Human Factors Guidelines report 4

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Human Factors Guidelines report 4: Human Factors Guidelines for Advanced Driver Assistance Systems and Automated driving Systems

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Contents

1 Introduction

Driver assistance systems and automated vehicle systems will only be able to realize their full potential in terms of safety effects if they take the end-user into account in their design. In 2019, the Ministry of Infrastructure and Water Management commissioned “Human Factors guidelines for safe in-car traffic information services” [ID5308][1]. These guidelines are intended to provide both policy makers and manufacturers / service providers with guidance in the safety assessment of nomadic devices in vehicles, in particular devices that provide information, such as navigation systems.

In recent years, however, there has also been a strong increase in driver assistance systems, ADAS (Advanced Driver Assistance Systems), which interact with the driver, support tasks, and sometimes even (partly) take over the driving task. The current version of the guidelines contains little or no guidelines specifically related to ADAS. In view of the current developments, it is advisable to expand the guidelines with these types of systems, allowing both system designers and policy makers to take these into account. Here, we follow the definition of ADAS as given by the Dutch Safety Board: *“Advanced Driver Assistance Systems (ADAS) are systems that assist the driver in carrying out the primary driving task. ADAS observe the environment using sensors and are able to take over control of speed or driving direction, subject to the responsibility of the person at the wheel. Systems of this kind are also able to warn the driver in situations that the system considers dangerous.”* [ID14] Where possible, Automated Driving Systems (ADS) will also be included in the development of the HF Guidelines.

If there are guidelines that a design must meet, these guidelines can also be used to check if the design complies with them. In other words, where the "HF Guidelines" specify what should be taken into account in the design of in-vehicle systems, they can also be used for the evaluation of these systems when the guidelines are combined with evaluation tools and criteria. After all, a good system must comply with the guidelines. In the end the objective of the development of the "HF Guidelines" is to arrive at a uniform evaluation framework of the interaction processes between vehicle and driver.

RWS has asked Rijksuniversiteit Groningen (RUG) and TNO to provide these Human Factor Guidelines for ADAS and Automated Driving Systems.
To come to these guidelines a number of separate reports have been prepared:

- Report 1: Literature review and overview
- Report 2: Overview and description of the different driver support systems
- Report 3: Literature study on the use of ADAS and the mental models of drivers
- Report 4: Human Factor Guidelines for ADAS and Automated Driving Systems

[1] The ID numbers between square brackets refer to the ID in the repository as explained in Report 1 [ID5357].

- Report 5: Overview of required knowledge to convert HF guidelines into an evaluation tool.

The current report (Report 4) describes the Guidelines that were derived from Reports 1 to 3.

1.1 Structure of the guidelines

In this document, guidelines are presented for different SAE automation levels, mostly for lower levels 0 to 2 (manual, assisted and partially automated driving) and to some extent for levels 3 and 4 (conditional and high automation). The SAE levels are based on the level of autonomy of the system versus the driver [ID5359]. Rather than organizing our guidelines according to automation levels, however, in this document they are organized according to information, warning, assistance, and automation functions of ADAS and ADS. This distinction is made because the requirements for interfaces are more specific than SAE levels allow. Independent of the SAE level, one system may interact at different functional levels with the driver. For example, an ACC may not only provide information about whether it is active or not, but also give a warning when system limitations are reached, or provide specific information about system performance while assisting the driver. For this reason, the guidelines in this document describe the HMI characteristics designers of ADAS and ADS should strive for when providing information on these different levels. Furthermore, these guidelines are applicable to longitudinal as well as lateral assistance systems and therefore no distinction between such systems is made.

Before describing the functional levels of ADAS and ADS in more detail, it should be noted that basic HMI design guidelines are the foundation for all four levels and their guidelines (see Figure 1). For this reason, these general HMI design guidelines will be described first. Subsequently, the four levels of ADAS and ADS functions with respect to system-user interaction and their guidelines will be described according to a hierarchical structure (Figure 1). This means that guidelines at the lowest level (information) are also valid for levels above (e.g., a warning function also serves as an information function, but an information function does not necessarily include a warning). To prevent a repetition of guidelines for every level, those that hold for multiple levels are only included at the lowest level.

