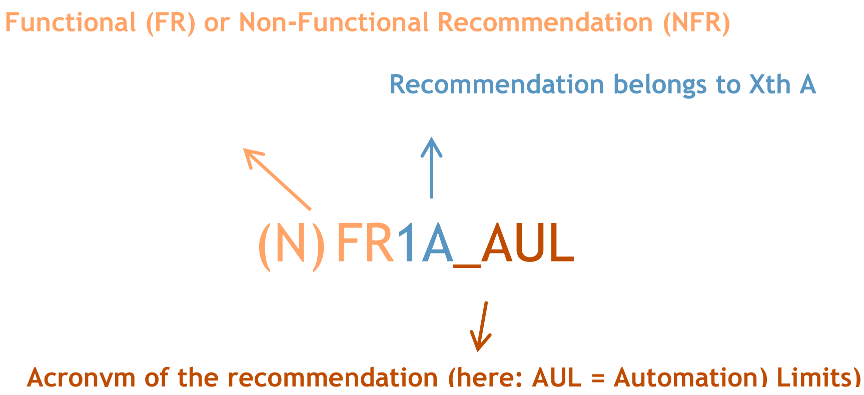


Figure 2.6: Explanation of the Index number

Examples: FR1A_AUL → Functional recommendation, first A (Agent state) about Automation Limits, NFR1A_AUL.1 → Non-functional recommendation, first A, Number 1

3 Human Factors recommendations catalogue

3.1 Agent State

ID	Name			
FR1A_AUL	"Automation limits"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AGENT STATE			
Automation State	Vehicle State	Environment state	Driver State
x	x	x	x

Related to the following applications		
Highway	Urban	Close-Distance
x	x	x

Human Factors challenge
The driver is not aware of upcoming automation limits.
Human Factors recommendation
The automation should inform in advance about an upcoming automation limit, and if possible, about upcoming automation failures. Non-functional HF recommendations: NFR1A_AUL.1: Automation failures and limits should be visually indicated by icon and text message and can be accompanied by audio signal (e.gl. critical take-over situations) NFR1A_AUL.2: Timing and strategy of the warning should be adjusted to the criticality of the situation (Use immediate and multimodal warnings in critical situations) NFR1A_AUL. 3: Timing and strategy of the warning should be adjusted to the state of the driver (earlier multimodal warnings for distracted driver) NFR1A_AUL.4: If the situation allows, implement a step-wise escalation strategy to ensure that the driver has more time to react NFR1A_AUL.5: Use graphical icons that illustrate how the driver should react (e.g. take over the vehicle control, brake) NFR1A_AUL.6: If available, use a local visual feedback (red/blue-blinking transition button) and/or peripheral visual feedback (orange/blue pulsing on a 360° LED Stripe) to communicate automation limits (Reference: AdaptIVeD3.2, DLR, Exp. 1) NFR1A_AUL.7: If car-2-x communication and map-based data is available, future systems should include a component that discretely announces the upcoming automation limit (Reference: AdaptIVeD3.2, WIVW, Exp.2) NFR1A_AUL.8: If available, display the afforded manoeuvre in case of a required take-over or any information that might help the driver to correctly choose the afforded manoeuvre (Reference: AdaptIVeD3.2, WIVW, Exp.2)

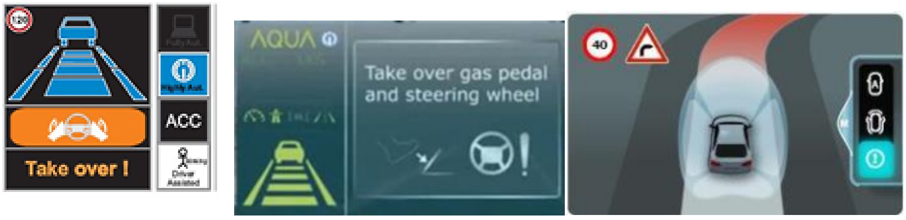
NFR1A_AUL.9: If this information is available, inform the driver at least 1000 m (at a speed of 120 km/h) prior to the system limit (longer timings did not show a benefit) (Reference: AdaptIVeD3.2, WIVW, Exp.2)

NFR1A_AUL.10: If possible, include a “timer” displaying the remaining distance until the next automation limit in the HMI concept that enables the driver to estimate the remaining time in automated driving mode (Reference: AdaptIVeD3.2, WIVW, Exp.2)

NFR1A_AUL.11: If the probability of automation failures increases while driving in SAE 3 (e.g. due to environmental factors, sensor failure, automation uncertainty), the automation should inform the driver and initiate a transition to SAE level 2 (driver should monitor the automation) (Reference: AdaptIVeD3.2, DLR, Exp.2)

Already existing approaches and examples

FR1A_AUL.E1: Display design from HAVEit, Interactive & AQUA system (Volvo)



FR1A_AUL.E2: Failure indication for ACC systems

FR1A_AUL.E3: Example of DLR local visual feedback on transition button and peripheral visual feedback on ambient light display to communicate automation limits (Reference: AdaptIVeD3.2, DLR , Exp.1)

FR1A_AUL.E4: Example of WIVW for an early announcement of a automation limit including a specific information about the planned manoeuvre (Reference: AdaptIVeD3.2, WIVW, Exp.2)

(text: “construction site 500m- please prepare for take-over -stay on your lane”)

FR1A_AUL.E5: Example WIVW for a “timer” displaying the remaining distance until the next automation limit

(text: “12 km until construction site”) (Reference: AdaptIVeD3.2, WIVW, Exp.2)

FR1A_AUL.E6: Example of DLR ambient light display: two times blinking in orange demonstrating automation uncertainty. Orange segment indicates an automaton uncertainty in front of the vehicle. Small blue bar indicates certainty and detected object by the automation (Reference: AdaptIVeD3.2, DLR, Exp.2)

References

HAVEit D61.1, P. 3 , Schömig (2010); Damböck et al. (2012); Petermann-Stock et al. (2013); InteractIVe D3.2, P. 20; InteractIVe D3.3, P. 57; Toffetti et al. (2009); Seeck et al. (2016); Seppelt & Victor (2016); Lu et al. (2016)

ID	Name
FR1A_IAU	"Inappropriate automation usage"

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AGENT STATE

Automation State	Vehicle State	Environment state	Driver State
			x

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

The driver uses the automation in a non-intended way (e.g. driver is doing something inappropriate, e.g. the driver leaves the seat, the driver is drinking alcohol, the driver moves to the sleeping compartment in the cab to take a nap).

Human Factors recommendation

Detect and avoid inappropriate usage of the automation.

