DESIGN REPORT

INTERFACE DESIGN

FOR THE TAKE OVER OF AUTOMATED DRIVING

Bachelorassignment of R. Vermeulen

UNIVERSITY OF TWENTE.

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Report Title:	Interface Design for the take over of automated driving *Interface concept proposals for the Traffic Jam Assist system of Ford.* April – July 2013
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X. PREFACE

Since I was a little kid I am crazy about cars. One of the benefits of me going to live on my own was the fact that my parents could get rid of the hundreds of toy cars that occupied my room, my parent's attic and sometimes even the entire living room. My passion for cars, combined with my love for/dedication to/skills in graphic design are a perfect match with this design assignment.

I enjoyed the way of working in the project. Executing the assignment in by order of the University of Twente, as part of the University Research Project of my tutor/principal, Arie Paul van den Beukel, gave me a lot of freedom. Working on my own with regular meetings with my tutor and two meetings at Ford resulted in a project I enjoyed.

The freedom recurred in the approach of the assignment. After a wide theoretical research I got the opportunity to determine (in consultation with my tutor) a detailed design focus. The significant amount of time I was able to put in actual designing resulted in a well thought-out design, created in multiple iteration steps.

Without benefiting greatly from the support of many people, this thesis would not have been lying at your table. Firstly, I want to thank my tutor Arie Paul van den Beukel. Without his full support and lots of feedback my design and design report would have been of significant less quality. I would also like to thank the Ford TJA design team for their helpful feedback upon my designs during the project and Niek van den Hout for building the driving simulator software, required for my experiments.

Though I had to give up half of my vacation I am happy with the result of my Bachelor Thesis. I did my best to create a compact, 'easy-to-read' design report with a focus upon the actual interface design. I hope some day I will drive a futuristic Ford with, at least a little part of my Industrial Design skills, implemented in the TJA interface.

Robin Vermeulen, July 2013

X. ABSTRACT

Interface design for the take over of automated driving

Interface concept proposals for Traffic Jam Assist of Ford

Background

The car industry is constantly being innovated. Currently the field of Advanced Driver Assistance Systems (ADAS) is brought to the commercial market. Automated driving could be beneficial for traffic safety and efficiency. The research aims at designing an interface which supports drivers in performing their supervisory task, i.e. being provided as good as possible with information about system state and supports drivers in taking over control (if required) as good and safe as possible.

Methods & Results

The first part of the report describes a literature research. Assistance systems of Ford, competitors and EU development projects are assessed with a focus on the interface of systems like Adaptive Cruise Control, Lane Keeping Aid and competitive systems for Traffic Jam Assist (TJA). Furthermore, an overview of possible human factors issues regarding automated driving are assessed.

With this theoretical knowledge, a set of design requirements and a design approach are defined. The interface is verified using multiple design principle sets. The design process is focused upon the human aspect. Multiple (human related) evaluations are performed during the interface development.

The first part of the design is a system concept from which the TJA interface is build up. An activation strategy, based upon a division in directions (lateral and longitudinal) and levels of automation (LoA) (Informing, Assisting, Taking Over), is defined. On the basis of system availability and usage, a set of TJA relevant systems is derived in order to be integrated in the TJA interface. By defining the system state flow, the interface could be designed.

Interface placement in the car, interactions with the driver, driver input and desired knowledge for the driver are investigated to design a visual interface. The interface is permanently visible in the car's cluster display, a concept for continuous feedback is defined. For each state (of the system state flow) a state is designed with regard to the transitions and division in directions and LoAs. The interface is subjected to multiple evaluations, including an exploratory simulator experiment. From the results, and further development, two proposals are derived; a human and an automation perspective. The two proposals are compared in a driving simulator experiment. The test results are used to determine a design focus for further research and make a design choice between the two interface proposals.

Conclusion & Recommendations

Both system and interface concept are evaluated using the defined design requirements. The system concept mainly needs further development in clarifying soft warnings. The amount of information the interface concept shows should be further assessed. Besides, the interface placement and other environmental variables should be taken into account during further testing and some improvements regarding the specific simulator experiment are mentioned.

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1 INTRODUCTION

The car industry holds a constant drive for innovation. The competition intensifies the need of new technologies. Large brands have to lure customers with new developments, there has been a significant change in needs. In the past the car was just a transportation vehicle, nowadays comfort is a big issue.; driving in situations like heavy traffic can be tiring and uncomfortable. Assistance technologies have made the task of a driver a lot easier. In this area the need for is growing.

Therefore automated driving would be a solution. Currently Ford is exploring the field of automated driving in their vehicles. They started developing a system that allows automated driving during a traffic jam. The following conditions are prerequisites to enable the system to function: the detection of a lead vehicle, detection of road lines and speed (max 50 km/h).

When the system is active, the driver is not committed to controlling the vehicle. One might think, he could do whatever he likes. However, when one of the system conditions is no longer fulfilled, the system will be deactivated and the driver has to take over. This matter requires a smooth transition to prevent accidents, the role of the driver can change very quickly, unexpected and without announcement while using an assistance system. While driving manually, the driver has to actively control the vehicle. Accelerating, braking and steering, as well as being aware of traffic, are part of the tasks a driver has to perform. However, while driving automated, the driver is committed to a supervisory task, a task with a significantly lower workload.

The driver has to be informed about the traffic and system situation to be able to react properly to possible take overs. Research and experience should clarify what information should be displayed exactly. An interface is designed to fulfill this information distribution.

In general the interface's main aims are to:

- support drivers in taking over control (if required) as good and safe as possible.
- support drivers in performing their supervisory task, i.e. being provided as good as possible with information about system state.

1.1 Assignment

The purpose of this assignment is making an interface design for the take over of Highly Automated Driving by the driver. The interface supplies the driver with information about system status and the traffic situation, it focuses on facilitating the driver in taking over control of the vehicle. This is acquired by performing a design based research; by making an analysis of the current situation and developments, the market and human factors issues that come along with Advanced Driving Assistance Systems (ADAS), a design approach is formed. Herewith drafts of the interface will be generated. Results are two final proposals which will be comparatively tested in the driving simulator. This will results in an advise for one of the two proposals is made for further research.

Ford's existing ideas, derived from an exploratory brainstorm session, serve as starting point. The designed interface is meant to be integrated in future Ford cars. The assignment is performed as part of the University Research Project of Arie Paul van den Beukel and Ford. The URP is described as follows:

> *' To avoid out-of-the-loop performance problems for transitions from 'Highly Automated Driving' (involving automation of both longitudinal and lateral vehicle position in situations of heavy traffic) to manually driving, this research creates solutions for adequate driver vehicle interaction that supports these transitions, in case of both planned and emergency take-over. '*

This assignment is part of the URP resulting in an unconventional setup of the project. In fact, Arie Paul van den Beukel initiated this project as part of the URP. A first proposal of the interface design concept is made. It is planned to further develop the final simulator experiment, outside of this project, in the URP. During the assignment Arie Paul van den Beukel will act as mediator for Ford. The completed work is evaluated with the mediator, as part of his URP. Expert reviews with Ford will also function as evaluations.
The interface could be divided in four main aspects:

- activation
- system status
- take over requests
- 'feed after'

During the assignment the design focus is shifted. The entire range of aspects is analysed. Afterwards, during the definition of requirements and the design approach the emphasis is put on system status, the system and interface concept are focused on this aspect. A further detailed description of the different aspects of the interface can be found in chapter 5, the design approach.

1.2 Report Structure

The project is divided in a theoretical and practical phase. Chapter 2 till 5 describe the theoretical phase, an analysis of the TJA system and existing ADAS (of Ford, competitors and development projects) as well as an overview of human factors issues. Afterwards a set of design requirements and a design approach is determined. The practical phase consists of chapter 6 till 8 in which the development of a system concept, interface concept and practical testing of the concept is described. Chapter 9 describes the evaluation of the concept and the entire project.

- Chapter 2 includes a literature research of the technical aspects concerning automated driving, with the focus on TJA. In addition, an overview of assistance systems of Ford and competitors as well as European projects involving ADAS are described.

- Chapter 3 describes the known human factors problems of ADAS development. An overview of possible issues the to be designed interface might deal with is made.

- Chapter 4 includes an overview of the design requirements which are derived from the presented literature research for both technical and human factors aspects.

- Chapter 5 describes the design focus and approach of the project used further on in concept development.

- Chapter 6 describes the design of the system concept which includes assumptions on a proposal of the activation strategy and the associated system definition.

- Chapter 7 builds on the system concept by presenting the design of the actual interface concept. The chapter includes the manner of interaction between system and driver, concept evolution and the final division in two interface proposals.

- Chapter 8 validates the interface concept by analysing and reporting the results from the final driving simulator experiment with two proposals. Therefore, this chapter includes a test plan, the interactive prototype used in the simulator, analysis and test results.

- Chapter 9 concludes with an evaluation of system and interface. Besides recommendations for future research and overall conclusions are handled.

2 ANALYSIS
OF INTERFACES FOR ADAS AND AUTOMATED DRIVING

Chapter 2 includes a literature research of the TJA system purpose and its limitations. Because TJA builds further on the development and integration of existing Advanced Driving Assistance Systems (ADAS), an overview of assistance systems of Ford and competitors as well as European projects involving ADAS are described.

Currently Ford is exploring the field of automated driving. It started to develop a system that will take over driving during a traffic jam called TJA.

2.1 SYSTEM PURPOSE

Traffic Jam Assist is a developing intelligent driving technology that helps address future mobility challenges in the world's constantly growing car fleet. TJA combines the technology of already available systems to actively support the driver in heavy traffic.

'DRIVERS SPEND MORE THAN 30% OF THEIR TIME IN HEAVY TRAFFIC'
according to Joseph Urhahne, engineer, Ford Research and Advanced Engineering

2.1.1 Expected Benefits

Traffic Jam Assist is designed to comfort the driver during heavy traffic and to help reduce road congestion. Automation technology can help detecting problems faster than drivers can. Machines handle tasks like perceiving distance and closing rate to or of other vehicles much better and accurately than people could do. Subsequently, machines can act faster in these situations. Therefore, it is expected that the system could help the driver in steering accurately and following the car in front during heavy traffic. Automated driving is expected to offer a major contribution to more efficient and environmental-friendly road transport (Intelligent Car Initiative, 2006).

Driving in traffic could be very uncomfortable and tiring. Besides, letting the car take over control could lead to more efficient traffic. 'Cooperative driving' could lead to smoother ac- and decelerations which reduces traffic jams; traffic could flow more smoothly and highway capacity could be increased two to three times (Thrun, 2011).

The system gives the driver the opportunity to perform other tasks while transporting himself by car. The system needs a monitoring function of the driver but the driver is able to take his hands and feet off the wheel and pedals and, for example, look up emails with a smartphone. Using TJA leads to the execution of multiple tasks simultaneously: supervising the system and secondary tasks (like using a smartphone). TJA is an example of a persuasive technology (Dorrestijn, 2011). However, the driver will always remain responsible for the system and behaviour of the entire vehicle. The driver should be made aware of that. Therefore the interface supports the driver in performing his supervisory task, i.e. being provided as good as possible with information about System State.

2.1.2 Interface

The system needs to be monitored by the driver. Technology performs well in terms of positioning and controlling the car (in both lateral and longitudinal directions) but it has its boundaries. Human are much better at perceiving complex, unstructured driving environments. So it is expected that there will be a point at which the system is not able to handle the situation anymore and the driver has to intervene. At this stage the Human Machine Interface comes into play. The HMI is of importance for:

- making the operational envelope of the system visible
- visualising to what extent the boundaries are fulfilled
- visualising the system status

The system works great within its 'operational envelope' but when its technical boundaries are no longer met, the system does not work (properly) anymore.

THE INTERFACE PROVIDES INFORMATION ABOUT ADJUSTING THE SYSTEM, SYSTEM STATUS AND CAPABILITIES.