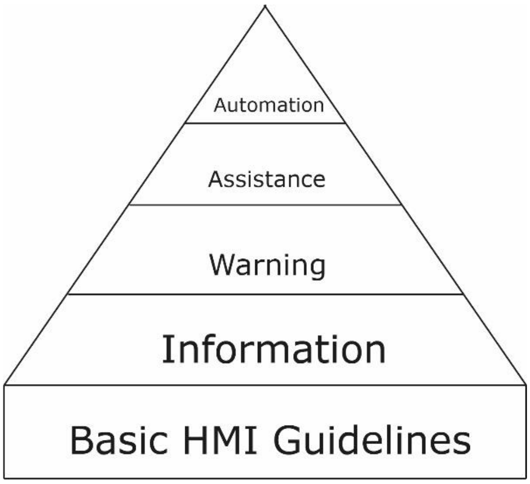

Figure 1. The hierarchical levels of ADAS and ADS functionality in system-user interactions

The first level of the hierarchy concerns the information function. This function includes all types of critical or non-critical information that an in-vehicle system may provide while the driver is in full control of the vehicle. For example, this level provides guidelines about workload, timing, priority, modalities, distraction, reliability, validity, and recognizability, similar to the guidelines for information systems [ID5308]. In principle, this category contains guidelines that are applicable to all types of systems that provide information to a driver.

The second level of the hierarchy is the warning function. This function provides information that is focused more on supporting a driver with safety-related, time-critical information on the tactical and operational level (e.g., information about maximum or advisory speed, vehicles in the blind spot during overtaking, collision warning for vehicles ahead, etc.). In contrast to pure Information functions, warnings require an action from the user and are therefore often more time-critical (especially in emergencies). In essence, this category of guidelines is aimed at emphasizing priority and higher risk situations to elicit accurate and on-time responses from the driver.

The third level is the assistance function. If a system contains an assistance function, the system is able to take over (parts of) the driving task on the tactical and operational level. This also means that the role of the driver changes from being in full control to being in partial control of the driving task while also monitoring and operating ADAS. In addition, ADAS allow for user-system interaction in both directions: the user can change system state or settings, while the system may also require the user to act or respond. This puts additional requirements on HMI design and, therefore, emphasis of the guidelines for assistance functions is on driver role awareness, system (state) monitoring, and transfer of control.

The fourth and upper-level in the hierarchy concerns automation functions. Although few of the currently available ADAS and ADS actually reach the level of automation, some guidelines can be provided for systems such as SAE level 3 or level 4 systems. The focus of these guidelines is on how the system and driver transfer control to each other and how the driver is able to monitor the system while the system is in full control of the driving task.

1.2 Existing guidelines

The guidelines in this document are based on guidelines reported in different publications as listed below. Most guidelines are cited as the authors have reported them in the referenced documents (the reference corresponds to the IDs in previous reports throughout this project). Some guidelines have been (slightly) adapted to fit the ADAS or ADS systems that are the topic of this document. Previous work in this project describes this literature review, and forms the basis for the structuring of the document [ID5357]. One of the outcomes of a workshop with experts in this project held on the formulation of guidelines, was that system-specific guidelines were desired in addition to generic guidelines. Some of the guidelines are open to interpretation, this is in some cases because there is a lack of knowledge and sometimes because the guideline can only become concrete when a specific system is used as an example or as a topic for the guideline. This could mean that to make them more concrete, the complete set should be made specific for every ADAS or ADS system considered.

The following documents are used that specifically report guidelines on ADAS or ADS:

1. Schömig et al. (2020) [ID795]: Focused on HMI
2. Kroon et al. (2019) [ID5308]: Focused on information systems
3. Campbell et al. (2016) [ID5311]: Focused on HMI
4. Campbell et al. (2018) [ID5323]: Focused on ADAS
5. Billings (1996) [ID5370]: Aviation automation guidelines

2 Guidelines

Human Factors Guidelines for Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) are HMI design guidelines intended to improve the usability of these systems. Usability has many different aspects, including safety, effectiveness, efficiency, learnability, memorability, utility, enjoyment and error tolerance and resistance (see ISO 9241-11, 2018 and ISO 9126, 2001). From these usability aspects, some overarching principles can be formulated for the design of ADAS and ADS:

Principle 1:
Systems should be designed in such a way that they allow users to use them effectively and efficiently without compromising traffic safety and without the need for training or manuals.