NFR1A_IAU.1: If an inappropriate usage of the automation is detected during Level 1, activation of Level 2 or Level 3 should not be possible

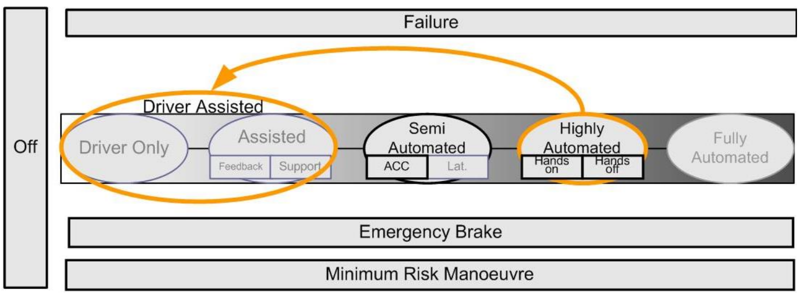
NFR1A_IAU.2: If an inappropriate usage of the automation is detected during Level 2 or Level 3, the automation should start a transition request to hand back control to the driver

NFR1A_IAU.3: In case the driver is not responding to a take-over request → see FR1A_FBS

Already existing approaches and examples

FR1A_IAU.E1: Transition from HA to DA (HAVEit)

The automation should be disabled and the driver should be requested to take-over the driving task.



References

HAVEit D33.2; ITS informal working group (2012); Meyer & Beiker (2015)

<table>
<tr><th colspan="15">ID</th><th colspan="45">Name</th></tr>
<tr><td colspan="15">FR1A_DMG</td><td colspan="45">“Driver monitoring”</td></tr>
<tr><td colspan="60">Related SAE Levels:</td></tr>
<tr><td colspan="12">SAE0</td><td colspan="12">SAE1</td><td colspan="12">SAE2</td><td colspan="12">SAE3</td><td colspan="12">SAE4</td></tr>
<tr><td colspan="12"></td><td colspan="12"></td><td colspan="12">x</td><td colspan="12">x</td><td colspan="12"></td></tr>
<tr><td colspan="60">Related to 4A subcategories: AGENT STATE</td></tr>
<tr><td colspan="15">Automation State</td><td colspan="15">Vehicle State</td><td colspan="15">Environment state</td><td colspan="15">Driver State</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td><td colspan="15"></td><td colspan="15">x</td></tr>
<tr><td colspan="60">Related to the following applications</td></tr>
<tr><td colspan="20">Highway</td><td colspan="25">Urban</td><td colspan="15">Close-Distance</td></tr>
<tr><td colspan="20">x</td><td colspan="25">x</td><td colspan="15"></td></tr>
<tr><td colspan="60">Human Factors challenge</td></tr>
<tr><td colspan="60">The driver state (inattentiveness due to drowsiness or directing attention towards non-driving related tasks) might influence driver’s reaction times to necessary take-over requests.</td></tr>
<tr><td colspan="60">Human Factors recommendation</td></tr>
<tr><td colspan="60">The automation should be able to verify the level of wakefulness/drowsiness and task-oriented attention of the driver (driver monitoring system).
NFR1A_DMG.1: For Level 3 the detection of drowsiness is more important than the detection of inattentiveness
NFR1A_DMG.3: In the situation where the driver is not responding to a take-over request → see FR1A_FBS</td></tr>
<tr><td colspan="60">Already existing approaches and examples</td></tr>
<tr><td colspan="60">FR1A_DMG.E1: The DMS should be able to detect driver’s glance direction and eye lid closure level and be able to inform the level of distraction and drowsiness of the driver
FR1A_DMG.E2: Dead man’s button as a possibility to verify level of attention for certain Close-Distance automation functions, in case there is no reliable minimum risk manoeuvre available (Reference: AdaptIVeD3.2, FORD, Exp.1)
FR1A_DMG.E3: The use of eye-movement cameras to monitor eye fixations and percentage road centre (PRC) i.e. the mode of gaze fixations that fall within the road centre area, could provide a beneficial tool for assessing drivers’ visual distraction (Reference: AdaptIVeD3.2, LEEDS , Exp.1)</td></tr>
<tr><td colspan="60">References</td></tr>
<tr><td colspan="60">HAVEit D61.1, P 111; HAVEit D33.2; Azim et al. (2014); Sigari & Soryani (2013); Heuer, S (2017); Merat et al. (2014)</td></tr>
</table>

ID	Name			
FR1A_TDT	"Takeover of driving task"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	
Related to 4A subcategories: AGENT STATE				
Automation State	Vehicle State	Environment state	Driver State	
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The automation does not check if the driver has taken over the driving task.				
Human Factors recommendation				
The automation should be able to detect that the driver has taken over the driving task.				
Already existing approaches and examples				
FR1A_TDT.E1: Consider a Hands-on check to ensure driver is ready to take over FR1A_TDT.E2: Consider a Foot-on check to ensure driver is ready to take over FR1A_TDT.E3: Check driver's inputs (e.g. button press) if he/she is ready to take over FR1A_TDT.E4: Check driver's attentional state if he/she is ready to take over				
References				
Flemisch & Schieben (2009); HAVEit D33.2 P. 27; Meyer & Beiker (2015); Vogelpohl et al. (2016)				

ID	Name
FR1A_FBS	“Fallback strategy”

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AGENT STATE

Automation State	Vehicle State	Environment state	Driver State
			x

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

The driver does not react to a take-over request.

Human Factors recommendation

Automation should provide an adequate fallback strategy.

NFR1A_FBS.1: Info/warning to drivers should escalate to make driver to take back control

NFR1A_FBS.2: If the driver does not react to take-over request, the automation should perform a Minimum Risk Manoeuvre (MRM)

NFR1A_FBS.3: The reason for activating the MRM should be clearly communicated to the driver

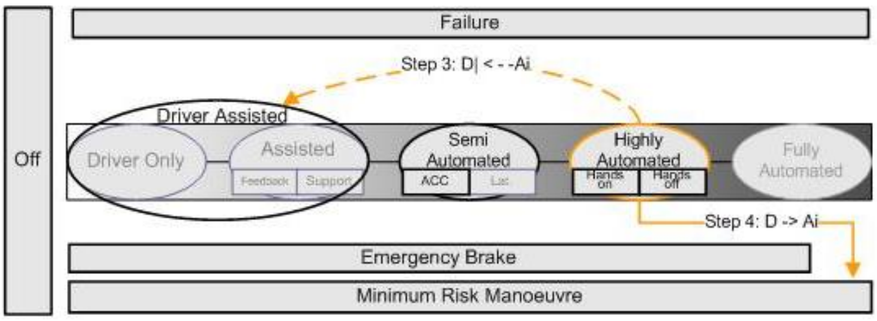
NFR1A_FBS.4: At higher speed, as long as lane detection is possible, the vehicle should reduce speed slowly to avoid risk exposure due to a sudden stand-still

NFR1A_FBS.5: When a MRM was performed, an E-call could be initiated if the driver does not resume in manual driving

Already existing approaches and examples

FR1A_FBS.E1: Driver became unconscious

Transition HA→MRS (HAVEit)



FR1A_FBS.E2: Display Solutions for a Take-over request followed by a MRM (HAVEit)

References

HAVEit D33.2; Dambock et al. (2013); Bucchianico & Stanton (2014); International Harmonized Research Activities (IHRA) (2010); Moreillon (2017)

ID	Name
FR1A_ALT	"Automation limitations"

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AGENT STATE

Automation State	Vehicle State	Environment state	Driver State
			x

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

The driver does not know all functions and limitations of the automation.