The interface should facilitate solutions for an adequate driver vehicle interaction that supports the transitions from automated to manual driving, it supports in the change of driver role from active driving to passive monitoring and vice versa. Situations in which the driver decides to take over himself and situations of emergency take overs demanded by the system are both taken into account. It should be possible for the driver to influence the occurrence of these transitions and other settings, the HMI should inform the driver when necessary. The possibility to do something else while 'driving' with TJA in traffic has a significant effect on the situation awareness of the driver. When the system cannot handle a traffic situation anymore the driver has to take over control. At this point it is critical that the driver knows what is happening around the vehicle. The interface could contribute with information about the traffic situation as well as the system status. As mentioned before, TJA consists of further development of existing ADAS which opens up opportunities for integration of these systems. Mutual integration and adaptation is possible. Therefore the interface could provide the driver the possibility to adapt TJA.

In brief, the vehicle and driver should act as a unit. The system is able to take over driving tasks but the driver should maintain an active role in monitoring TJA. Understanding of take over situations by the driver are decisive in acceptation of TJA by the driver.

In short the HMI provides:

- the possibility for the driver to adapt TJA
- information and warnings for taking over control
- the ability for the driver to gain knowledge about TJA

2.2 TJA BOUNDARIES

Before the interface could be designed it is wise to have some knowledge about existing ADAS of both Ford and competitors and the current developments of TJA. TJA is limited by its operational envelope and determined system boundaries. Both are described in detail below.

2.2.1 Operational Envelope

TJA offers a lot of possibilities. However, the system is limited by technical boundaries. A question that can be raised is: *When is the system 'able' to function?*

System functionality is dependent on the used technology monitoring system components and their sensibility. The system is build upon two pillars: detection of a lead vehicle and detection of road lines. These conditions are detected with a combination of two different methods: radar and camera technology. A camera is placed behind the rear view mirror, in front of the windscreen. The front grille shelters a radar and in each side of front and back bumper a camera is placed (Figure 2.1). The combination of obtained data results in detection of a lead vehicle and road lines. The system is dependent on quality and boundaries of these technologies and quality of offered 'visual clues' like worn out lane markings or bad light conditions (e.g. while entering or exiting a tunnel). When the system technology is not able to make a proper observation it will request for a take over by the driver.

At a mechanical level the system is not able to keep the car stationary for a long time. The car will not be put in Neutral when stopped (TJA prototypes use an automatic gearbox), like a driver could do, so there is constant braking activity when the car is stationary. The required mechanical power can only be produced for a couple of seconds.

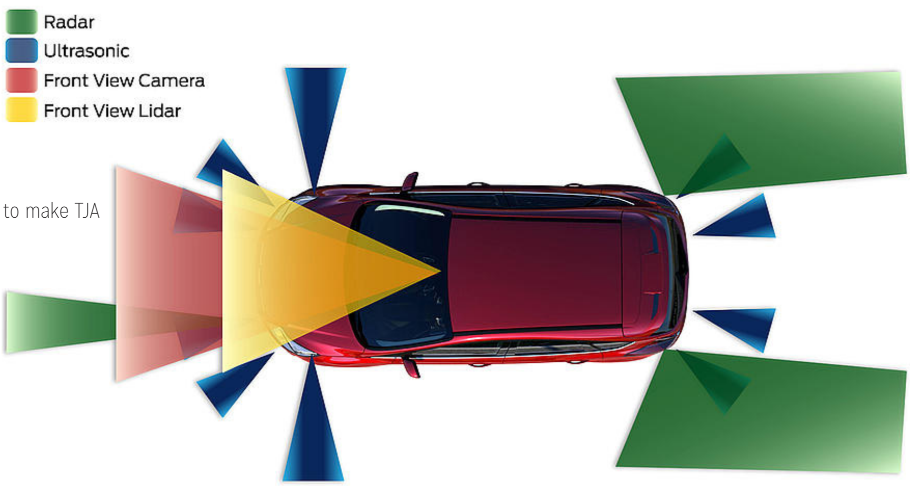

Fig. **2.1**: The technology that is used to make TJA function properly.

2.2.2 System Boundaries

In addition to technical boundaries, Ford has restricted the usage of TJA with system boundaries. Question that is raised is: *When 'may' the system function?* Simple restrictions are:

- maximum speed of 50km/h
- only available on motorways
- not available within roadworks
- maximum of 0,3G deceleration

When a deceleration larger than 0,3G is required the system will ask for a hard take over by the driver. The driver is responsible for the system and therefore the system will request the driver to intervene when an emergency braking manoeuvre, braking with more than 0,3G, is necessary.

2.2.3 Take Overs

When a technical or system boundary is exceeded the system will request a take over (TO) of the driver. Besides, the driver can decide at any time to take over himself. Ford currently divides TOs in a soft and hard category. Hard TOs require an immediate intervention of the driver, soft TOs mainly have an informative character.

2.2 OVERVIEW OF FORD ADAS

Traffic Jam Assist could be seen as a combination of Adaptive Cruise Control and Lane Keeping Aid. These existing systems assist the driver in respectively longitudinal and lateral control. Both systems can be used as a warning system or assistance aid, the driver has to activate the systems manually. Therefore, it is not possible that the driver will be surprised by unforeseen intervention of ACC or LKA.

The overview of Ford ADAS should give an indication of Ford's standard and aim in designing ADAS interfaces. This knowledge can be used to create an interface for TJA which fits in with other Ford interfaces.

2.3.1 Adaptive Cruise Control

Adaptive Cruise Control (ACC) is an evolution of the conventional cruise control. The system actively assists the driver in longitudinal control. Like normal cruise control, the system keeps the vehicle at a set speed without the driver having to accelerate or decelerate. In addition, the system reacts to vehicles ahead, making it adaptive. When a vehicle is in range it is detected and the system adapts its speed to maintain the desired following distance. When the lead vehicle is no longer detected, the system accelerates to the desired speed again. Besides, the system will warn the driver when he has to intervene to apply emergency braking to prevent an accident.

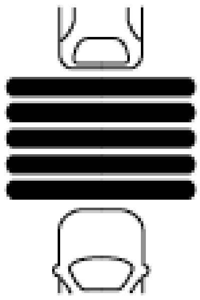

Fig. **2.2**: Interface of ACC displaying the ego vehicle, a lead vehicle and the set following distance.

Fig. **2.3**: The controls of ACC which are placed at the steering wheel.

System Settings

The system is controlled by using steering wheel buttons (Figure 2.3). Besides activating the system or resuming an earlier ACC session, following distance and set speed could be modified. The system is deactivated when the CNCL button or the brake pedal is pressed. In addition, the set speed and gap distance can be overridden by using the accelerator pedal. The system has certain boundaries, the vehicle will maintain a constant distance with the lead vehicle ahead until:

- the vehicle in front of you accelerates to a speed above the set speed
- the vehicle in front of you moves out of your lane or out of view
- the vehicle speed falls below 20 km/h
- a new gap distance is set

System Display & Information Distribution

The system shows a top view of the car when active (Figure 2.2). The lines, perpendicular to the vehicle, represent the set gap. With the UP and DOWN buttons the gap with the lead vehicle can be modified. When a lead vehicle is detected it will illuminate at the display. The system is not able to apply full braking. When the systems' braking level is not sufficient to maintain the desired distance to the vehicle ahead, the system will give an audible warning to the driver to intervene and brake. When the driver overrides the system, the green light of the indicator and the lead vehicle at the display disappear.

2.3.2 Lane Keeping Aid

Lane Keeping Aid (LKA) actively assists the driver in lateral control. LKA retrieves its information from a camera, mounted in front of the rear view mirror. The camera detects lane markings and the vehicle's position on the road. When the vehicle is leaving its lane, the system intervenes by making a steering correction. Subsequently, the driver is warned.

System Settings

The system can be used with three settings: Alert, Aid and Aid & Alert (Figure 2.5). The left-hand cluster display is used to modify the predefined settings of LKA by using the five way steering wheel buttons. The Alert mode will warn the driver when the vehicle is heading out of the lane, the Aid mode will actively react to the situation. The vehicle will correct itself with adjusted steering to keep the vehicle in the lane. A combination is also possible with Aid & Alert.

Fig. **2.4**: The interface of LKA as displayed in the cluster display.

Fig. **2.5**: Three options are available while using LKA.

System Display & Information Distribution

The system is displayed in the left cluster display (of the new Ford Fusion/Mondeo with SYNC Technology) or the central display (between the speed and rpm gauge, Figure 2.4) in other models. A top view car is shown with lining on each side. Everything is grey when the system is active and the interface will not be visible when the system is inactive. Warnings are distributed in multiple ways. The display will show a yellow line at the side of the vehicle when a line would be crossed unintendedly and an auditory warning is given. When the situation becomes critical a direct warning will be given in the form of force feedback through the steering wheel. When the Aid & Alert mode is used the vehicle will correct itself and will simultaneously give the driver a warning through force feedback.

The system can be overridden by the driver when the turn indicator is used. Lining will become green at the displayed interface to indicate that the system 'allows' the driver to change lanes. When the driver changes lanes without using the turn indicator a warning will be displayed and transmitted through audio. This feature contains a certain learning effect. The driver has to use the turn indicator to prevent hearing the annoying sound of LKA each time a lane change is performed. The driver can also customise the settings to his preferences: at what location the warning will be shown and the intensity of force feedback are customisable.

2.3.3 Blind Spot Information System

The Blind Spot Information System (BLIS) informs the driver about other vehicles that surround the car but cannot be seen. The so called 'blind spot' (Figure 2.6) is the area just left or right behind the car. When another vehicle drives in the blind spot it cannot be seen in the mirrors of the driver. Therefore BLIS informs the driver about vehicles in this area.

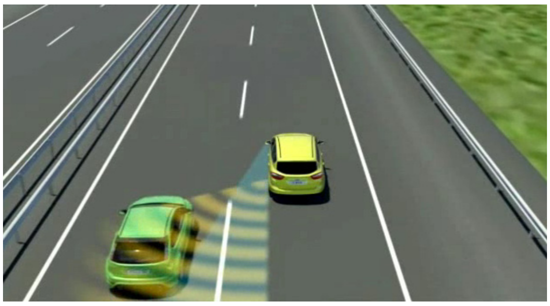

Fig. 2.6: How BLIS functions in practice.

Fig. 2.7: The indicator light of BLIS, implemented in the side mirror.

System Settings & Information Distribution

The system is quite simple and informs the driver with just the needed information, it is either on or off. When a driver decides to pass another vehicle he will (be expected to) take a look in his side mirror. In the corner of the side mirror an indicator light is placed to inform the driver about the blind spot (Figure 2.7). When the light is on a vehicle is driving in the blind spot. BLIS could also be used as Cross Traffic Alert (CTA). The radars detect cross-traffic when the driver backs out of a parking space. The application in CTA transmits two additional warnings. An audible alert is heard in the car and a message center warning is displayed when a vehicle is approaching.

2.3.4 SYNC Technology

SYNC is a technology that should replace separated interfaces and integrate all systems (ADAS, entertainment, navigation, etc.) into one 'command center' (Figure 2.8). Ford describes SYNC as a technology that 'helps you keep your eyes on the road and stay connected to the world' (Ford Motor Company, 2013). The system is split into four divisions: Climate (blue), Entertainment (red), Phone (yellow) and Navigation (green). The central touch screen and the cluster screens are colour based to make it easier to spot different aspects of the menu. The left cluster screen is mainly used for driving related information like fuel efficiency, a vehicle health report and displayed warnings. The right side is meant to show entertainment based information like music but also navigation.

Fig. 2.8: The command center, from which SYNC is controlled with steering wheel buttons, in the cluster display.

Fig. 2.9: The middle console touchscreen used with SYNC.

Command Center
The technology is organised in the so called Command Centre (Figure 2.8). Ford presents the information on the instrument panel. On both sides of the centered speed gauge, 4,2'' customisable displays are placed. Features that can be displayed include fuel usage, a rev counter, phone book and music info. There is also an 8'' display in the central part of the dashboard which is a touch screen (Figure 2.9). The command center is controlled from the steering wheel with five-way control buttons.