The ideal should be a system that is transparent and intuitive for every user. Users should be able to understand the purpose, functionality and limitations of a system simply by using it. In practice, this is often hard to realize, but it should nevertheless be the ideal to strive for. Designers should also take differences between users into account and be aware for which users a design might work well (or not).

Principle 2:
Systems should be designed in such a way that they make driving more comfortable and more enjoyable.

System design should not only focus on safety, effectiveness and efficiency, but also aim for more comfort and enjoyment for the user. This increases the likelihood that users will actually use the system.

Principle 3:
Systems should only allow activation within their operational design domain (ODD).

In an ideal world, the user should only be able to use a system under the conditions which it was designed for. If a system is not able to deal with a situation, it should not be possible to switch it on or to use it.

Principle 4:
Systems should make it clear to the user which role is expected of the user.

With the number of assistance systems steadily increasing and automated systems around the corner, it becomes increasingly important that the user knows at all times what his/her role regarding the driving task is when using these systems. The system should communicate clearly to the user whether the system or the driver is in control and who is responsible for (parts of) the driving task. In the case of information and warning systems, both control and responsibility lie with the user. For assistance systems, control is (partially) taken over by the system, but the user is still responsible and should therefore supervise the system. A special case is an automated system that takes both control and responsibility for (part of) the driving task.

Principle 5:
Systems should support the development and maintenance of a functionally accurate mental model of the system through design and training [ID5323].

Users develop mental models of the systems they use through expectations, instructions, training and above all through actual use of the system. A mental model serves to understand how a system works, what its limitations are and to predict its behaviour in various circumstances. In order to be able to use a system safely and effectively, a user's mental model needs to be sufficiently accurate. Systems should be designed in such a way that they allow the user to develop these models while using the system. User instruction/training before use can provide an initial sufficiently accurate mental model, which can then be further refined through use.

Principle 6:
System design should not only take first use into account, but also consider behavioural adaptation effects in the long run.

Users are known to change their behaviour when interacting with a system over time. Use of advanced ADAS, which supports the user by controlling both longitudinal and lateral velocity of the vehicle, has been shown to lead to increased time spent on non-driving related tasks. System design should consider these effects and how to minimize them.

In the following sections, the human factors guidelines for ADAS and ADS are reported. First the basic HMI guidelines are described, followed by guidelines for information, warning, assistance, and automation, respectively. Guidelines will be accompanied by an explanation and illustration, except for the basic HMI guidelines. These apply to a wide variety of HMIs, not just those relevant to ADAS and ADS, and are therefore given without further explanation.

2.1 Basic HMI Guidelines

2.1.1 Select displays that convey information in a way that is consistent with the functional requirements of the application [ID5311].

2.1.2 The visual interface should have a sufficient contrast in luminance and/or colour between the foreground and background [ID795].

2.1.3 Design for colour-blindness by redundant coding and avoidance of red/green and blue/yellow combinations [ID795].

2.1.4 Texts (e.g., font types and size of characters) and symbols should be easily readable from the permitted seating position [ID795].

2.1.5 Select sizes for text and icons in warning messages that support rapid legibility of the message [ID5311].

2.1.6 Present messages to the driver in the simplest form possible so the driver can readily perceive, comprehend, and act upon the information [ID5311]. For example, text messages should be as short as possible [ID795].

2.1.7 Use clear and simple alphanumeric characters in support of message legibility [ID5311].

2.1.8 Messages should be conveyed using the language of the users (e.g., national language, avoidance of technical language, use of common syntax) [ID795].

2.1.9 Control activation feedback should be immediate and clearly noticeable [ID5308].

2.1.10 Not more than five colours should be consistently used to code system states (excluding white and black) [ID795].

2.1.11 The colours used to communicate system states should be in accordance with common conventions and stereotypes [ID795].

2.1.12 Ensure that control placement and operation does not interfere with the driving task, or with use of other driving controls [ID5311].