Human Factors recommendation

Driver should know the functions and limitations of the automation to ensure proper vehicle control and to avoid overreliance in the automation.

NFR1A_ALT.1: For level 2 systems, the automation should inform the driver that he/she is still responsible for monitoring the driving environment

NFR1A_ALT.2: For level 3 systems, the automation should inform the driver that he/she is requested to get back to the driving task within a defined time frame (when the driver is still the fallback level of the automation)

NFR1A_ALT.3: In systems with changing levels of automation (monitoring required vs. not) the driver must be explicitly informed when he/she has to know about the upcoming situational changes and when not (Reference: AdaptIVeD3.2, WIVW , Exp.2)

NFR1A_ALT.4: Driver training with the automation should be offered for safe and appropriate interaction between the driver and the automation (Reference: AdaptIVeD3.2, VTEC , Exp.2)

Already existing approaches and examples

FR1A_ALT.E1: Notification when automation is activated: "be aware that you are still responsible for monitoring the driving environment" (on SAE Level 2)

FR1A_ALT.E2: Inform the driver in the manual or by explicit notifications about automation functions and limits at the beginning of a drive

FR1A_ALT.E3: Example of WIVW announcement 15 seconds before approaching a situational change using visual and auditory feedback (Reference: AdaptIVeD3.2, WIVW , Exp.2)

FR1A_ALT.E4: Automation can give an instruction to the driver before the drive in the form of: "Please take over the vehicle control when asked!" (Reference: AdaptIVeD3.2, WIVW , Exp.1)

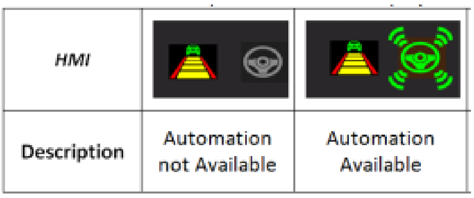
References

Larsson et al. (2014); Dzindolet et al (2003); Tellis et al. (2016); Seppelt (2009)

3.2 Awareness

ID	Name			
FR2A_AOA	"Availability of the automation"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x
Related to 4A subcategories: AWARENESS				
Mode awareness	Situation Awareness			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The driver does not know if the automation is available or not.				
Human Factors recommendation				
The automation should display to the driver if the functionality is available for activation. NFR2A_AOA.1: Available step-ups in automation should be restricted to the minimum possible number, and displays should reflect this NFR2A_AOA.2 If available, use local visual feedback (blue-blinking transition button) and/or peripheral visual feedback (animation on a frontal LED Stripe) to signalize that automation is available (Reference: AdaptIVeD3.2, DLR , Exp.1) NFR2A_AOA.3 If available, change symbol colours and use flashes to indicate that automation is available/unavailable (Reference: AdaptIVeD3.2, LEEDS , Exp.1)				
Already existing approaches and examples				
FR2A_AOA.E1: Automation mode display from InteractIVe 				
FR2A_AOA.E2: Example of DLR peripheral visual feedback on Ambient light display for automation availability (Reference: AdaptIVeD3.2, DLR , Exp.1) 				

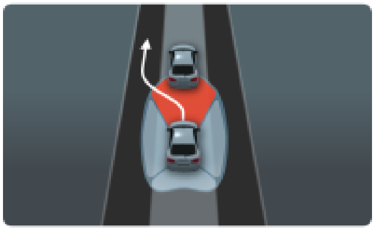
FR2A_AOA.E3: Example of Leeds HMI display for showing automation availability (Reference: AdaptIVeD3.2, LEEDS, Exp.1)



HMI		
Description	Automation not Available	Automation Available

References

HAVEit D33.2; InteractIVe D3.2; Gordon & Lidberg (2015); Flemisch et al. (2014); Tellis et al. (2016)

<table>
<tr><th>ID</th><th colspan="4">Name</th></tr>
<tr><td>FR2A_CAM</td><td colspan="4">“Current automation manoeuvre”</td></tr>
<tr><td colspan="5">Related SAE Levels:</td></tr>
<tr><td>SAE0</td><td>SAE1</td><td>SAE2</td><td>SAE3</td><td>SAE4</td></tr>
<tr><td></td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td colspan="5">Related to 4A subcategories: AWARENESS</td></tr>
<tr><td>Mode awareness</td><td>Situation Awareness</td><td></td><td colspan="2"></td></tr>
<tr><td>x</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Related to the following applications</td></tr>
<tr><td colspan="2">Highway</td><td colspan="2">Urban</td><td>Close-Distance</td></tr>
<tr><td colspan="2">x</td><td colspan="2">x</td><td>x</td></tr>
<tr><td colspan="5">Human Factors challenge</td></tr>
<tr><td colspan="5">The driver is not aware of the automation’s current manoeuvre.</td></tr>
<tr><td colspan="5">Human Factors recommendation</td></tr>
<tr><td colspan="5">The current automation manoeuvre should be displayed i.e. speed changes, route changes, overtaking etc.
NFR2A_CAM.1: Display future traffic light status on the ambient light display, Head-down display (HDD) to make automation behaviour understandable and predictable (Reference: AdaptIVeD3.2, DLR, Exp.3)</td></tr>
<tr><td colspan="5">Already existing approaches and examples</td></tr>
<tr><td colspan="5">FR2A_CAM.E1: Show icons for lane changes, speed change, route change, platoon joining/leaving (Display design from InteractIVe)
</td></tr>
<tr><td colspan="5">FR2A_CAM.E2: Example of WIVW display of a automation-initiated lane change (Reference: AdaptIVeD3.2, WIVW , Exp.1)
</td></tr>
</table>

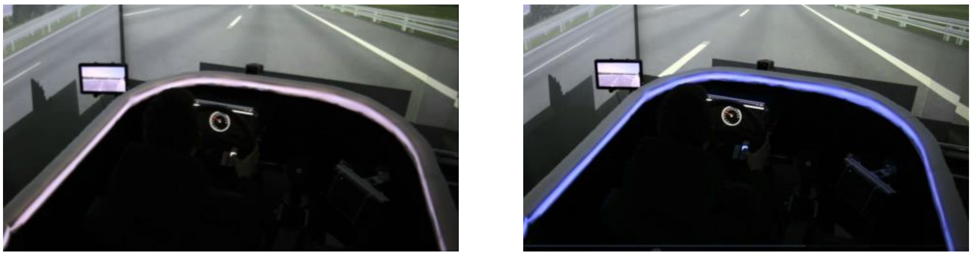
FR2A_CAM.E3: Manoeuvres can be displayed using visual images through the dashboard HMI (Reference: AdaptIVeD3.2, LEEDS , Exp.2)  
FR2A_CAM.E4 Example of DLR: Future traffic light status communicated by ambient light display and HDD (Reference: AdaptIVeD3.2, DLR , Exp.3)  
InteractIVe D3.2, P. 20; Beller et al. (2013); Flemisch et al. (2014); Campbell et al. (2016); Lee & Seppelt (2009)