SYNC Applink Feature
SYNC AppLink lets you use voice control to connect with your smartphone. This feature could be used while TJA is active. It is likely that drivers pick up their smartphone when TJA is driving the car. Possible TO requests could be shown at the smartphone when occurring, resulting in a extra flow of information distribution.

2.3.5 Traffic Jam Assist: current interface
The current HMI is build upon four conditions. The system indicates whether each condition is met, displayed at the right. The left figure indicates whether TJA is available (Figure 2.10), active (Figure 2.11) or a TO is required (Figure 2.12 and 2.13).

Fig. 2.10: All boundaries are met and TJA is available.

Fig. 2.11: All boundaries are met and TJA is active.

The four conditions are as follows:
- driving lane detected (upper left)
- traffic jam detected (upper right)
- all conditions are met (lower left)
- highway detected (lower right)

Notable is the ambiguity of the icons. The lower left icon represents a state in which all other three icons are positive. So, in fact the icon is needless in this interface.

Fig. 2.12: A soft take over is resquested.

Fig. 2.13: A hard take over is requested.

All four indicators are green when TJA is available. When it is activated the left figure will turn green. Soft and hard TOs are represented by yellow and red overlays which are accompanied by an acoustic signal. A detailed description of TOs is found in Appendix I.

2.3.6 Wrap-up

Ford mostly uses visual information distribution. The described systems use the cluster display to inform the driver about their status.

There is division made between soft and hard warnings. Both warnings make use of audible signals. The driver is made aware that something is happening., but these signals are not the information transfer. The actual information is outside of the vehicle, instead of at the cluster display. Therefore the effect of the audible warnings can be disputed. The use of force feedback (used in LKA) enables a more direct information transfer. The driver receives feedback directly from the object is has to react to, the steering wheel. However, the value of this feature could be questioned. Nowadays it is established by law that the driver should always keep his hands at the steering wheel, but the system should be 'future proof'. Therefore, the possibility to take your hands of the wheel and feet of the pedals should be taken into account. It is very important to maintain a good balance between the way and amount of information transferred and the situation which the driver should be aware of.

When the driver has to intervene he has to know as much about the system to be able react properly. Additional information is not necessary and could even be disturbing in the take over or lead to misinterpretation (Stanton & Young, 2000). Therefore additional information about occurring situations could be handed afterwards, when the driver has the time to analyse it and his adrenaline level (and mental workload) has dropped. It is desirable to make a combination of the existing systems. As described earlier, TJA is in fact a combination of LKA and ACC, an interaction with the other safety systems is conceivable. Considering integration with the central SYNC technology is obvious.

In addition, some extra research in the field of comparable ADAS is perfomed. The results can be found in Appendix II.

2.4 OVERVIEW OF COMPETITIVE ADAS

The competitive interface designs that are described below are used in the generation of new concepts. The overview serves as inspiration for the Traffic Jam Assist interface.

Multiple car manufacturers are currently developing technologies similar to TJA. While most developments are focused on the technical aspect, competitors have shown some of their interface techniques. The interface that accompanies the systems differs significantly throughout the spectrum of brands. The supposed interaction and visualisation of three brands, BMW, Audi and Mercedes, are analysed to inspire the TJA interface process.

2.4.1 BMW - Traffic Jam and Queing Assistant (TJQA)

The system is activated with a button on the steering wheel. Besides the driver can make certain customisations. The desired speed and following distance can be set to the desired values. The system uses both the cluster display and a heads up display (HUD). The information display is drawn up in driver's perspective.

Fig. **2.14**: BMW's TJQA, displayed at both the cluster and a Heads Up Display during automated driving.

The system presents a reference when it is met, the indicators appear stepwise. A road lane which dissapears at the horizon is visualised with a car (when available) at the end. The projected car represents the car in front of the driver, the perpendicular lines indicate the following distance which can be customised just like ACC has this option. Lastly, the system indicates steering can be taken over, with a projection of a steering wheel and arrows linking it with the projected lanes. The interface is displayed at both the cluster display and a Heads Up Display (HUD, Figure 2.14).

2.4.2 Audi - Traffic Assist

The system is identical to Ford's TJA, it uses the same references as requirements for the system to be available. The interesting difference is the developing interface that Audi presented in multiple press releases (writing and video, Audi, 2013). The cluster display prompts that Traffic Assist is available.

Fig. **2.15, 2.16 and 2.17**: Audi's Traffic Assist during active automated driving state, indication of cleared traffic and inactive state in which the display could be used for navigation.

When the driver activates the system (with a button on the steering wheel) the gauges disappear and Traffic Assist uses the entire cluster display. A visualisation of a city is shown, with a driver's perspective view (Figure 2.15). Surrounding traffic will be displayed in this 'city'. When one of the references of the system is not met anymore, the display moves up out of the 'city' with an animation returning to the 'normal display' with conventional speed and rpm gauges (Figure 2.17). The center display prompts a warning that the driver has to take over and an audible warning is given (Figure 2.16). When Traffic Assist is not active the center display is used for other purposes like navigation, in the same style (but now top view) as Traffic Assist (Figure 2.17).

2.4.3 Mercedes - Distronic Plus

Distronic Plus works similar to other systems, but Mercedes designed the system to function up to a speed of 200 km/h. Like Ford, Mercedes also has systems like LKA, ACC and BLIS equipped on production vehicles. The automated system is a combination of Distronic Plus and Steering Assist which is a system comparable to LKA.

Fig. **2.18**: The interface of Distronic Plus, placed in the cluster. The ego vehicle moves relative to the road in this interface.

The interface of Mercedes's system is equal to BMW's driver's perspective except the use of colour. A projection of the driver's vehicle front is shown, from driver's perspective. In front, the lead vehicle is shown and next to the car, the driving lane is visualised (Figure 2.18). The lines are fixed in this view, when the vehicle crosses a line, the projected vehicle on the display is moved to the left or right to indicate the line is crossed. Additionally, the crossed line becomes red. An audible warning is given and the driver receives force feedback from the steering wheel.

In addition, some extra research in the field of comparable ADAS is perfomed. The results can be found in Appendix II.

2.5 OVERVIEW OF DEVELOPMENT PROJECTS

2.5.1 AIDE - Adaptive Integrated Driver-vehicle InterfacE

AIDE is a general European joint effort set up to research HMI issues within large-scale deployment of Advanced Driver Assistance Systems (ADAS). Aim is to design an interface for maximising safety benefits of the new ADAS. AIDE's aim is to generate knowledge and methodologies to develop HMI technologies for safe and efficient integration of ADAS, as well as nomad devices. Main indicators that are studied are the influence upon driver's behaviour of ADAS.

Behavioural Adaptation

Interesting aspect of AIDE according to the TJA interface is the described behavioural adaptation. Behavioural adaptation is covered by multiple definitions; an OECD expert group (AIDE, 1990) defines it as 'those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change'. However, behavioural adaptation could, in general, be described better as the driver's response (either positive, negative or neutral) to a system it is put in touch with. Therefore, it has a significant influence upon the vehicle driver interaction.

The changes in behaviour that occur depend on the type of tasks the system is designed for. In designing the HMI the type of mediation of the system with the driver is essential. Driver's behaviour can be divided in 'description', 'prescription' and 'intervention' (Saad & Villame, 1999). In general this is a division in information about situations, proposed actions of the driver and actions performed by the system. The way the HMI interacts with the driver in certain situations has an effect on the way the driver handles the situation, the behavioural adaptation.

The experiments of AIDE generated interesting results regarding driver's perceptual state. Drivers have quite an amount of trust in information provided by ADAS. For example, the experiment stated that drivers have a regardless trust in Time To Collision information provided by the system, even when this information is purposefully inaccurate en therefore a dangerous miscalculation (Ben-Yaakov et al., 2002; Shinar and Schechtman, 2002). The driver's awareness is significantly lower because the driver accepts his perceptual limitations and trusts TTC warnings. The findings show that driver's reliance on ADAS are analogous to driver's awareness of their perceptual limitations on making accurate distance estimations, independently of their experience. However, information about lateral position is relied upon more by novice drivers because of the learning effect of driving experience in this matter (Taeib-Mainon & Shinar, 2001; Fairclough et al., 1997). Therefore, learning effects of the HMI could be focused on lateral position.

System Perception

Besides, the connection between reliance and perception of vehicle interventions is described. Interventions in the vehicle or driving environment that do not intend to change drivers' motives will have a limited effect in time, due to behavioural adaptation or an unchanged perceived risk (Summala, 1988). Not knowing potential interventions of a system could occur while driving, could influence drivers' behaviour in the opposite of the desired direction. Therefore, it is very important to have communication between vehicle and driver about any intervention and the reason behind it. The driver should be provided with this information to make sure it has no negative effect on the drivers' perception of the system.

Changes at maneuvering level		Changes at strategic level	
		ADAS as a reference tool	*ADAS as a "slave" system*
Unsafe acts under Critical traffic situations	High ↑	• Learning to comply with warnings	• Allocating attention to secondary tasks
	Low	• Learning to make better distance estimations	• Driving to the limit

Fig. **2.19**: Four possible behavioural changes in both strategic and maneuvering level as a result of behavourial adaptation to ADAS.

The way ADAS will be used by drivers should be taken into account, as stated in the AIDE project. At strategic level of system usage a division between users can be made; usage as a 'reference tool' or a 'slave system' could be made as seen in figure 2.19. Inexperienced drivers could use ADAS as a reference tool to support in traffic and let ADAS have a learning effect upon estimations and perception in traffic (Shinar and Schechtman, 2002). In this case, the driver monitors the system. However, using TJA as a 'slave system' is the main aim of the technique; using the system to take over the task of driving in traffic will facilitate the driver with a certain 'freedom' in the car (Hoedemaeker, 1999). In this case interaction is more important to maintain situation awareness while the driver is using the system. Experience in ADAS could lead to more reliance and therefore less Situation Awareness.

In summary, it is important to bear in mind the different types of users. The different levels of perceptual limitations and sources of information (along with driving experience) influence the way TJA is used and the reliance of drivers in the system. This should be taken into account in the way the system interacts with the user.

2.5.2 CityMobil

CityMobil is a research, development and demonstration project that addresses the integration of automated transport systems in the nowadays society. Interesting aspects of CityMobil that are applicable in this project address transitions of control, responding to system failures and usability and guidelines.

Transition in Control

Facilitating transitions between operator and automation controls is a major task of the HMI. Transitions can be divided according to control changes from and to operator and automation. Within Ford systems, the following levels occur: manual, assisted, partial automated and highly automated. Manual is the conventional driving, assisted is comparable with a system like Cruise Control, semi-automated is like ACC and highly automated represents TJA. An abrupt transition from highly automated to manual needs a significant adaptation of both driver and system. A stepwise transition is desirable in this situation. Fundamental questions in classification of transition of control are (CityMobil, 2008):

WHO HAS 'IT'   &   WHO SHOULD GET 'IT'

Transition can either be 'voluntary', the driver takes over at an arbitrary moment, or 'forced', the system cannot handle the situation anymore and operator controls are required.

	Operator (initiator) > Automation	Operator > Automation (initiator)	Automation > Operator (initiator)	Automation (initiator) > Operator
who has 'it'?	Operator	Operator	Automation	Automation
who should get 'it'?	Automation	Automation	Operator	Operator
who initiates transition?	Operator	Automation	Operator	Automation

Fig. **2.20**: A systematic overview of the possible transitions in control between operator and automation.

The 'tool' described in figure 2.20 (CityMobil, 2008) can help in the evaluation of transitions in control and therefore help with take overs. Both operator initiated and automation initiated transitions should be evaluated to make a decent choice in further stages.

Responding to System Failure

The response of the driver to system failures is influenced by many aspects like (above mentioned) transitions in control. It is important that the driver maintains a certain amount of responsibility for the driving task to ensure his position in the driving loop (Martens & van den Beukel, 2013).

To make this possible, task allocation needs to be evaluated. The division of tasks between the automation and operator controls determine a big part of the driver's position in or out of the loop (CityMobil, 2008). In this case, it is desirable to give the driver the opportunity to influence the task allocation and therefore decide where he is positioned in the system. It could be possible that a driver only wants the longitudinal control to be automated leaving lateral control in the hands of the driver.