2.1.13 Provide controls that allow operation with minimal mental or physical effort [ID5311].

2.2 Guidelines for Information functions

2.2.1 System use should make driving more comfortable.

This might be interpreted as a 'super-guideline' which might be so obvious, that it may be overlooked. In principle, for any system to be used, drivers should 'like' them and see the additional value during their driving experience (Project Expert Meeting). Furthermore, a system that is enjoyable and satisfying to use will be used more often, as opposed to a system that causes frustration. It is therefore crucial that systems are designed to accommodate the driver (user-centred design) instead of drivers having to accommodate to a system.

2.2.2 System use should support the driver in the driving task.

A system that gives information should make the driving task safer or easier to perform (e.g., navigation). The 'costs' of giving information should provide a benefit to the driver, at the very least using the system should not make the driving task more complex or difficult.

2.2.3 System use should not reduce driving safety.

Systems should at the very least not reduce driving safety, and preferably increase it. Especially when the direct goal of ADAS or ADS is not increasing safety (but comfort for example), care must be taken that the system does not decrease driving safety by distracting, overloading, or underloading (tiring/boring) the driver.

2.2.4 User overload should be prevented [ID5308].

Driving can be a complex task that requires (mental) effort, which is determined by the (skills of the) driver and the complexity of the environment. This guideline is aimed at providing information only when the driver workload is low. In practice, this means that in complex situations (e.g., busy traffic, intersections), the amount of information provided to the driver should be minimized and only urgent messages should be issued [ID5308]. Consequently, less urgent messages should be postponed to situations where the driver's workload has decreased again.

2.2.5 The modality of messages should match with driver tasks, needs, and expectations in order to enhance drivers' comprehension and performance [ID5311].

Drivers have limited capacity for perceiving driving-relevant information (e.g., the visual, auditory, and haptic 'channels'; see [ID5372]). To ensure that drivers act quickly and effectively, messages should be easily relatable to the task at hand. One way to achieve this is to adapt the modality of messages to be in accordance with the required driver response. For example, a lane keeping system should provide vibrotactile information through the steering wheel because a driver than instantly knows that a steering manoeuvre may be required. Furthermore, as driving is largely a visual task, providing information through one of the other modalities may prevent increasing visual load.

2.2.6 Information should be presented in a time window when the information is relevant and allows time to respond. Not too late, not too early [ID5308].

Regardless of the type of information, drivers should have sufficient time to *perceive, understand, and act based on that information. For this reason, one could argue that information should always be provided as early as possible to allow the driver the most time to respond. However, drivers should also be able to connect the information received to the driving situation and by providing information too early, drivers may not believe that it is relevant at that time. For this reason, the guideline states that information should be given in a time window that is relevant (i.e., not too early) and in which the driver still has sufficient time to react (i.e., not too late) to be effective.*

2.2.7 Develop and present messages in a manner that supports accurate and timely comprehension by the driver [ID5311].

This guideline states that the format of a message should be appropriate for the time that is available for the driver to react. In practice, this means that if there is little time to respond, the message should be as simple as possible and only aimed on the response of the driver (e.g., simply proving a "TAKE OVER" or "STOP" message if the driver is urged to take over or stop rapidly). However, to develop an accurate mental model, it is important for a driver to know why a message occurred. For non-critical situations it may therefore be feasible to provide the reason before the reaction/manoeuvre takes place in order to increase understanding and compliance. During a critical situation, however, there is no time for the driver to process such details and providing this information should therefore be limited to non-urgent situations. For cases where after the situation the message is still not clear, details about an urgent warning could be postponed until after the driver's response when the situation is no longer critical.

2.2.8 The semantics of a message should be in accordance with its urgency [ID795].

This guideline states that based on the semantics of a message, it should be clear for the driver whether a message is urgent or not. For example, [ID795] differentiate between a 'notification-style' for non-critical information and a 'command-style' for critical information. Furthermore, the selection of words should also be according to well-known, recognisable principles (such as "caution", "danger", "warning") [ID795].

2.2.9 Information is prioritised by importance to the driver in relation to the context and urgency [ID5308] [ID5311].

In case of multiple messages close in time, potentially from multiple systems, this guideline states that high priority information should always override low priority information. In practice, this means that safety-related information should always be prioritised over non-safety-related information, particularly if an action is required from the driver [ID5308]. For example, if an LKA is being disabled while at the same time a navigation message is given, the information about the LKA should be prioritised because the driver has to immediately respond to keep driving safely.