<table>
<tr><th colspan="11">ID</th><th colspan="49">Name</th></tr>
<tr><td colspan="11">FR2A_AST</td><td colspan="49">“Automation status”</td></tr>
<tr><td colspan="60">Related SAE Levels:</td></tr>
<tr><td colspan="12">SAE0</td><td colspan="12">SAE1</td><td colspan="12">SAE2</td><td colspan="12">SAE3</td><td colspan="12">SAE4</td></tr>
<tr><td colspan="12">x</td><td colspan="12">x</td><td colspan="12">x</td><td colspan="12">x</td><td colspan="12">x</td></tr>
<tr><td colspan="60">Related to 4A subcategories: AWARENESS</td></tr>
<tr><td colspan="15">Mode awareness</td><td colspan="15">Situation Awareness</td><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td colspan="15">x</td><td colspan="15"></td><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td colspan="60">Related to the following applications</td></tr>
<tr><td colspan="22">Highway</td><td colspan="23">Urban</td><td colspan="15">Close-Distance</td></tr>
<tr><td colspan="22">x</td><td colspan="23">x</td><td colspan="15"></td></tr>
<tr><td colspan="60">Human Factors challenge</td></tr>
<tr><td colspan="60">The driver is not aware of the current automation level and functions and might therefore react in-correctly.</td></tr>
<tr><td colspan="60">Human Factors recommendation</td></tr>
<tr><td colspan="60">The current automation level and functions shall be permanently displayed.
NFR2A_AST.1: Display the functionality of the automation. Don’t display SAE/BASt/NHTSA levels
NFR2A_AST.2: If for more than one level of automation activation is possible, then the available functionalities should be arranged either vertically from the bottom meaning “low automation” up to “high automation” or horizontally from left to right
NFR2A_AST.3: A maximum of 3 clearly distinguishable levels of functionality is recommended
NFR2A_AST.4: The automation should clearly communicate which agent (driver or automation) is in control of the driving tasks (operational, tactical and strategic) (Reference: AdaptIVeD3.2, VTEC , Exp.2)
NFR2A_AST.5: The driver should be kept informed about the progress of the requested mode change (Reference: AdaptIVeD3.2, VCC , Exp.2)</td></tr>
<tr><td colspan="60">Already existing approaches and examples</td></tr>
<tr><td colspan="60">FR2A_AST.E1: Automation level display in HAVEit

</td></tr>
</table>

AdaptIVe

FR2A_AST.E2: Example of DLR local visual feedback (white for “manual mode”, blue for “conditional automated mode”) and peripheral visual feedback to communicate the current automation level (white for “manual mode”, blue for “conditional automated mode”) (Reference: AdaptIVeD3.2, DLR , Exp.1)

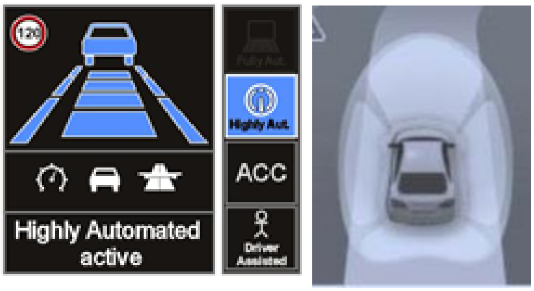


FR2A_AST.E3: Example for WIVW automation status displays (Reference: AdaptIVeD3.2, WIVW, Exp.1)

References

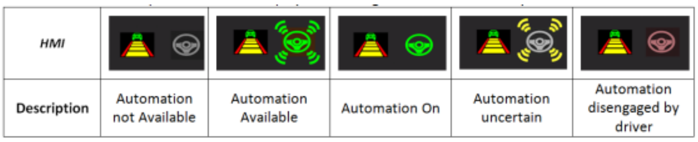
HAVEit D33.2; HAVEit D33.6, P. 102; InteractIVe D3.2, P. 138; Beller et al. (2013); Flemisch et al. (2014); Campbell et al. (2016)

ID	Name				
FR2A_CAF	"Change of automation function"				
Related SAE Levels:					
SAE0	SAE1	SAE2	SAE3	SAE4	
x	x	x	x	x	
Related to 4A subcategories: AWARENESS					
Mode awareness	Situation Awareness				
x					
Related to the following applications					
Highway	Urban	Close-Distance			
x	x				
Human Factors challenge					
The driver is confused by frequent changes in the automation functions.					
Human Factors recommendation					
The automation should not change the automation functions too often. NFR2A_CAF.1: Use cool-down times i.e. periods where automation is unavailable, prior to the reactivation of automation.					
Already existing approaches and examples					
FR2A_CAF.E1: If availability pre-conditions for automation levels are constantly changing then the minimum constant level of automation should remain.					
References					
InteractIVe D3.2, P. 24; Endsley et al. (2003)					

<table>
<tr><th>ID</th><th colspan="4">Name</th></tr>
<tr><td>FR2A_WFS</td><td colspan="4">“Warning feedback strategy”</td></tr>
<tr><td colspan="5">Related SAE Levels:</td></tr>
<tr><td>SAE0</td><td>SAE1</td><td>SAE2</td><td>SAE3</td><td>SAE4</td></tr>
<tr><td></td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td colspan="5">Related to 4A subcategories: AWARENESS</td></tr>
<tr><td>Mode awareness</td><td>Situation Awareness</td><td></td><td colspan="2"></td></tr>
<tr><td></td><td>x</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Related to the following applications</td></tr>
<tr><td colspan="2">Highway</td><td colspan="2">Urban</td><td>Close-Distance</td></tr>
<tr><td colspan="2">x</td><td colspan="2">x</td><td>x</td></tr>
<tr><td colspan="5">Human Factors challenge</td></tr>
<tr><td colspan="5">The driver is overloaded by too much information presented at once.</td></tr>
<tr><td colspan="5">Human Factors recommendation</td></tr>
<tr><td colspan="5">Warnings and feedback about automation functions should be kept to a minimum.
NFR2A_WFS.1: Group functions and use a reduced design
NFR2A_WFS.2: Do not repeat warnings too often within a specified time frame
NFR2A_WFS.3: Assign priorities to each information, warning and intervention
NFR2A_WFS.4 If available, use peripheral visual feedback to communicate warnings, recommendations and automation levels (Reference: AdaptIVeD3.2, DLR , Exp.1)
NFR2A_WFS.5 The automation should adapt the information (amount and format) and the demand for attentiveness depending on the environmental situation (Reference: AdaptIVeD3.2, VTEC, Exp.1)
NFR2A_WFS.6 Information provided to the driver when driving in different automation levels should be customizable according to the driver’s needs and preferences (Reference: AdaptIVeD3.2, VTEC, Exp.1)
NFR2A_WFS.7: Display only relevant and certainly detected objects (front car, lane changing cars) on the ambient light display (Reference: AdaptIVeD3.2, DLR, Exp.2)</td></tr>
<tr><td colspan="5">Already existing approaches and examples</td></tr>
<tr><td colspan="5">FR2A_WFS.E1: Display from HAVEit and InteractIVe
</td></tr>
</table>