However, it is critical to adapt the interface to the types and the amount of errors. In this way, the HMI can help to keep the communication between operator and system at an acceptable level and therefore guarantee the operators' trust in the system (CityMobil, 2008). The way errors are presented could also change analogous to the driver's experience. A certain learning effect is possible.

2.5.3 interactIVe

Sequence Interaction

The interactIVe project focused specifically at the HMI of automated vehicles. The support and automation in critical situations is an important aspect. InteractIVe divided the interaction between driver and vehicle in 'sequences'. Dividing warnings in different stages is considered an effective framework in providing the driver with information during a driving situation preceding a potential crash (Richard, Brown & McCallum, 2007). Figure 2.21 shows the division; which sequence is 'active' depends on how critical the situation (and therefore the warning) is. A warning is build up stepwise which recurs in the proposed interfaces.

In the example, a possible Rear End Collision is simulated. Sequence 0 shows the driver information at a secondary visual display which is used to keep the driver aware of the situation. Nothing special is happening, the system still drives the car. Sequence 1 changes both displays. The primary display, only used for warnings, gives information about the situation. The secondary display also changes according to the situation. Force feedback is applied in the accelerator pedal and simultaneously the automation system decelerates the car. In sequence 2 the system becomes critical. In this case the visual warnings reoccur. On top of the signals of sequence 1 the automation system will auto brake and perform an evasive manoeuvre. The secondary visual display shows information about the lane change. In sequence 3 the dangerous situation is passed. All systems are inactive again, except for the secondary display which provides feedback information about the occurred situation.

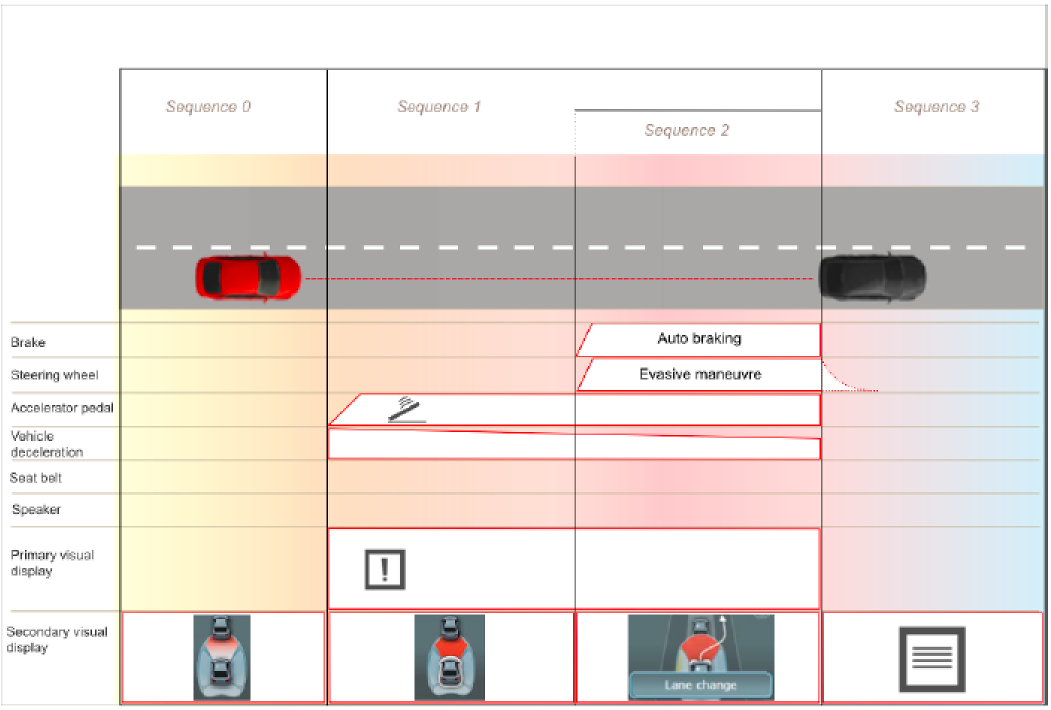

Fig. **2.21**: The sequence of interaction of a possible rear end collision of the interactIVe proposal.

User Assessment of Preliminary Display Concept

Part of the project contained the development of an iterative display. Goal was an exploration of multiple design drafts and setting up the process towards a 'visual language' with common design elements for interactIVe functions in general (Figure 2.22).

Fig. **2.22:** Examples of the displays used for the interactIVe study.

Most striking findings are as follows:

- The shield around the car (indicating different states with different colours) was well received, but the colour white was not recognised as system not available. Hiding the shield would be better.
- The lines alongside the vehicle were perceived as either different lanes of a motorway or lane markings. A more generic display could resolve these problems.
- The realistic bird view gave participants the idea that the actual relative position of the vehicle on the road was displayed, currently the vehicle would drive in the middle lane of a three-lane motorway in this case. However, no amount of lanes on the motorway is detected by the system.

Concluding, the results show that a realistic bird's view in general has a good impact (interactIVe, 2012). The visualisation shows a good connection between display and reality and therefore informs the driver well about, for example, surrounding traffic. However, the amount of information about situations and the boundaries of what information is shown should be more clear to the driver. The shield could also be used as an information distributor for stepwise activation of the system. For example, part of the shield stands for ACC, another part for LKA, etc.

2.6 CONCLUSION

This chapter introduced the purpose of the TJA system. The system is a first step of ADAS implementation in commercial vehicles. Both system and interface are thought through at an exploratory level. The 'to be designed' HMI will facilitate the driver in customising the system and informing the system status to enlarge the understanding and acceptation of the system.

A literature review of current assistance systems is made for Ford, competitors and development projects. Current system interfaces of Ford (and Ford's inonic language, Appendix III) should be taken into account while designing the HMI of TJA. Wit the upcoming SYNC technology, Ford's central command center, an opportunity arises to implement TJA in current systems. The main issue of the systems used nowadays is the complexity of activation. Each system uses a different interface, both in visual information transfer and in activation. The overlap between TJA and already available systems clears the way for a different approach of the 'to be designed' system and interface concept.

The overview of automated driving systems of competitors shows clearly different approaches of the interface. Following the mentioned proposal of joining the different systems in one interface, the competitive interfaces show good inspiration. These perspectives can be used in a decision which perspective/perception fits the system concept best.

An overview of major development projects concerning ADAS is made. The relevant aspects are described. The behavioural adaptation and system perception described in the AIDE project show the importance of taking into account the human reasoning. The different types of users want to use the system in a different way and each user wants to be fulfilled in its desires. The CityMobil project showed the development of transitions in control. The amount of different automation levels a driver (and system) can select greatly influences the oversight. The transition initiator is also important in these automation changes. The driver should be able to clearly distinct who is in control of which system changes. At last, the interactIVe project describes an interface proposal which is developed by collaboration of multiple car manufacturers and research institutes. The results are used as inspiration for the to be designed interface.

3 HUMAN FACTORS PROBLEMS REGARDING AUTOMATED DRIVING

Chapter 3 describes the known human factors problems in development of ADAS concepts. Problems arising from technical aspects of ADAS are described.

With the development of new technologies, problems are likely to arise. The development of Traffic Jam Assist sounds tempting, especially for technical engineers, but: 'there are some human factors considerations that need to be taken into account that will determine the success and failure of the implementation of automated vehicles on our roads' (Martens & van den Beukel, 2013).

The interaction between driver and vehicle influences multiple aspects of TJA and manual driving. A proper function allocation between driver and vehicle should optimise the application of TJA. However, there are also drawbacks related to automated driving which include the following aspects (Kaber & Endsley, 1997):

- reduced ability to observe system changes
- reduced ability to intervene when necessary
- over-trust of the operator in computer control (complacency)
- misinterpretation of the system
- driver loss of situation awareness
- role change of the driver

Nowadays, automation systems are developed with a goal to assist the driver. As Martens and Van den Beukel (2013) describe, so far most developments were focused on technology alone. However, multiple aspects prevent optimal functioning of the system, like the variety of driving situations. Just like other systems TJA works within an operational envelope (see chapter 2) which is not always fulfilled, according to the driving situation. From these boundaries problems arise, starting with the level of automation.

3.1 LEVEL OF AUTOMATION

The level of automation is a unit to determine in which degree a human or machine is in control. The LoA rises when the system automation increases. Intermediate levels of LoA may provide an approach to human-centered automation, automation that is designed and implemented to optimize the role of human in automation (Endsley & Kaber, 1999).

Endsley and Kaber (1999) developed a definition to describe different degrees of automation. The research was focused on the influence of different LoAs on the performance of executing a task, especially after deactivation of the automation. System functions are allocated to human and computer controllers based on capabilities and capacities of each. A division is made in monitoring, generating, selecting and implementing. The definition is specifically aimed at advanced manufacturing, teleoperations and air traffic control and aircraft piloting. When looking at controlling the vehicle and avoiding targets, the supervision of TJA seems similar to supervising a commercial airplane. The highlighted LoAs represent current car driving and the expected LoA for TJA which are relevant for the development of TJA.

	FUNCTIONS			
LEVEL OF AUTOMATION	MONITORING	GENERATING	SELECTING	IMPLEMENTING
1. Manual Control	Human	Human	Human	Human
2. Action Support	Human/Computer	Human	Human	Human/Computer
3. Batch Processing	Human/Computer	Human	Human	Computer
4. Shared Control	Human/Computer	Human/Computer	Human	Human/Computer
5. Decision Support	Human/Computer	Human/Computer	Human	Computer
6. Blended Decision Making	Human/Computer	Human/Computer	Human/Computer	Computer
7. Rigid System	Human/Computer	Computer	Human	Computer
8. Automated Decision Making	Human/Computer	Human/Computer	Computer	Computer
9. Supervisory Control	Human/Computer	Computer	Computer	Computer
10. Full Automation	Computer	Computer	Computer	Computer

Fig. **3.1:** Endsley and Kaber's taxonomy of levels of automation.

While driving a contemporary car:
(2) Action Support - The system assists the driver with performance of the selected action, the driver will take action himself. For example, the driver decides to steer while parking and the system helps performing the action by applying power steering. Monitoring of the system is also done by system and driver, both check variables like speed, rpm and oil pressure.

When TJA is active:
(9) Supervisory Control - The system is in control of generating options, selecting options and carrying out those actions. The driver monitors the system and only intervenes if the system 'askes for help'. When TJA is used, this is the LoA.

The highlighted LoAs show levels which are relevant for TJA. Other levels are not used in current driving for various reasons: completely manual driving is no longer common in the car industry and full automation is a development for the future. Separating levels are not used because decision making is blended in these situations. Either TJA 'decides' what the car does, or the driver does.

However, levels of automation distributing the role of option generation and implementation between human and computer have a significant impact on automated system performance (Kaber & Endsley, 1997). During normal operations, especially LoAs that combine human generation of options with computer implementation result in good performance compared to manual control.

LoAs that provide computer guidance in option selection led to distraction of the operator. New information distracted the operator from task performance and doubts of their own choices occurred. Performance was better when either human or machine selected options, instead of a cooperation between the two. Additionally, the results did not show a lead that practice or experience should have a major effect in this matter.

The LoA affects the relative capabilities of the operator to intervene when an automation failure occurs. A higher level of LoA gives the operator the opportunity to become less involved with the primary task, the driving task, and plan future actions. However, when automation failure occurs, the operator has to step back in this plan. A lower level of direct feedback from the system may be of effect in this case (Kessel & Wickens, 1982). The optimal situation keeps the operator involved in current operations.

Out of the Loop

The level of automation describes automation from a system perspective. The higher the level, the more 'automated' the system is. The consequences of the automation are defined as out of the loop problems. The higher the automation, the more a driver could be 'out of the loop'.

When a driver is actively controlling the vehicle, like during conventional driving, he is 'in the loop'. By driving the car the driver is able to monitor information of both traffic and system and able to recognise dangerous situations and able to respond to them. Falling back on the LoA functions, 'out of the loop' performance means the driver is not directly aware of the traffic situation because the driver is not actively monitoring, not making decisions and not providing input to the driving task (Kienle, et al., 2009).