2.2.10 High-priority information should be presented close to the driver's expected line of sight [ID795].

In order to increase the likelihood of the driver registering high-priority information timely and effectively, this guideline states that this information should be displayed close to where the driver is looking already. This means that the interface should be positioned in such a way that information is detected and interpreted rapidly with *minimal time gazing off the road [ID5311] [ID795]. For example, a FCW should be visible directly ahead of the driver (e.g., by means of a HUD) instead of a driver having to look at a centre console that draws attention further away from the road.*

2.2.11 Distraction from the driving task should be minimized [ID5308].

In principle, any display or message will cause distraction to some degree. The question, however, is whether that information is related to the driving task. This guideline states that providing information that is not relevant for the driving task should be prevented. In practice, this means that information systems (e.g., 'multifunctional displays') should not provide (notifications of) phone text messages, e-mails, commercials, or similar, while the driver is responsible for the driving task. Furthermore, a system should require minimal driver interaction that interferes with the driving task: physical interaction with the driver should be minimised and the driver should be able to keep both hands on the wheel most of the time. For example, a navigation system should zoom automatically based on the speed of the vehicle and accept alternative routes based on the strategical choices of the driver, without needing otherwise physical input from the driver.

2.2.12 Create auditory messages that are distinguishable from other auditory signals in the cabin [ID5311].

Auditory messages should be perceptible in any possible condition that a vehicle may be in. This means that an auditory message should sound different from 'normal' in-vehicle sounds and that the volume is sufficient to actually perceive the sound. Furthermore, it should be intuitively clear for a driver what such messages mean. Navigation instructions, for example, should be clearly differentiable from warning signals.

2.2.13 Auditory output should raise the attention of the driver without startling her/him or causing pain [ID795].

Whereas the previous guideline was aimed at the lower-bound threshold for auditory messages, this guideline concerns the upper-bound threshold by stating that auditory messages should not cause drivers to startle or make involuntary movements. Concretely, this means that any sound provided by the system should not be emotionally loaded or so loud that it shocks the driver, causes involuntary movement, or even pain.

2.2.14 Information presented should be non-ambiguous, valid and reliable [ID5308].

Firstly, information provided by a system should be clear and not interpretable in multiple ways. If a message is difficult to interpret, this may delay the timing and/or quality of the driver's response. Secondly, the information provided needs to be valid and reliable, in other words: it should be appropriate and correct. It is important to minimise false alarms and/or misses as these may cause annoyance and/or decrease trust and acceptance [ID5311]. There seems to be a balance between annoyance and usefulness, however, as some annoyance may be accepted if the driver believes that the system is sufficiently reliable and useful. However, if a system gives too many false alarms or misses, its perceived reliability may decrease and a similar level of annoyance may not be accepted anymore.

2.2.15 Information should be recognisable and consistent with legal traffic signs, signals, and local road side information [ID5308].

To facilitate recognition and understanding, this guideline states that in-vehicle information should not only be in line with local (road-side) information, but also be displayed in a similar manner. For example, in-vehicle information about the current speed limit should not only be correct (reliable), but also be displayed similar to the (national) speed limit signs along the road. This means that the system should use signs and symbols that are accepted in the country that the driver is in. If non-conventional symbols are used, these should be accompanied by an explanation [ID5308].

2.2.16 Commonly accepted or standardized symbols should be used to communicate the automation mode. Use of non-standard symbols should be supplemented by additional text explanations [ID795].

In line with the previous guideline, information about in-vehicle systems and their states should also be communicated by means of conventional or standardized symbols. This way, drivers may quickly recognize this information based on earlier experiences, perhaps even from other vehicles. For example, the availability and status of an LKA could be visible according to the symbol of a car between two lines.