FR2A_WFS.E2: Example of DLR peripheral visual feedback on ambient display to communicate in a reduced way warnings (red), recommendations (green) and automation levels (blue) (Reference: AdaptIVeD3.2, DLR , Exp.1)

FR2A_WFS.E3: Example of Leeds design of visual display (Reference: AdaptIVeD3.2, LEEDS , Exp.1)



HMI					
Description	Automation not Available	Automation Available	Automation On	Automation uncertain	Automation disengaged by driver

FR2A_WFS.E4: Example of WIVW design of visual display (Reference: AdaptIVeD3.2, WIVW , Exp.1)

FR2A_WFS.E5: Example of DLR ambient light display: Blue bar indicates relevant and certainly detected object by the automation (Reference: AdaptIVeD3.2, DLR , Exp.2)

References

Beller et al. (2013); InteractIVe D3.2; Ho et al (2007)

ID	Name
FR2A_DAN	“Driver awareness ”

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AWARENESS

Mode awareness	Situation Awareness		
	x		

Related to the following applications

Highway	Urban	Close-Distance
x	x	

Human Factors challenge

The driver loses situational awareness while being out of the vehicle control loop.

Human Factors recommendation

Keep the driver aware of the situation through providing consistent informational feedback and warnings.

NFR2A_DAN.1: If available, peripheral vision can be used as a communication modality. Due to the 360° display it is possible to inform drivers wherever they look. Animation or blinking and pulsing colors can be used for a higher salience in critical situations (Reference: AdaptIVeD3.2, DLR , Exp.1)

NFR2A_DAN.2: Different symbol colors can be used to convey a changing automation status (Reference: AdaptIVeD3.2, LEEDS , Exp.1)

Already existing approaches and examples

FR2A_DAN.E1: Provide haptic/visual feedback on active steering wheel and pedals (see H-Mode, HAVEIt)

FR2A_DAN.E2: Provide waypoint checks in order to keep drivers somewhat aware of where they are in space and time (similar to aviation requirements during autopilot)

FR2A_DAN.E3: If the driver is visually distracted and his attention should be directed to a certain location (e.g. warning) either uses a visual cue that can also be perceived peripherally or other modalities (acoustic or haptic). (Reference: AdaptIVeD3.2, VVC , Exp.1)

FR2A_DAN.E4: Ambient Display solution in a DLR driving simulator using peripheral vision (Reference: AdaptIVeD3.2, DLR , Exp.1)

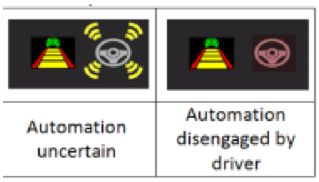
FR2A_DAN.E5: LED solution in a WIVW driving simulator study, e.g. a display message plus LED lights flashing in the windscreen could direct driver's attention back to the driving task more effectively, + auditory warning could also be included when needed (Reference: AdaptIVeD3.2, WIVW , Exp.1)

FR2A_DAN.E6: Example of Leeds in-vehicle HMI with the forward collision warning (FCW) on the left and the Automation Status Symbol on the right, in each image. The changing colour of these symbols can be used to convey current automation states. (Reference: AdaptIVeD3.2, LEEDs , Exp.1)

FR2A_DAN.E7: Example of WIVW combination of visual focal (GUI in instrument cluster), visual peripheral (LED strip in windshield) and acoustic modality for information transfer to the driver (Reference: AdaptIVeD3.2, WIVW, Exp.1)

FR2A_DAN.E8: Additional cues to the visual cues in the cluster, such as sound and haptic cues can facilitate driver understanding of the changes in automation level (Reference: AdaptIVeD3.2, VTEC, Exp.1)

FR2A_DAN.E9: Flashing images and a 'beep' tone can be used to draw attention in critical situation (Reference: AdaptIVeD3.2, LEEDS , Exp.1)



References

Code of Practice 2009; Saffarian et al. (2012); Seeck et al. (2016); Campbell et al. (2016); Seppelt & Victor(2016); Morando (2017)

ID	Name
FR2A_RIN	"Recognition of information "

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	

Related to 4A subcategories: AWARENESS

Mode awareness	Situation Awareness		
	x		

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

A distracted driver overlooks visual information on the display.

Human Factors recommendation

Use effective HMI modalities or images to ensure that information can easily be recognized by the driver.

NFR2A_RIN.1: Combine HMI modalities, e.g. in critical situations in order to strengthen the communication to the driver. Use visual cues/ peripheral vision or directed haptic/ acoustic to guide drivers attention

NFR2A_RIN.2: For Information about frontal threats (e.g. rear-end collisions, sharp curves) use visual head-up information in combination with haptic feedback in the pedals

NFR2A_RIN.3: Use auditory icons for short and simple messages to reduce response times

NFR2A_RIN.4: Avoid the use of too much text

Already existing approaches and examples

FR2A_RIN.E1: Vibrational perception has the lowest threshold at the fingertips

FR2A_RIN.E2: Auditory icons should be used to reduce response times. Auditory icons are most efficient for short and simple messages

FR2A_RIN.E3: Ambient Display design for a lane change recommendation in a DLR driving simulator using peripheral vision (Reference: AdaptIVeD3.2, DLR , Exp.1)

References

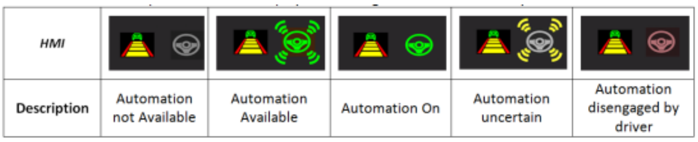
HAVEit D33.6, P. 17; Schömig & Kaussner (2010); Graham (2010), McKeown & Isherwood (2007); Lerner et al. (2011); Campbell et al. (2016); Debernard et al. (2016)