The level of automation and 'out of the loop' performance are directly related. The more automated a system is functioning, the more a driver is 'out of the loop'. Being 'out of the loop' entails certain problems which are described in detail further on.

3.2 PROBLEMS ARISING FROM OOTL

With drivers being out of the loop (OOTL), it is expected that problems occur. System errors are more difficult to detect and the driver is less capable to respond to them while being OOTL. This leads to:(Endsley & Kiris, 1995; Parasuraman et al., 2000; Saffarian et al., 2012)

- Decreased driver readiness, longer reaction times
- Reduced situation awareness
- Influenced workload (and acceptance)
- Overreliance
- Skill decay
- Behavioural adaptation

These problems are directly or indirectly affected by OOTL performance. Direct influenced matters are described in detail below. Driver readiness is not described in detail, because it is mainly influenced by the driver's physical state. 'Driver readiness can be affected by fatigue or by engagement in non-driving related tasks, but it may also differ between individuals and driving conditions' (Martens & van den Beukel, 2013). Experience with the system (which is taken into account in concept testing in chapter 8) is also of importance; the interface should work for al drivers.

3.2.1 Situation Awareness

One of the aspects which are of influence on the quality of taking over (performed by drivers,) is situation awareness. SA is described as follows:

> *'(An experts) perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projecten of their status in the near future.'* – (Endsley, 1988)

SA could be divided in system and traffic SA. The driver should be aware of surrounding traffic when a TO is required. Besides, vehicle/system SA has to be taken into account. Aspects like speed of the car, but also system status of TJA are a part of this. The interface could fulfill in maintaining SA in both fields.

SA in driving requires reasoning in dynamic, uncertain environments with an overload of information. The driver has to be aware of the situation and extract the relevant information. From here it can be concluded that SA is a very subjective aspect which is heavily influenced by the driver's competence and psychical state. However, driver vehicle interaction influences the SA of drivers. Each system implemented in the car affects the SA. For example, a driver can be fixated on the radio while changing station. His concentration on traffic is hereby reduced. When another human or system is in charge of decision making, human are likely to be less aware of the changes in the environment and system status (Kaber & Endsley, 1999; Endsley, 1996; Endsley & Kiris, 1995; Sarter & Woods, 1995). SA includes awareness of system state as it has influence on what the driver expects of how the vehicle would react in a certain situation, the projection of future state.

The attention of the driver is therefore important. The implementation of TJA gives drivers the opportunity to do other things which leads to distraction. This fixes the attention of the driver inside the vehicle. To maintain an acceptable level of SA, the interface should prevent this from happening and it should provide the driver with relevant information. However, this information is already available outside of the vehicle. Therefore, complex displays (or other information transfer within the vehicle) with an overload of information could have a negative effect on the SA. The system should draw the driver's attention outside of the vehicle while the driver is able to react with the information outside of the vehicle. In situations like a vehicle in the dead angle this could give problems because the driver is unable to see this danger. In this case, the interface should handle with the situation and provide the adequate information.

Being out of the loop could decrease the awareness of traffic and system situation, but there is no causal relationship established. It is possible that a driver is completely out of the loop but taking his monitoring task very serious, resulting in a high situation awareness.

3.2.2 Mental workload and Acceptance

Acceptance of the automation system by the driver is an interesting aspect of TJA. There has to be a certain amount of trust of the driver to make the system and driver work together as a unit. Multiple aspects influence this matter: knowledge and collaboration of the system, trust of the driver in the system, probability of system changes, etc.

An important part of acceptance is the mental workload. While driving automated, the driver has to monitor the system. The more information sources a human has to handle, the higher the workload. An interface with too much information could result in an increased workload. In this case, the higher the automation, the more information is displayed and the higher the workload (Parasuraman & Riley 1997; Wiener, 1988). Modifications of the interface could help decrease the workload while maintaining the amount of displayed information. Highlighting and integration of different information sources results in a lowered mental workload (Wickens, Mavor, Parasuraman & McGee, 1998).

Human tend to link different types of information transfer with different levels of severity of warnings. For example, haptic feedback is perceived as a final warning before a possible crash (van Driel, 2007). Using these associations of severity of information (from low to high severity: visual, auditory and haptic) in an interface design should lower mental workload. It will also be desirable to use as less types of information transfers simultaneously as possible. The less information a driver needs to process, the lower the mental workload could be. Along with increased or decreased workload, the acceptance is affected. A driver often expects ADAS to have a positive safety effect. However, handing over full control of the car to the automation system is not immediately accepted (Hoedemaeker, 1996; Hoedemaeker & Brookhuis, 1998). Therefore, giving the driver the power to affect the LoA and according mental workload will increase acceptance. The interface should help in achieving an acceptable level of workload for each used LoA.

3.2.3 Overreliance and Skill decay

A high level of automation that is not perfectly reliable in executing decision choices, has to be monitored by the driver. However, the more time a driver uses the system without failure, the more likely the driver is relying to much on the system. This could possibly result in a the driver failing to detect automation failure when the system is in fact unable to handle the situation (Wiener, 1981; Parasuraman et al., 1993).

When the automation system is fairly reliable it is possible that the system is consistently performing the driving task. Constantly letting the system perform the active driving task results in skill degradation of the driver (Rose, 1989). This, in combination with other human factors problems, could increase the driver in exhibiting its 'out of the loop' status and therefore its ability to intervene when necessary (Wickens, 1994).

3.2.4 Behavioural Adaptation

The designed automation system could have a big impact upon the driving behaviour of users. Usage of the system could be approached from multiple angles. For example, young drivers could use the system to help them gaining experience in traffic. An inexperienced driver could drive with a lower mental workload when the system takes over (part of) control of the driving task, the system is used as a 'reference tool' (AIDE, 2004). Monitoring traffic could help in gaining experience in perceiving traffic while the system does the driving job. The opposite is usage as a 'slave system' (AIDE, 2004). Busy drivers would want to perform secondary tasks during driving.

Using ADAS results in a significantly changed role of the driver. Instead of actively controlling the car, the driver has to monitor an assistance system. Monitoring a system seems easy, but constantly having to check multiple parameters/indicators could lead to an increased workload (Hancock & Parasuraman, 1992). In order to make each type of user able to use the system properly it is critical to assess what information should be presented and what should be hidden. One could say a division could be made between what the system needs to know and what the driver needs to know. Temporarily switching (part of) vehicle control from automation system to driver should positively affect the ability of the driver to detect automation failures (Parasuraman et al., 1996). From this could be concluded that the driver should be provided with just the right information to take over when a transition in control is required. Besides TO situations, the system should just inform the driver with enough information to make sure in what state the system is so the driver can perform is adapted monitoring task. This should guarantee the driver accepts the system without having trouble with an increased workload or complacency.

3.3 CONCLUSION

This chapter described human factors problems that come along with the implementation of ADAS. Covering these issues is critical in the success of TJA. As the level of automation increases, the 'out of the loop' performance decreases and human factors problems increase. Proper interface design should resolve these issues.

The issues could also be dealt with at a higher level. Making sure the driver can affect the LoA could lead to a driver being less 'out of the loop' and therefore less problems with human factors issues could occur. When the driver is able to influence the amount of automation, he could be more engaged with the system and therefore have a higher situation awareness.

The causal relationship between the LoA and OOTL should be benefited from in designing the interface to make sure human factors problems are minimised, because these problems could lead to reduced driving performance.

4 DESIGN REQUIREMENTS

Chapter 4 describes the transition from analysing to executing the actual design process of the interface. The main goals of the interface are described. General, and driver focus specific, guidelines are used to create a basic list of requirements, at a high level. Besides, a design focus from the human factors issues is described on the basis of the interface goals.

The to be designed interface should help preventing the expected human factors problems. In order to resolve these issues, a set of guidelines is used to correct and improve the interface. With relevant interface principles and driving interface guidelines an overview of design requirements is composed. The principles and guidelines are 'tools' for evaluating the interface proposal.

In addition, the iconic language of Ford is examined so the to be designed TJA interface could 'fit in' with existing Ford systems. See Appendix III for further details about Ford's iconic language.

At a high level, the interface could be defined with a list of goals it should fulfill. The requirements the interface should meet follow on from the interface goals. In general, the interface is defined in the following goals:

- providing adequate information about system status
- help drivers realise and understand system changes
- (indirectly) help drivers to gain acceptance
- help drivers to gain knowledge about system capabilities
- provide information about required driver's role

4.1 GUIDELINES

The interface could be verified using basic heuristics and principles. The guidelines are used as 'tools' to build upon design choices during the concept development and to evaluate the interface afterwards.

4.1.1 Nielsen's Heuristics

Nielsen is an expert in the field of user experience who created a list of Usability Heuristics for User Interface Design. The list of heuristics is used to perform a heuristic evaluation which is a usability engineering method for quick evaluation of a user interface design. A systematic walkthrough of the ten heuristics gives an overview of possible usability problems in the design during the iterative design process. The heuristics are a list of thumb rules describing general points the interface could use like preventing errors, matching the system with the real world and flexibility of use (Nielsen & Molich, 1990). The list of heuristics can be found in Appendix V.1.

4.1.2 Principles of Display Design

Wickens' et al. thirteen principles of display design are utilised to create an effective display design. The principles describe different aspects of human perception and information processing. A proper balance between the principles should result in an effective interface design (Wickens et al., 2004). The principles are divided in perceptual, mental model, memory principles and principles based on attention. Each category contains some principles which are useful in the iterative design process of the TJA interface proposal and are used throughout the concept development. The list of principles of display design can be found in Appendix V.2.

4.1.1 Driver Focus Guidelines

The Auto Alliance Driver Focus Guidelines consist of 24 driver focus principles, divided in five subgroups. The Auto Alliance is an association of 12 vehicle manufacturers. Normally, automotive technology precedes the issuing of rules. The Auto Alliance tries to set guidelines for future technology throughout the whole vehicle manufacturing industry. The Auto Alliance (2006) describe the use of the guidelines as follows: ' The intended application of the Guidelines is to provide criteria and evaluation procedures for use by automotive manufacturers and manufacturers of telematic devices during product development.' A division is made in the following groups: Installation, Information Presentation, Interactions with Display and Controls, System Behaviour and System User Information. Within this project Information Presentation, System Behaviour and System User Information are the most relevant aspects of the guidelines. The guidelines are work in progress and are constantly renewed to keep up the pace of the technological advancing automotive manufacturing world. Each guideline can be verified using the developed verification procedure. In this project the verification will not be went through, the guidelines are purely used for design choices and evaluation.

The list of guidelines can be found in Appendix V.3. During the design process these heuristics, principles and guidelines are used to make design choices and to evaluate the interface proposal afterwards.

4.2 HUMAN FACTORS ISSUES

The problems related to SA, LoA and being out of the loop are mainly influenced by the way the system interacts with the driver and vice versa. The amount of contact that is necessary simply determines the level of SA of the driver that is maintained (Martens and van den Beukel, 2013). The interface should inform the driver about system changes without being annoyingly present. A proper dose of information is needed. Referring to the interface goals, the interface should give the driver a hand in changing system status in order to help him realise and understand system changes. By widening the user control and freedom (Nielsen & Molich, 1990) the driver interacts more to get to know the system. This could result in a higher level of SA while the system is in full control. More knowledge of the system makes it easier for the driver to react to warnings and taking back its place in the loop.

The aspect of user control and freedom is assumed to be important in improving the acceptance of the system. When the user is able to use the automation step by step, at is own pace, the system is easier accepted. Mental workload of monitoring the automation is thereby gradually increased while the workload of the driving task gradually decreases. Besides, the system should minimise usage of errors (Nielsen & Molich, 1990). The way TO requests are presented influence the acceptance significantly. When the user is known with the matter of TOs and their occurrence in the system structure, the driver will understand a TO is a system change instead of an error. The consistency of icon usage and standards in different states also intends to help in a more easily perception of the system by the driver.