2.3 Guidelines for Warning functions

2.3.1 Effects of system limitations should be predictable for the user.

It is important that a driver knows in which situations a system will function correctly. Level 2 and level 3 systems are by definition not capable of dealing with every situation, when the vehicle enters such a situation it is important that the driver already knows the system is probably going to indicate it will not function properly or switch off. For example, a LDW or LC system will only operate correctly when the lane markings can be detected, when the driver sees the markings disappear, he/she can expect these systems to stop functioning. Some of these limitations can be learned more easily than others. In the example of lane markings, a message to the user that no lane markings have been detected and therefore LDW or LC is switched off, will teach the driver the necessity of lane markings for the system. There are many cases in which this is more difficult of course, especially when the vehicle has no information on why (or even if) the system is no longer functioning, e.g., in foggy situations where a camera cannot detect predecessors at a safe distance by camera images.

2.3.2 In case of system failures or when the limits of the system have been reached, the change in system state should be clearly and timely communicated to the user; an explanation should be given in non-urgent situations [ID795].

When the system enters a situation that it cannot safely operate in or when it detects a sensor failure due to which safe operation cannot be guaranteed, the driver should be notified of this. Firstly, the driver should know what the situation is and whether and how he or she must act. If there is time an explanation should be given as well, this will contribute to increase the accuracy of the mental models of the user.

2.3.3 Unintentional activation and deactivation of a system should be prevented [ID795].

Unintentional activation can occur by placement of controls in a position where drivers may accidently touch them (e.g., buttons on levers on the steering wheel). This can be prevented by better placement or a two-step activation (e.g., ACC that has to be activated and then set to a certain speed). Unintentional activation can also occur because drivers misinterpret the function of the controls. Clear and preferably separate controls for systems can prevent mode confusion. Location of controls can help indicate it concerns ADAS.

2.3.4 Use appropriate warning stages to promote the driver's comprehension and response to a hazard [ID5311].

ADAS will give warnings in situations when actions are required or systems fail. For example, when using ACC or LC, a driver is required to hold the steering wheel with at least one hand and will be warned if he/she does not do so for some period of time. When a situation allows, the driver should be warned in an early stage with a mild warning. In later stages when urgency is higher, the driver must be warned with an urgent warning. ADAS without these levels of progression of urgency, such as FCW which only knows a high level of urgency, should immediately warn with the highest level of urgency.

2.3.5 Urgent messages should be multimodal [ID795].

By using multiple sensory modalities (visual/auditive/tactile), and temporal characteristics (flashing, beeping), multimodal warnings increase the chance of reaching one of the available 'channels' of the driver. For urgent messages, an auditory alert should at least be used.

2.3.6 Warning messages should orient the user towards the source rapidly and accurately [ID795] [ID5311].

It is efficient to direct attention directly to the location of the source of danger. The system should prevent directing attention to a place where there is no danger (e.g., a generic place on the console), which would require additional steps for the driver to assess the situation and make a decision and act. A good example of this is a Blind Spot Warning System, where the attention is drawn to the mirror where the driver should be looking at, or providing a warning of an imminent collision by means of Head Up Displays in front of the driver. But also auditory warnings may be sent from the direction where the danger is (e.g., a bicycle on the right-hand side of the vehicle).

2.3.7 Use changes in colour or temporal characteristics of visual displays, such as flashing, blinking or apparent motion when immediate user visual attention is required [ID5311].

Contrast, especially temporal contrast, is easily detected by humans. Warnings can only be effective if they attract the driver's attention, therefore temporal changes of the signal giving the warning should be used for warnings that need immediate attention. A good example is the flashing red rectangle used in some vehicles which uses contrast in both the visual and the temporal domain, making them even more detectable.

2.3.8 Use an auditory warning to clearly communicate a level of urgency consistent with the urgency of the hazard [ID5311].

Much research has been done within and outside the automotive field on the urgency of alarms. Different characteristics of sound can convey different levels of urgency (loudness, pitch, temporal frequency). Although warnings should not annoy drivers (the frequency of messages should not be too high, see also 2.3.10), it is important that the level of urgency conveyed by the warning matches that of the warning/problem itself. For urgent messages a sound should be used.

2.3.9 For auditory warnings, select a signal type that facilitates drivers' understanding of the hazard and supports appropriate and timely responses [ID5311].

Use standard HMI rules for auditory warning characteristics so that they match the user response; much research has been done in and outside the automotive domain on sound.