<table>
<tr><th colspan="2">ID</th><th colspan="6">Name</th></tr>
<tr><td colspan="2">FR2A_WSQ</td><td colspan="6">“Warning sequences”</td></tr>
<tr><td colspan="8">Related SAE Levels:</td></tr>
<tr><td>SAE0</td><td colspan="2">SAE1</td><td colspan="2">SAE2</td><td>SAE3</td><td colspan="2">SAE4</td></tr>
<tr><td>x</td><td colspan="2">x</td><td colspan="2">x</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="8">Related to 4A subcategories: AWARENESS</td></tr>
<tr><td colspan="2">Mode awareness</td><td colspan="2">Situation Awareness</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2">x</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="8">Related to the following applications</td></tr>
<tr><td colspan="3">Highway</td><td colspan="3">Urban</td><td colspan="2">Close-Distance</td></tr>
<tr><td colspan="3">x</td><td colspan="3">x</td><td colspan="2"></td></tr>
<tr><td colspan="8">Human Factors challenge</td></tr>
<tr><td colspan="8">The driver does not understand a warning about an imminent danger (e.g. because he is not aware of the danger).</td></tr>
<tr><td colspan="8">Human Factors recommendation</td></tr>
<tr><td colspan="8">Use different warning sequences for different dangers (e.g. collisions or lane departures) with directional warnings and make them understandable for the driver.
NFR2A_WSQ.1: The driver should get feedback about the warning event and its purpose. Give the driver the "explanation" after a quick warning
NFR2A_WSQ2: A haptic or auditory warning should be accompanied by a visual component, which should last a certain time longer than the warning itself
NFR2A_WSQ.3: For a collision alert use an enhanced visual warning (e.g. red LED-array Head-up display (HUD) + front shield red) + auditory warning (e.g. frontal chime) + haptic warning (e.g. repeated/enhanced double tick at Accelerator Force Feedback Pedal (AFFP)
NFR2A_WSQ.4: Ambient light display can be used for directional warnings. Directional warnings presented by the ambient light are effective and easy to understand. Pulsing or blinking of LEDs can be used to inform about criticality of the situation (Reference: AdaptIVeD3.2, DLR , Exp.1)
NFR2A_WSQ.5: The use of different symbol colours can be used to convey a changing automation status. Using flashing images and a ‘beep’ tone can be used to draw attention in critical situations. (Reference: AdaptIVeD3.2, LEEDS, Exp.1)
NFR2A_WSQ.6: If available, use ambient light display for sub-symbolic communication via peripheral vision (Reference: AdaptIVeD3.2, DLR , Exp.1)
NFR2A_WSQ.7: Use the ambient light display for directional warnings. Directional warnings presented by the ambient light are effective and easy to understand. Use pulsing or blinking of the LEDs to inform about criticality of the situation (Reference: AdaptIVeD3.2, DLR , Exp.1)</td></tr>
</table>

Already existing approaches and examples

FR2A_WSQ.E1: InteractIVe Display with longitudinal collision warning

FR2A_WSQ.E2: Example for in-vehicle HMI with the forward collision warning (FCW) on the left and the Automation Status Symbol on the right, in each image. The changing colour of these symbols can be used to convey current automation states (Reference: AdaptIVeD3.2, LEEDS, Exp.1)



HMI					
Description	Automation not Available	Automation Available	Automation On	Automation uncertain	Automation disengaged by driver

FR2A_WSQ.E3: Example for DLR peripheral directional warnings (red in front for longitudinal, red on side for lateral warnings) (Reference: AdaptIVeD3.2, DLR , Exp.1)

References

InteractIVe D3.3, P. 45; LeBlanc et al. (2008); Baldwin (2011); Gray (2011)

ID	Name
FR2A_AUC	“Automation uncertainty”

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	

Related to 4A subcategories: AWARENESS

Mode awareness	Situation Awareness		
	x		

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

The driver is unable to predict if the automation is able to handle a situation or not.

Human Factors recommendation

Provide warnings when detecting situations the automation is uncertain about.

NFR2A_AUC.1: If available, use visual feedback e.g. a flashing steering wheel symbol to indicate automation uncertainty (Reference: AdaptIVeD3.2, LEEDS , Exp.1)

NFR2A_AUC.2: If available, use the ambient light display to communicate automation uncertainty and initiate a transition to SAE 2 to bring the driver in the monitoring task (Reference: AdaptIVeD3.2, DLR , Exp.2)

Already existing approaches and examples

FR2A_AUC.E1: Displaying automation uncertainty in the head-down display

FR2A_AUC.E2: Example for in-vehicle HMI with the forward collision warning (FCW) on the left and the Automation Status Symbol on the right in each image. Automation uncertainty can be conveyed using a flashing light and beep tone. The changing colour of these symbols can be used to convey automation uncertainty (Reference: AdaptIVeD3.2, LEEDS , Exp.1)

HMI	
Description	Automation uncertain

FR2A_AUC.E3: Example of DLR ambient light display: two times blinking in orange for automation demonstrating automation uncertainty (Reference: AdaptIVeD3.2, DLR , Exp.2) 
References
InteractIVe D3.2, P. 20; Beller et al. (2013); Helldin et al. (2013)

3.3 Arbitration

<table>
<tr><th>ID</th><th colspan="4">Name</th></tr>
<tr><td>FR3A_OVF</td><td colspan="4">“Override functions”</td></tr>
<tr><td colspan="5">Related SAE Levels:</td></tr>
<tr><td>SAE0</td><td>SAE1</td><td>SAE2</td><td>SAE3</td><td>SAE4</td></tr>
<tr><td></td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td colspan="5">Related to 4A subcategories: Arbitration</td></tr>
<tr><td>Interaction</td><td>Decision</td><td>Meaning</td><td colspan="2">Scheduling</td></tr>
<tr><td>x</td><td>x</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Related to the following applications</td></tr>
<tr><td>Highway</td><td colspan="2">Urban</td><td colspan="2">Close-Distance</td></tr>
<tr><td>x</td><td colspan="2">x</td><td colspan="2">x</td></tr>
<tr><td colspan="5">Human Factors challenge</td></tr>
<tr><td colspan="5">The driver wants to override the automation.</td></tr>
<tr><td colspan="5">Human Factors recommendation</td></tr>
<tr><td colspan="5">All assisting functions should be designed in a way that the driver can always override them.
See →FR4A_UID
See → FR4A_UIA</td></tr>
<tr><td colspan="5">Already existing approaches and examples</td></tr>
<tr><td colspan="5">FR3A_OVF.E1: The dead man’s button strategy, if used, should provide a possibility to resume the automation again after a stop (Reference: AdaptIVeD3.2, FORD , Exp.1)</td></tr>
<tr><td colspan="5">References</td></tr>
<tr><td colspan="5">Code of Practice (2009); International Harmonized Research Activities (IHRA) (2010); Naujoks et al. (2014); Lu et al. (2016); Seeck et al. (2016)</td></tr>
</table>

ID	Name
FR3A_ECS	"Escalation scheme"

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
		x	x	

Related to 4A subcategories: Arbitration

Interaction	Decision	Meaning	Scheduling
		x	x

Related to the following applications

Highway	Urban	Close-Distance
x	x	

Human Factors challenge

A critical situation occurs while the driver is out of the loop.

Human Factors recommendation

In a critical situation, the driver must be brought back to the control. The escalation scheme should be adapted to the situation and to the current automation level.