The way the system is presented to the driver heavily influences his expectations and therewith his driving behaviour. TJA could be an automation system, but a presentation as e.g. 'personal assistant' clarifies the responsibility of the driver. An active TJA system should not indicate the driver that he is free to do what he likes. The driver should not be focused upon the interface, a fixation of view inside vehicle is not desirable. The interface should hint about emergencies what the driver has to do without trying to mimic reality. The more detailed the interface, the more the driver thinks it visualises the entire real traffic situation. The driver has to be assured he has to oversee the traffic himself and adapt his behaviour to the real situation.

4.3 CONCLUSION

As described, the design requirements result from the composed main goals of the interface. The to be designed interface proposal should fulfill these goals. To make sure the interface is proper designed, the design choices that have to be made during the iterative design process are verified using interface and driver focus principles. The principles are used as 'toolset' in verifying and developing the system and interface concept.

The thought behind the interface goals altogether is 'helping the driver to gain back SA in an accelerated way'. By visualising helpful aspects of TO situations the driver's perception is influenced. Just like verification with principles, the interface goals can help in making design choices and eventually in verifying the final test results in which the thought behind the interface is evaluated.

Other cognitive aspects that could be influence the system and interface design are examined in an additional cognitive research which can be found in Appendix IV.

5 DESIGN APPROACH

Chapter 5 describes the approach of the design process. The chosen approach of both interface and concept development are determined as well as an overview of the iterative process. The chapter builds upon the detailed analysis and (thereon build) requirements in order to create an approach for the executing of the actual concept designing.

As described in the introduction (chapter 1) the designed interface is part of a covering project. The interface could be divided in four aspects:

- Activation
- System Status
- Take Over Request
- 'Feed-after'

5.1 DEVELOPMENT

Interface Development

The different aspects of the interface heavily influence each other with each design choice. The activation handles the physical interaction with the driver. (De)Activation is performed by the driver who interacts with the interface. However, the activation is dependent on the designed system states. Different states require different types of activation. In the same manner, Take Over requests are included in the transitions between different system states and the types of TOs more or less determine the situations that are presented in a Feed-after.

The design focus is aimed at System Status, which is expected to be the main aspect influencing the understanding and acceptation of the system by the driver. Developing an interface which constantly provides the driver with information about the current status of the system leads to more interaction between the system and driver which could lead to a reinforced learning effect.

In designing a system status concept, the covering project is bore in mind. Designing this part of the interface influences the complete picture of the project and therewith the other aspects of the interface. The system status is designed and other aspects are taken into account in design choices.

Concept Development

The process used to develop the interface concept differs from the conventional industrial design process. The interface is based on a system concept, which describes the way the system should work. We allow us to take this freedom, because from Ford's side, the system structure is not completely established yet. Therefore, before starting to develop an interface concept, a system concept is developed.

The system concept represents the different states which the system can be in. The interface concept 'fills the framework' with visualisations of each state. All states together provide a state flow diagram, a complete overview of the system states.

5.2 ITERATIVE PROCESS

The design process is focused upon the human aspect. Design choices and iterations are based upon human examination and the concepts are mainly developed from a user perspective. Multiple iteration steps in both system and interface concept are made in cooperation with experts and test participants. These sessions are used to make iterations of the designed system and interface concept. The design process could be divided in three stages, as mentioned below.

PROTOTYPE	EVALUATION	RESULTS
'Conceptual model' (activation strategy)	Expert review of Ford	System state flow
Concept continuous feedback	Comparison with existing interface Brainstorm sessions Exploratory experiment Design principles	Status indicator designs System state designs User perspective on system
Two interface proposals	Simulator experiment	Design focus proposal for further research

Fig. **5.1:** An overview of the taken iteration steps , with the prototype, evaluation and results, during the design process.

The ‘conceptual model’ is described in the next chapter, the system concept. The build up of the system is defined and visualised at a basic level. At Ford Technology an expert review is held to verify the conceptual model. The design team that is developing the technical part of TJA at Ford gave his opinion on the proposed activation strategy. From the results a system state flow is defined and results are used in further detailing of the visual aspect of the interface. The results of the conceptual model are described in chapter 6.

From a defined system state flow, a complete concept of continuous feedback is designed. All states are visualised and a ‘visual build up’ of the interface is made. The proposed design is evaluated in multiple brainstorm sessions with Arie Paul van den Beukel who acted as mediator for Ford during the project. Besides, the existing interface (and those of competitors and development projects) and earlier mentioned design principles are used to evaluate the concept. The user’s perspective was derived from the results of an exploratory simulator experiment. Together with the input from the brainstorm sessions and comparisons, results are used to create an overview of the user’s perspective and associated interface design consequences. The results of the continuous feedback concept are described in chapter 7.

The results of the exploratory experiment are used to design two interface proposals, each from a different perspective. The different thoughts of participants on a system perspective and the approach of the earlier described development projects are used to create two interface proposals. The proposals are compared in a final simulator experiment which lets the participants actively use and experience the interfaces in realistic traffic situations. The results of the experiment are used to define a design focus for further research. The results of the continuous feedback concept are described in chapter 7 and 8.

5.3 CONCLUSION

The development route of both interface and concept are described. The interface design focuses on providing adequate information about system status. The design process is approached from a human perspective. 'Prototypes' of (part of) the interface are evaluated with human contribution, both from experts and possible participants. The results of each 'prototype' are used in making design iterations.

6 SYSTEM CONCEPT

Chapter 6 describes the design of the system concept, including the development of the proposed activation strategy and the associated system definition. Subsequently the conversion in a System Concept and State Flow is described in detail and validated in practice.

As described in chapter 2, Traffic Jam Assist is one of many driver assistance systems. To prevent an overkill or overlap of assistance, TJA should work together with other assistance systems. The driver could be assisted stepwise. TJA is divided in lateral and longitudinal control.

	LATERAL CONTROL	LONGITUDINAL CONTROL
LoA	LANE DEPARTURE WARNING (LDW)	CRUISE CONTROL (CC)
	LANE KEEPING AID (LKA)	ADAPTIVE CRUISE CONTROL (ACC)
	TRAFFIC JAM ASSIST (TJA)	

6.1 ACTIVATION STRATEGY

The TJA interface mainly facilitates the driver in recognising transitions of who is in charge, driver or automation system. (De)Activation of multiple systems could occur simultaneously and very quickly. Nowadays cars are equipped with loads of assistance and information systems. To make a rough division in these systems the Level of Automation comes into play.

6.1.1 Level of Automation

According to the level of automation (LoA)(Endsley & Kaber, 1999), TJA entails three levels, when the (at the left) mentioned division in subsystems and directions is made (Figure 6.1). Level 2, Action Support, is the equivalent of informing systems. These systems warn the driver in critical situations, but no interventions are made by the system. Level 4 explains itself, the term Shared Control clarifies a blend of human and automation control. The driver controls the car but in critical situations the system actively supports and intervenes. Level 9, Supervisory Control, describes a situation in which the system is in control of the car while the driver has a monitoring role. An active TJA system is fitted in this LoA. The driver is not actively driving but he is still responsible for the car's behaviour.

	MONITORING	GENERATING	SELECTING	IMPLEMENTING
2. Action Support (INFORMING)	Human / Computer	Human	Human	Human / Computer
4. Shared Control (ASSISTING)	Human / Computer	Human / Computer	Human	Human / Computer
9. Supervisory Control (TAKE OVER)	Human / Computer	Computer	Computer	Computer

Fig. **6.1:** An overview of the relevant levels of automation, derived from the taxonomy of Endsley and Kaber (1999).

6.1.2 Overview of assistance systems

The large amount of assistance systems of a contemporary car forces the driver to gain knowledge about multiple systems. Experiencing the possibilities, limits and overlap of the different systems is required to shape a clear picture of the choices a driver has in different situations. It would be too simple to say TJA is a standalone system within a contemporary car. An overview of other systems and their boundaries could help in determining systems with which TJA 'comes into contact'.

Based on the derived LoAs a division in three system levels is made: Inform, Assist and Take Over. These levels could be used to structure the overview of existing assistance systems with which nowadays Ford's luxury cars are equipped. The currently used systems are shown in figure 6.2 and 6.3, mapping out the assistance systems in LoA related with the speed or type of road at which they could be used.

It is clear that there is a significant amount of overlap between the different systems. This could be very confusing for the driver. Somehow an indication (indicator light, auditory signal, etc) of activity of the system should be presented to the driver which leads to a lot of information when each system communicates separately from another. As seen in figure 6.3 there is a clear distinction in the area where the systems are used. Parking assist systems are completely separated from main road assistance systems. TJA is limited to a motorway in contrast to other assistance and warning systems which are separated in parking specific systems and main road systems.

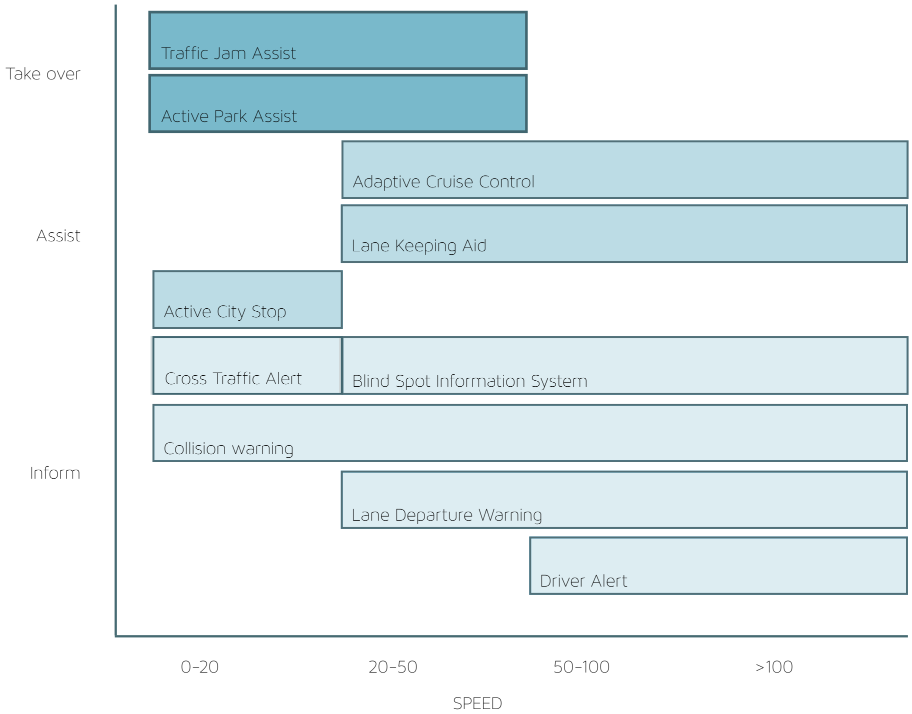

Fig. **6.2:** An overview of assistance systems in accordance to the level of automation and speed.

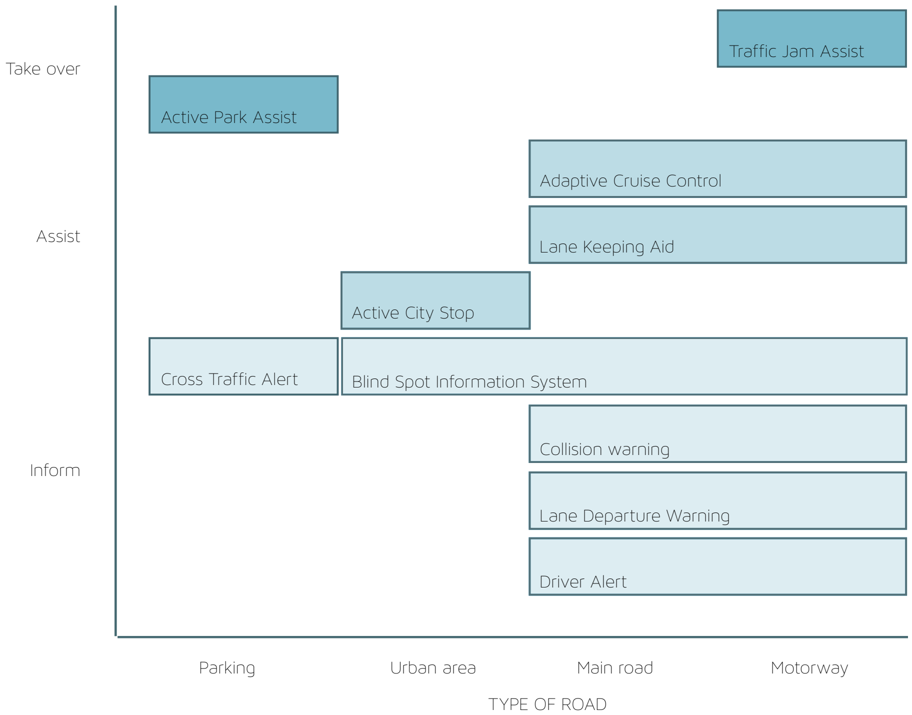

Fig. **6.3:** An overview of assistance systems in accordance to the level of automation and type of road.