2.3.10 Select auditory warnings that cause a minimal amount of annoyance in drivers [ID5311].

Prevent users wanting to disable systems because warnings are experienced as annoying; e.g., loudness, frequency and type of sound can be annoying to drivers, this can differ among individuals.

2.3.11 Integrate haptic displays with vehicle controls, seats, motion, or other elements of the vehicle [ID5311].

Integrating the haptic feedback with the controls of the vehicle minimizes the need to interpret the message given by the haptic feedback. An example is force feedback in the steering wheel for LDW systems.

2.3.12 Ensure haptic warnings are clearly perceivable and distinguishable from other haptic signals in the vehicle [ID5311].

Haptic signals given by the system should be distinguishable from movements, sounds or vibrations made by others systems or the vehicle itself.

2.3.13 Select haptic display characteristics that elicit rapid and accurate responses [ID5311].

The characteristics of the haptic signal should be appropriate for the targeted body location and content of the warning. Force on the steering wheel is easier to detect and more informative on the nature of the warning than a general vibration in the steering wheel, for example. See also 2.2.8 for a guideline on matching characteristics in information functions.

2.3.14 Time-critical interactions with the system should not require continuous attention [ID795].

It should not be necessary to continuously have to monitor a display to detect when a response is necessary; e.g.: visual warning of FCW which can only be seen when inspecting the instrument cluster; or only visual warning of lane departure with red icon in instrument cluster.

2.3.15 Systems with user-adjustable settings should have default settings that are safe to use.

The appropriateness of settings can depend on the experience of the user with driving in general or the specific system. Therefore, the default setting should be safe for all users, effectively including a safety margin for the weakest users*. For example, the default distance setting of the ACC system should be safe for inexperienced drivers as well as experienced drivers, even when experienced drivers may prefer a shorter distance setting.*

2.4 Guidelines for Assistance functions

2.4.1 User underload should be prevented.

Because an assistance system can take over part of the driving task from the driver, drivers are forced into a monitoring role, which could lead to the driver falling asleep or initiating non-driving related tasks because of boredom.

2.4.2 Encourage adequate driver supervision, appropriate for the requirements of the assistance system [ID5323].

The driver should be aware of his/her expected role in the driving task. With assistance systems, the driver is still responsible for executing the driving task safely. Therefore, system design of assistance systems should make sure the driver keeps attending to surrounding traffic and to system behaviour even when the assistance system is active. In the case of assistance systems, the driver should be ready to take over vehicle control at any time not only when prompted to do so by the system, but also when the demands on the system exceed its capabilities. The system design should support the driver in being able to take over quickly by keeping him/her in the loop. An example how systems try to keep the driver in the loop is the requirement to keep both hands on the steering wheel, even when both longitudinal and lateral vehicle control are being regulated by ADA.

2.4.3 Use of an assistance system should not reduce the driver's attention for the driving task.

Systems should be designed in such a way that the driver is encouraged to attend to the driving task (including supervising the assistance system) when using an assistance system. Behavioural adaptation effects leading to decreased attention for the driving task and increased time spent on non-driving related tasks compared to manual driving should be prevented.

2.4.4 The system state should be displayed continuously [ID795].

A system should enable the driver to know at all times which part of the driving task is supported by the system. The user should not have to rely on memory or reasoning, but be able to verify system state with one simple action (e.g., one glance, or one finger movement). This way, mode confusion can be prevented or at the very least reduced. Examples are standardized system icons with consistent colour codes which are easy to use.

2.4.5 System state changes of assistance systems should be communicated timely and effectively [ID795].

A system may not fall out of automation silently, nor should it change its state or mode otherwise without notifying the user. Every relevant change in system state should be communicated effectively to the user, with appropriate urgency and timing, to prevent mode confusion. This included both user-initiated and system-initiated state or mode changes.

2.4.6 Support the transition from assisted to manual driving by providing timely information about the need for the driver to take manual control and about its urgency [ID5323].

State changes that require the driver to take over control may arise from the predictable or unpredictable deactivation of a system. In the case of predictable deactivation, the system should notify the user and indicate the required user action within the time that is required for a taking over the assisted part of the driving task without compromising traffic safety. The amount of time required or allowed for takeover may depend on the situation. The possibility of unpredictable deactivation should be minimised by the design of the system. However, an assistance system is by definition a system that is allowed to be deactivated because the driver is still supervising. In the case of unpredictable deactivation, for instance due to system failure, the system should notify the user immediately and indicate the required user action.