NFR3A_ECS.1: The driver should always know how much time is available to resume control

NFR3A_ECS.2: If possible, show the driver how to resume control by visual feedback

NFR3A_ECS.3: The hand-over procedure should be adapted to the time available for the driver to take control

NFR3A_ECS.4: For short hand-over time multi-modal cueing should be deployed with less information in displays

NFR3A_ECS.5: The driver's reaction should be enhanced by the output channel (e.g. steering wheel, brake pedal) that should be used for performing the wanted action

NFR3A_ECS.6: If the driver does not resume control → see FR1A_FBS

NFR3A_ECS.7: The automation should take into account inform-warn-intervene (IWI) strategies to achieve compatibility between driver and the automation. (VTEC) (Reference: AdaptIVeD3.2, VTEC , Exp.2)

Already existing approaches and examples

FR3A_ECS.E1: Display showing the activated automation level and a take-over request

References

Schömig & Kaussner (2010); HAVEit D33.6; Naujoks et al. (2014); Toffetti et al. (2010); Gold et al. (2013); Van den Beukel & Van der Voort (2013); Lorenz et al. (2014); Radlmayr et al. (2014); Wulf et al. (2013); Zeeb et al. (2015); Petermeijer et al. (2017)

3.4 Action

ID	Name			
FR4A_VRP	"Visual representations"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x
Related to 4A subcategories: Action				
Ergonomics	Controllability			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The input devices do not fit the visual representation of the visual HMI.				
Human Factors recommendation				
The used control element should be compatible with the design of the visual HMI (e.g. colours, symbols).				
Already existing approaches and examples				
FR4A_VRP.E1: Pushing the lever up means the activation of an additional or higher automation function. FR4A_VRP.E2: Consistent illuminating of the switching component should be used etc. E.g. Local visual feedback via transition button design from DLR (Reference: AdaptIVeD3.2, DLR , Exp.1) FR4A_VRP.E3: Example for DLR local visual feedback on transition button (red/white for driver initiated but refused transitions, red/blue for automation initiated transitions) (Reference: AdaptIVeD3.2, DLR , Exp.1)  				
References				
HAVEit D33.2; Blanco et al. (2013); Campbell et al. (2016)				

ID	Name			
FR4A_UID	"Unintentional deactivations"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x
Related to 4A subcategories: Action				
Ergonomics	Controllability			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The driver accidentally deactivates the automation.				
Human Factors recommendation				
Unintentional deactivation should be prevented. NFR4A_UID.1: Define useful thresholds for transitions NFR4A_UID.2: Use hands-on detection threshold to prevent unintentional deactivation				
Already existing approaches and examples				
FR4A_UID.E1: Controls should not react to very low forces FR4A_UID.E2: Consider a redundant switching strategy (e.g. 2 of 8; 3 of 8)				
References				
International Harmonized Research Activities (IHRA) (2010)				

ID	Name			
FR4A_UIA	" Unintentional activation"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x
Related to 4A subcategories: Action				
Ergonomics	Controllability			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The driver accidentally activates the automation.				
Human Factors recommendation				
Unintentional activation should be prevented. NFR4A_UIA.1: Always inform about a automation activation NFR4A_UIA.2: Information on how to activate the automation should be provided (Reference: AdaptIVeD3.2, FORD , Exp.1)				
Already existing approaches and examples				
FR4A_UIA.E1: Steering wheel controls with redundant activation strategy (e.g. 2 of 8, 3of 8) FR4A_UIA.E2: Dead-man button strategy will help to prevent unintentional activation (FORD) (Reference: AdaptIVeD3.2, FORD , Exp.1)				
References				
International Harmonized Research Activities (IHRA) (2010)				

ID	Name
FR4A_UNI	“Understandable Information”

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x

Related to 4A subcategories: Action

Ergonomics	Controllability		
x			

Related to the following applications

Highway	Urban	Close-Distance
x	x	x

Human Factors challenge

The driver is not able to understand the information provided by the automation.

Human Factors recommendation

The information presented to the driver should be appropriate to the function and be understandable to the driver.

NFR4A_UNI.1: A uniform optical picture language should be used

NFR4A_UNI.2: Ensure that it is possible to understand the information on the display with a few glances

NFR4A_UNI.3: Colour should be used consistently and its meaning should be clear

NFR4A_UNI.4: Redundant coding is required (e.g. in case of colour-blind people)

NFR4A_UNI.5: Avoid flashing of icons or messages

NFR4A_UNI.6: Use orange colour for directional automation uncertainty and blue for directional automation certainty, e.g. automation being in control on lateral/longitudinal axis. (Reference: AdaptIVeD3.2, DLR , Exp.2)

Already existing approaches and examples

FR4A_UNI.E1: Consider an appropriate size of image, contrast, brightness, illumination, image stability, resolution, and colour

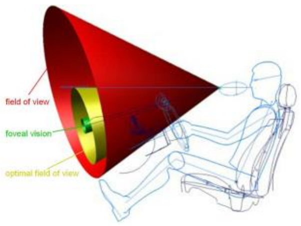
FR4A_UNI.E2: Use the following suggested colour codes for providing the user with accurate status of the urgency level of the message: Red – Danger, Alarm, Amber – Caution, White - Status indicator on/off, Blue- Handled by automation

FR4A_UNI.E3: Example of DLR ambient light display (Reference: AdaptIVeD3.2, DLR , Exp.2)

References

InteractIVe D3.2, P. 34; HAVEit D33.6, P. 16; Code of Practice (2009); ISO 2575; Rasmussen & Vicente (1998); Campbell et al. (2016)

ID	Name			
FR4A_ACS	"Acoustic signals"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	x
Related to 4A subcategories: Action				
Ergonomics	Controllability			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The driver cannot interpret an acoustic signal (e.g. confused about its meaning).				
Human Factors recommendation				
Sounds should be used appropriately and made distinguishable from other sounds in the vehicle. NFR4A_ACS.1: Visual explanations for sounds shall always be available NFR4A_ACS.2: Warning sounds should be more obtrusive than information sounds				
Already existing approaches and examples				
FR4A_ACS.E1: The louder the sound, the more urgent it becomes but also more annoying to the driver. Function status sounds are less urgent and should, therefore, be played at a relatively low volume while warning sounds can be played at a higher volume				
References				
InteractIVe D3.2, P. 134; HAVEit D33.6, P. 16; Ricci & Fong (2014); Liu & Jhuang (2012); Campbell et al. (2016)				

<table>
<tr><th colspan="12">ID</th><th colspan="48">Name</th></tr>
<tr><td colspan="12">FR4A_FOP</td><td colspan="48">“Field of perception ”</td></tr>
<tr><td colspan="60">Related SAE Levels:</td></tr>
<tr><td colspan="12">SAE0</td><td colspan="12">SAE1</td><td colspan="12">SAE2</td><td colspan="12">SAE3</td><td colspan="12">SAE4</td></tr>
<tr><td colspan="12">x</td><td colspan="12">x</td><td colspan="12">x</td><td colspan="12"></td><td colspan="12"></td></tr>
<tr><td colspan="60">Related to 4A subcategories: Action</td></tr>
<tr><td colspan="15">Ergonomics</td><td colspan="15">Controllability</td><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td colspan="15">x</td><td colspan="15"></td><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td colspan="60">Related to the following applications</td></tr>
<tr><td colspan="20">Highway</td><td colspan="20">Urban</td><td colspan="20">Close-Distance</td></tr>
<tr><td colspan="20">x</td><td colspan="20">x</td><td colspan="20">x</td></tr>
<tr><td colspan="60">Human Factors challenge</td></tr>
<tr><td colspan="60">Important information might be missed.</td></tr>
<tr><td colspan="60">Human Factors recommendation</td></tr>
<tr><td colspan="60">Relevant information shall be in driver’s field of perception.
NFR4A_FOP.1: Information to be exactly perceived (e.g. warning texts) should be displayed in instrument cluster or HUD
NFR4A_FOP.2: Information which is not supposed to distract the driver should be displayed in an (peripheral) ambient display (Reference: AdaptIVeD3.2, DLR , Exp.1)
NFR4A_FOP.3: Important objects, such as Close-Distance vehicle when Parking outside should be in the field of perception of the operator (Reference: AdaptIVeD3.2, FORD, Exp.1)</td></tr>
<tr><td colspan="60">Already existing approaches and examples</td></tr>
<tr><td colspan="60">FR4A_FOP.E1: Simplified demonstration of a field of view limits.