This leads to possibilities in switching between the different systems. Some boundaries of TJA, both technical and system related, are related to the road type, a motorway. Currently the system would switch off when one of these boundaries is not met. However, switching to a provincial highway could lead to a transition between TJA and assistance systems like ACC or LKA. A switch to the urban area could lead to a transition between TJA and informing systems like BLIS and CW (Ford technology, 2013).

A selection of scenarios shows these possibilities. An visual description of the situations could be found in Appendix VII. Besides the limitations of motorways, TJA's system status is influenced by speed, lane and lead vehicle detection and possible threats (see chapter 2 for a detailed description). These situations could initiate the following transitions between TJA and other assistance systems (Figure 6.4):

SITUATION	TRANSITION IN LOA	SYSTEM ACTIVE AFTERWARDS
End of motorway	Take Over > Assisting	ACC or LKA
Close Cut-In of other vehicle	Take Over > Informing	BLIS and/or CW
Emergency Brake of vehicle in front	Take Over > Informing	BLIS and/or CW
No road lane detected	Take Over > Assisting	ACC
No lead vehicle detected	Take Over > Assisting	ACC or LKA
Speed to high	Take Over > Assisting	ACC or LKA

Fig. **6.4:** Possible take over situations, the related transition in control and its affect upon the system.

These examples mention scenarios in which the system is forced to translate from one system status to another. But taking the conclusions of the analysis into account, this build up could also help in improving the acceptation of TJA (Hoedemaeker, 1996; Hoedemaeker & Brookhuis, 1998). It is plausible (especially bearing in mind older, more experienced drivers) that a driver starts experiencing TJA with badly prejudiced thoughts. Automated driving could be seen as a threat for human control of a car, a great trust in the system is necessary for proper interaction. Therefore it could be desirable for more experienced drivers to build up usage of TJA in steps: first an active warning system before partial and full take over is activated. In these situations the driver should have the possibility to initiate a step back in automation, and therefore a step from e.g. TJA to ACC or LKA, to experience partial take over at first. This thought is inspired by the Flexilibity of efficiency of use heuristic of Molich and Nielsen (1990). The system should be adaptable to each type of driver.

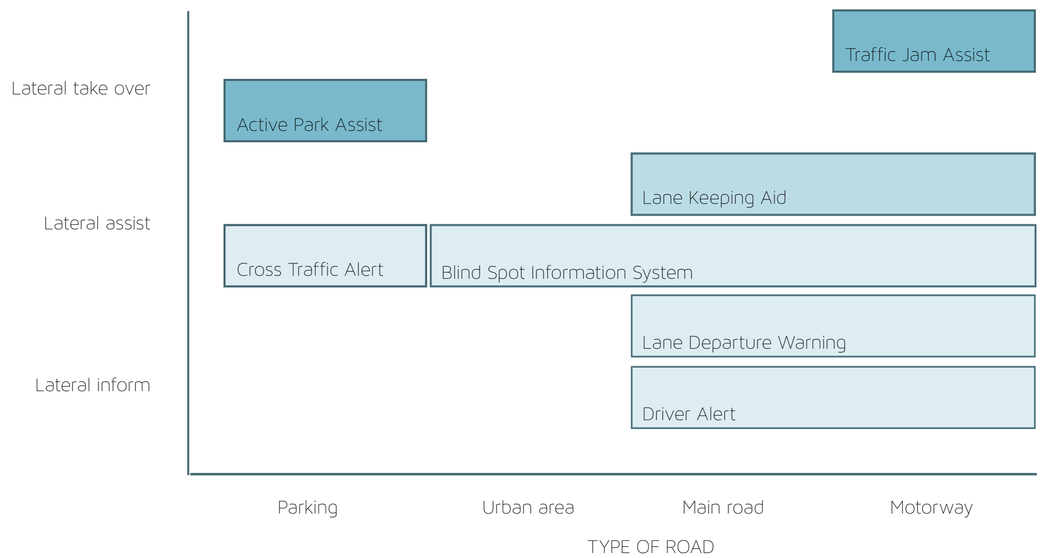

Fig. **6.5:** An overview of assistance systems iwhich function in lateral direction in relation to the road type.

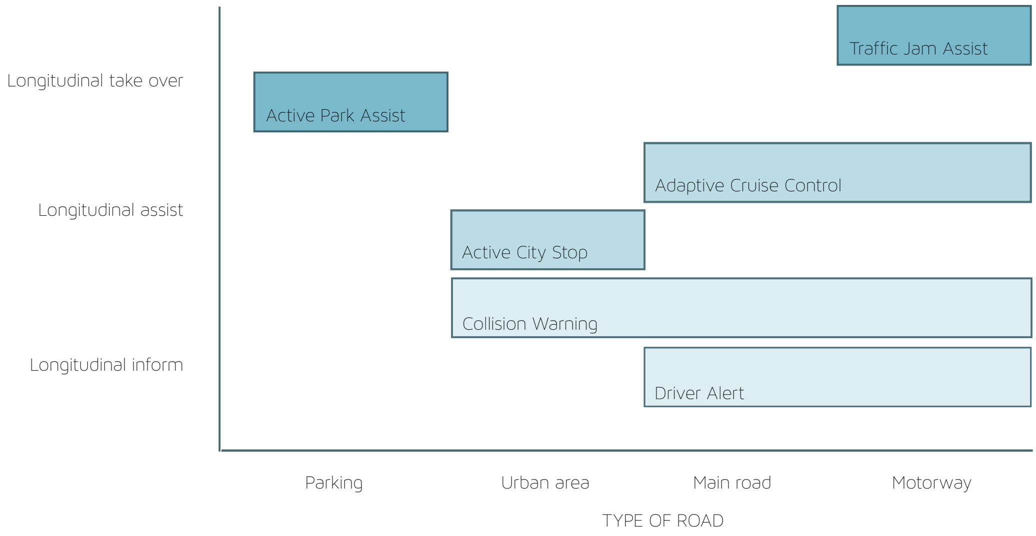

Fig. **6.6:** An overview of assistance systems which function in longitudinal direction in relation to the road type.

Hitching in to the (above stated) fact of partial take over, a division in the automation is already introduced. Comparable systems like ACC and LKA could be seen as representatives of a part of TJA, each in a different 'direction'. ACC assists the driver in longitudinal direction. Simultaneously, it actually handles the longitudinal automation of TJA. For LKA the same situation is applied in lateral direction. This opens up the possibility to implement the different systems into a covering activation system. Figure 6.5 and 6.6 show the overlap that appears between the systems in the different directions. A clear distinction between parking systems and main road systems could be made. A contemporary feature like parking sensors represents the informing system of a covering parking system, while Active Park Assist is the, as its name reveals, intervening assist system. The remaining systems could be present in the covering system intended for main roads.

6.1.3 Overview of system usage

As mentioned earlier, the driver needs to be informed about the status of systems. However, not every system needs to be clearly observed and interacted with by the driver. Most systems which are active in critical situations operate in the background. The driver could only notice a warning or intervention when the system actively intervenes. For example, the Anti Blocking System (ABS) of conventional brakes is activated when the driver brakes heavily in emergency. In fact, a system like ABS or Electronic Stability Program (ESP) could even be activated unnoticed by the driver. The intervention of ABS while braking reduces the risk of the car slipping or having a too long braking distance. The driver just brakes as hard as he can, the extra help of ABS could be noticed or not; it does not change the role and reaction of the driver.

EMERGENCY SYSTEMS	FREQUENTLY USED ASSISTANCE SYSTEMS
ABS/ESP/etc	Traffic Jam Assist
Active City Stop	Adaptive Cruise Control
Blind Spot Information System	Lane Keeping Aid
Collision Warning	Lane Departure Warning
Cross Traffic Alert	Active Park Assist
Driver Alert	

Fig. **6.7:** Assistance systems divided on the basis of their usage.

Therefore, a division in system usage is made in interaction with the driver (Figure 6.7). The left column of the table contains systems which are activated in emergency situations. These systems could support the driver unnoticed (ABS/ESP/etc), could intervene (ACS) or could give the driver a warning (BLIS, CW, CTA and DA). The right column comprehends systems which the driver regularly interacts with. Settings are regularly adjusted and turned on or off.

The systems highlighted in blue are relevant systems for the developed activation strategy. The systems overlap in usage situations, both in time and type of assistance. In fact these systems each represent a step in the derived LoAs. It is clear why systems like ABS and ESP would not be implemented in the system concept. These systems work without the driver's knowledge, notice or interaction, as mentioned before. Active City Stop does its work in the urban area. The destined area for the system concept is a main road, a provincial highway or a motorway.

BLIS is used most at motorways; however, the mentioned usage of the system does not directly stroke with the usage of BLIS. BLIS informs the driver about its dead angle which is mainly meant as a warning for the driver, emerging from danger that arises from the driver's behaviour; a lane change could lead to danger when BLIS is active. The system concept should (in the first instance) inform the driver about danger of other vehicles. LDW and CW inform about other traffic that enters some kind of 'buffer area' around the ego vehicle. CTA is an extension upon BLIS and is not implemented for equal reasons. Driver Alert informs the driver about his own state. This does not stroke with the information about automation and danger of other traffic intervening this automation.

6.2 SYSTEM DEFINITION

The described activation strategy entails a network of system states. Each degree of automation has to be represented by a certain instance of the interface. In fact, the system could be described in different states which are connected with each other, facilitating system status changes. As mentioned earlier, ACC and LKA could be seen as the building blocks of TJA in longitudinal and lateral direction. LDW is in fact the informing/warning version of LKA, CW informs about critical situations in longitudinal direction. These four systems complete a build up in informing, assisting and take over blocks.

6.2.1 System building blocks

FOUR PHASES OF THE SYSTEM: OFF - INFORM - ASSIST - TAKE OVER

The mentioned systems each represent a phase in the system layers. In fact, the system could be off, in Inform mode, in Assist mode or in Take Over mode. Transitions could be both system or driver initiated. The driver himself will be able to initiate a transition which increases the degree of automation. A step back in automation could be initiated by the driver, but the system would also initiate these transitions when system limitations/boundaries or traffic situations require this.

6.2.2 Detection building blocks

FOUR PHASES OF DETECTION: OFF - ACTIVE - POSSIBLE THREAT - MAJOR THREAT

Traffic situations which require these transitions are major threats, both soft and hard take over (TO) requests are covered by this state. Threats could be separated in possible and major threats. A major threat, in this case, represents a situation which the automated system could not handle anymore. During a major threat, the driver is forced to intervene. A possible threat warns the driver for a possible dangerous situation. Traffic changes in a way which could lead to a required TO of the driver. Because it is possible (but not definite) that the driver should intervene, this threat should be communicated in a less urgent and penetrating way than a major threat. When no threats are detected the system is either in active state or turned off.

6.3 CONCEPTUAL MODEL

The system concept is aimed at simplifying the network of assistance systems. From a driver point of view, all these systems have their own possibilities and limitations which are connected to multiple aspects like speed, road type, amount of congestion and other environment related aspects. System clutter is avoided and a an overview of the systems is arranged by focusing the system concept on merging the different systems. As described in the proximity compatibility and minimising information access cost principle, the driver can derive required information about system status from one source without system clutter (Wickens et al., 2004).