2.4.7 Support the transition from manual to assisted driving by acknowledging a driver's request to engage automation (if applicable) and provide information about the status of the transfer of control [ID5323].

In the case of user-initiated transfer of control from the user to the system, the system must give clear feedback on receiving the request and on the resulting change in system state. Feedback can occur by clearly noticeable changes in vehicle control, by visual, auditory, tactile or haptic displays, or by a combination of these. In the case of a transition of control from user to system that is system initiated (for example, by Autonomous Emergency Braking or Steering), the system should provide the user with clear information about what the system is doing and why.

2.4.8 User initiated changes in the state of a system should not interfere unexpectedly with the use of other systems.

Activation or deactivation of a system or changing its settings should not change the functioning of other systems in any for the user unexpected way. If the state of other systems does change, the user should be notified about this. If these changes have immediate safety consequences, the user should be asked for confirmation before implementing them. An example of expected interference is temporary deactivation of the Lane Keep System by activation of the Lane Change Assist. An example of unexpected interference is deactivation of ACC when the user deactivates the Electronic Stability Program or Traction Control.

2.4.9 HMI display elements should be grouped together according to their function to support the effective and efficient perception of system state indicators [ID795].

As per 2.4.4, the user should be able to verify system state easily and quickly. To have a complete overview of all relevant system states, displays for related systems should be shown together in an intuitive way. For instance, state indicators for ACC and LC could be displayed in close proximity, allowing the user to see rapidly which aspects of the driving task are currently being supported by assistance systems.

2.4.10 Provide driver-automation interactions that are interactive and collaborative in nature [ID5323].

The objective of ADAS should be to keep the user involved in the driving task, while making that task both easier and safer. System and interaction design should aim to prevent the user from becoming out-of-the-loop, with potentially dangerous effects in case the user has to take back control. One way to achieve this is by conceptualizing the user-system interaction as a partnership, in which both partners are aware of each other's state and actions through constant communication. An example of this is the Lane Centering system, which communicates its actions to the user through shared control of the steering wheel.

2.4.11 User vehicle control via throttle, brake or steering wheel must always have priority over system control as long as the driver is responsible for driving.

Since the user is always responsible for the driving task when using assistance systems, he/she should be able to take over vehicle control at any moment by means of the three actuators that control longitudinal and lateral vehicle motion.

2.4.12 When multiple systems are available, potential conflicts, interference or confusion between systems should be prevented.

The use of multiple systems should not lead to unexpected changes in the functionality of the individual systems.

2.5 Guidelines for Automation functions

2.5.1 The system should show at all times whether the system or the user is responsible for the driving task.

In contrast to assistance systems, automated systems do not need supervision by the user, as the automated system is responsible for the driving task. However, this can create a situation in which the driver is responsible for some, but not for other parts of the driving task (e.g., driving within the current lane is automated, but the driver is responsible for initiating lane changes). The system has to make clear to the user which parts of the driving task are currently automated.

2.5.2 Ensure adequate driver supervision, appropriate for the requirements of the current level of automation [ID5323].

In the case of automated systems, the driver cannot be expected to take over the driving task at any time, he or she is allowed to disengage from the driving task. Therefore, before taking over, the driver will need time to build up situation awareness again. The system must therefore provide sufficient time for the driver to build this situation awareness successfully.

2.5.3 Support the transition from automated to manual driving by providing timely information about the need for the driver to take manual control and about its urgency [ID5323].

A system should notify the user and indicate the required user action within the time that is required for a takeover of the automated part of the driving task. The amount of time required or allowed for takeover may depend on the situation, but must in the case of automated systems always allow the driver to understand the reason for taking over and provide sufficient time to re-engage with the driving task.

2.5.4 In the case of planned transitions from automated to manual driving, the system should verify the user’s readiness to take over control before actually giving back control.

The driver should confirm taking over control. In case the system does not receive confirmation from the driver, mitigating actions must be undertaken by the system (e.g., slowing the vehicle down to a safer speed, parking in the emergency lane, depending on the situation and system).

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