FR4A_FOP.E2: The human eye is able to see sharply in an area of approx. 3 degrees (foveal vision) while the periphery (peripheral vision) mainly serves the recognition of movements and three-dimensional recognition.
FR4A_FOP.E3: Example for DLR peripheral visual feedback on ambient display to communicate warnings (red), recommendations (green) and automation levels (blue) (Reference: AdaptIVeD3.2, DLR , Exp.1)
</td></tr>
<tr><td colspan="60">References</td></tr>
<tr><td colspan="60">Code of Practice 2009; Beller et al. (2013); Campbell et al. (2016)</td></tr>
</table>

ID	Name			
FR4A_EGM	" Emergency manoeuvre "			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
	x	x	x	
Related to 4A subcategories: Action				
Ergonomics	Controllability			
	x			
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
The driver is not able to control an emergency manoeuvre in time.				
Human Factors recommendation				
In emergency situations, which cannot be handled by the driver anymore, the automation should initiate an intervention without driver input (e.g. Minimum Risk Manoeuvre). NFR4A_EGM.1: Automatic intervention without driver input shall be available for Close-Distance automation emergencies (Reference: AdaptIVeD3.2, FORD , Exp.1) → See FR4A_SAF				
References				
Moreillon (2017); Seeck et al. (2016); International Harmonized Research Activities (IHRA) (2010); Code of Practice (2012)				

D	Name
FR4A_MRM	“ Minimum risk manoeuvre”

Related SAE Levels:

SAE0	SAE1	SAE2	SAE3	SAE4
				x

Related to 4A subcategories: Action

Ergonomics	Controllability		
	x		

Related to the following applications

Highway	Urban	Close-Distance
x	x	

Human Factors challenge

The driver is surprised by an unexpected MRM.

Human Factors recommendation

The driver should be informed about an imminent or ongoing minimum risk manoeuvre.

References

Moreillon (2017); Rieth & Raste (2015); Seeck et al. (2016)

ID	Name			
FR4A_SAF	"Safety functions"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
x	x	x	x	
Related to 4A subcategories: Action				
Ergonomics	Controllability			
	x			
Related to the following applications				
Highway	Urban	Close-Distance		
x	x	x		
Human Factors challenge				
An intervention of the driver is necessary, but the driver does not react appropriately.				
Human Factors recommendation				
Active safety functions should be active in all automation levels and intervene in situations where the driver is not reacting to prevent accidents. NFR4A_SAF.1: in case of limits for Close-Distance systems the vehicle should stop				
Already existing approaches and examples				
FR4A_SAF.E1: ABS, ESP, Emergency Brake Assist etc.				
References				
HAVEit D61.1 P. 34; Rieth & Raste (2015)				

ID	Name			
FR4A_CAC	"Cab configuration"			
Related SAE Levels:				
SAE0	SAE1	SAE2	SAE3	SAE4
			x	x
Related to 4A subcategories: Action				
Ergonomics	Controllability			
x				
Related to the following applications				
Highway	Urban	Close-Distance		
x	x			
Human Factors challenge				
The drivers' usage of mobile or other devices in 2nd tasks causes poor physical sitting/holding positions for the driver.				
Human Factors recommendation				
The configuration of the cab should take into account ergonomic issues for drivers engaged in non-driving 2nd tasks (Reference: AdaptIVeD3.2, VTEC , Exp.2)				

4 Discussion & Outlook

In this deliverable we presented our approach for the documentation of Human Factors recommendations for the User-Centred Design of automated vehicles within the AdaptIVe project. These were regarded as a less stringent practice of requirements analysis. For that purpose, we developed a structuring methodology, which we named the 4A-Structure. The main categories of the 4A-Structure (Agent State, Awareness, Arbitration and Action) are based on the homogenization of three concepts of cognitive science (sequential cognitive information processing, situation awareness, and arbitration). The sub-categories of the 4A's are based on the most important aspects considering the design of DAVE (driver-automation-vehicle-environment) systems we are dealing with in AdaptIVe.

We documented 27 functional HF-recommendations with several non-functional HF-recommendations for each. All recommendations were compiled in a catalogue following the newly developed 4A-Structure. Examples were documented in the HF-recommendations catalogue. This catalogue was continuously revised during the whole lifetime of the AdaptIVe project. We cannot claim to have found and organized all possible HF-recommendations, as there are countless issues to consider, and we focussed only on those we anticipated to be useful for AdaptIVe.

Our starting point was an analysis of the functions and use cases the demonstrator owners had in mind. After a thorough literature search we documented over 120 functional recommendations, which were later reduced down to 27. There were two reasons for this reduction. Firstly, we found that much of the information in the community dealing with design of DAVE systems has a high repetition rate, i.e. many recommendations are focussed on the importance of dealing with transitions of control between the driver and automation. Secondly, the majority of information in the area of designing DAVE systems relates to non-functional recommendations, for example, how exactly these transitions of control can be implemented.

Not only was the development of the HF-recommendations catalogue distributed over the lifespan of AdaptIVe, but the demonstrator owners also made use of this document from the very early stages of the project. We continuously distributed the most up-to-date versions of this document within AdaptIVe, to support the early discussions between HF professionals and technical system developers. It turned out to be a quite helpful approach for both sides. On the one hand, the HF professionals from SP3 got an early feedback on how the catalogue should be developed and used. On the other hand, the demonstrator owners (VSPs) received early information on the HF-recommendations to be included in their specific demonstrator development.

The 4A-Structure seemed to fulfil its purpose as a means to structure and guide the documentation of the HF-recommendations, and to catalogue them in a useful manner for DAVE system developers. Furthermore, the 4A-Structure was successfully used to organise the HF-related research questions required to set up the HF experiments in SP3. The categories and sub-categories of the 4A-Structure were generally well understood by both the HF experts and the catalogue users, i.e. the demonstrator owners and technical experts. However, it took some time to explain the advantages of such a concept-based structuring, rather than presenting the DAVE-related design categories in a random order.

Future work will involve a further refinement of the 4A-Structure to increase its clarity and ease of use. The structure can continue to guide considerations about HF-research questions and HF-experiments, and can help in the design of future use cases. With the AdaptIVe catalogue of HF-recommendations we provide a document that inspires further HF-research and supports designers of DAVE systems in their work. As a living document the catalogue itself will be improved and continuously enriched by new functional and non-functional HF-recommendation and examples.

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