As seen in figure 6.8 below, the designed system concept enables activity over the full range of speeds. TJA is, within system boundaries, limited to the range of 0 - 50 km/h. The system concept enables a transition to longitudinal take over or lateral semi-take over. In this situation it is likely that a transition to longitudinal take over takes place. It is possible that the partial take over fails to meet some boundaries for the system. In this case, a step back to the warning state in this direction is a possible transition. In the lateral direction the same options are possible.

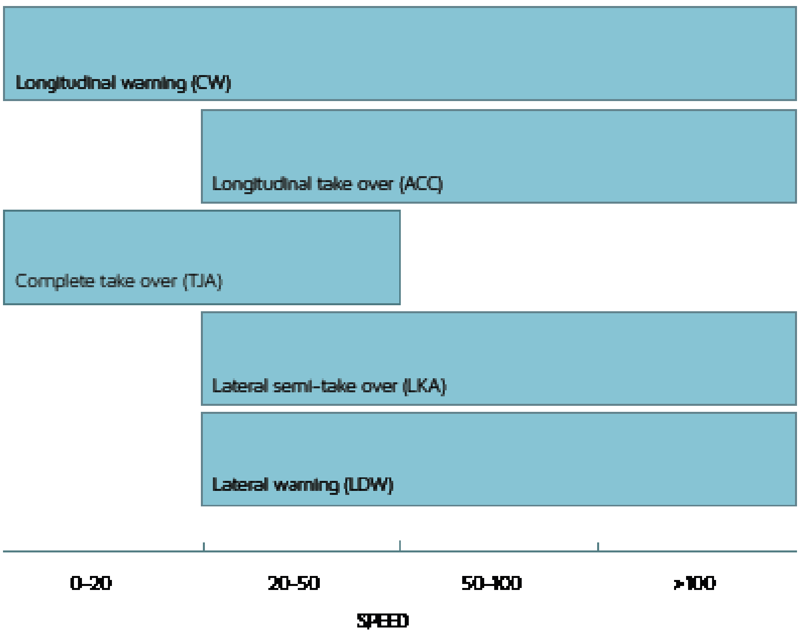

Fig. **6.8:** The proposed system concept, divided in lateral and longitudinal direction.

Main feature of the system concept is the division in two directions, both longitudinal and lateral directions could be active simultaneously but also apart from each other. It is possible that longitudinal warning is active aside lateral semi-automation and vice versa. When one of the directions' states is unavailable, for example when a system boundary is not met, the other directions' states could still be active. The building blocks, which are introduced before, could be perceived from both human and automation point of view.

6.3.1 Automation perspective

From automation perspective, there is a clear distinction of the system in three dimensions: Informing, Assisting and Taking Over. These three automation levels are further divided in longitudinal and lateral direction which results in six states; however, the take over state in both directions results in a merged state which enables complete take over: Traffic Jam Assist. Remaining states are a warning and assist (semi-take over) level in both longitudinal and lateral directions.

6.3.2 Human Perspective

From the driver's point of view the three levels are separated by amount of support. The driver will be supported, either by information of critical situations (in the form of warnings) by intervention in critical situations (active support in car-controlling tasks), or in partial or complete take over of the driving task. The build up in states of the system is the same. However, the states are perceived different. The first state (in both directions) just helps the driver in perceiving traffic situations, the second state takes over a part of driving and should lower the mental workload, because the driver has to perform only one of two (steering and handling the pedals) driving tasks while the third state takes over the driver's complete driving task .
A low mental workload gives the driver the opportunity to drop his active driving task aside. However, the interface concept should ensure the driver stays aware of the situation and his responsibility for the vehicle.

6.3.3 Initiating transitions

Transitions are initiated by the system or the driver. The system could initiate a step back in states. TJA always falls back to longitudinal and lateral warning in critical situations (hard TOs) while soft TOs result in a transition to longitudinal take over and lateral warning. Critical transitions are always a result of emergency traffic situations while soft TO transitions could also be the result of exceeded system boundaries. For example, exceeding 50 km/h forces the system to deactivate TJA and initiate a step back. Human initiated transitions could be both a step forwards or backwards in the automation. The driver has to turn on the system; only the driver is able to initiate transitions which increase in LoA. The driver is also able to initiate these steps back: from take over to assisting, from assisting to informing and from informing to complete deactivation of the system.

6.3.4 System state flow

The system state flow is build up with a rigid path. It is not possible to directly change from a deactivated system to an assisting state, which results in a simplified state flow. Each state, both in direction and degree of automation, could either be active, available or unavailable. The system directions, lateral and longitudinal, could be activated apart from each other so two paths are derived from the state flow. The complete definition and simplification of the system state flow can be found in Appendix VIII, the final state flow is shown at the right (Figure 6.9).

6.4 CONCLUSION

This chapter describes the development of the systematic aspect of an interface design concept for TJA. Building on earlier findings, an Advanced Driver Assistance System wide activation strategy is designed, derived from the overlap of the different ADAS which are already available, like Adaptive Cruise Control and Lane Keeping Aid. ACC and LKA each represent a direction of assistance of TJA and both contain a version which takes a step back from assistance to information transfer, LDW and CC.

From the overview of the different assistance systems Ford uses, a division is made upon LoA, speed and type of road where it is used. Subsequently these systems are divided upon their type of usage. The systems that interact with the driver are included in the system concept. The system is founded upon four phases: Off – Inform – Assist – Take Over. Each phase represents an assistance system which is part of TJA's build up. The concept is divided in longitudinal and lateral direction and the mentioned phases. Warnings and transitions are based upon four phases of detection: Off – Active – Possible threat – Major threat. These transitions could be human or system initiated. The system is unable to increase the LoA while the user could both increase and decrease the LoA. In the next chapter, the defined state flow is used to develop the different 'paths through the system' in a visual way.

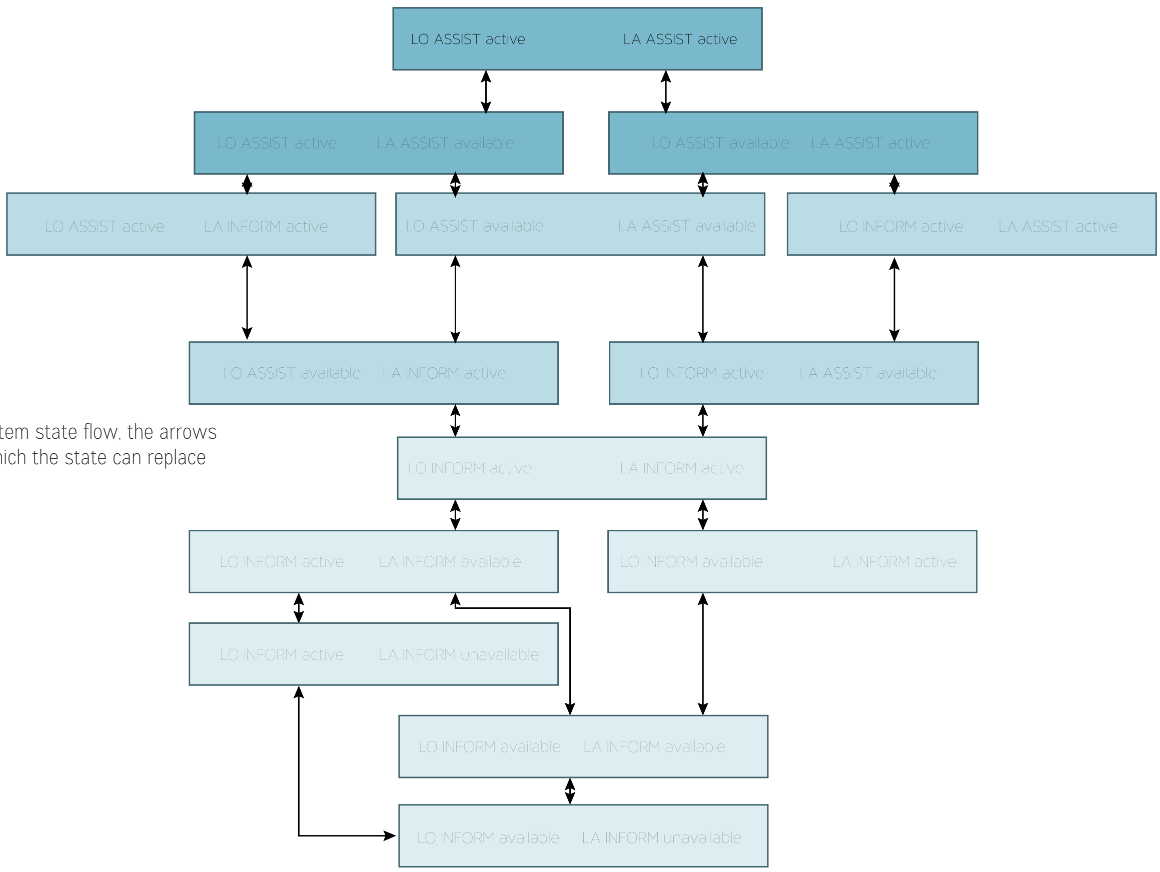

Fig. **6.9:** The simplified system state flow, the arrows indicate the direction in which the state can replace each other.

7 INTERFACE CONCEPT

Chapter 7 builds upon the system concept by presenting the design of the actual interface concept. The chapter includes the manner of interaction between system and driver, concept evolution and the final concept which is divided in two versions, each matching a different perspective of the system.

The interface is meant to enable the interaction between the system and the driver. The interface has to ‘tell’ the driver what he needs to know about the occurring traffic situations and what he needs to know about the system status. Both are integrated in the interface. Main goal of the interface is properly distributing information. The way the information is presented to the driver has a significant share in creating possibilities for the driver to react properly. Clear distinction between visual, auditory and haptic information distribution should be present (van Driel, 2007; Principle of multiple resources, Wickens et al., 2004). The driver’s task of analysing presented information is a lot easier when each type of information distribution has its own objective.

The system cannot function properly without fullfilling the technical and system boundaries. An active TJA system, which competely takes over driving, requires the detection of a road lane in which the vehicle has to drive as well as a lead vehicle to follow. Another important boundary is the occurrence of a highway. In fact, the desire to present these boundaries in the interface could be questioned. The system has to interact its status to the driver, not its boundaries. Therefore, a different approach is made. The interface is build up from the system concept. Main feature of the interface is the division in states, both in longitudinal and lateral direction and Inform, Assist and Take over status. More important objects that the system has to detect are other vehicles which could harm the active automation of the ego vehicle (Principle of pictorial realism, Wickens et al., 2004). Other vehicles entering the ‘clear zone’ of the ego vehicle are detected and the driver is informed about these situations which could lead to a TO request.

7.1 INTERACTIONS

7.1.1 Information Distribution

The information distribution is consciously divided per type of information in order to prevent misinterpretation of the severity of types of information distributors (van Driel, 2007). System status and information about the traffic situation are visually presented. The driver can see his own vehicle (the ego vehicle), a lead vehicle (when available) and traffic on the front or sides of the car when they are possible or major threats. Besides, the active state (system status) is visible. Auditory information is only distributed in situations which require the driver's attention. The auditory signals are presented as a redundancy gain. The signal informs the driver about a possible or definite TO. The necessary information is also visible at the display in order to prevent that the driver has to make absolute judgements (Avoid absolute judgment limits & Principle of multiple resources, Wickens, 2004) . Haptic information distribution is only used for driver input. The driver can change settings with buttons which could be reached without taking a look at their location because of their haptic attributes.

7.1.2 Interface Placement

The interface is placed in the center of the cluster display. The interface is permanently visible so the driver is always able to check the system status (Visibility of System Status, Molich & Nielsen, 1990). Placement in the cluster enables a quick look at both the gauges and system interface when a TO is requested. Another possibility is placement in a Heads Up Display. However, the amount of information which is desired to be displayed and the permanent visibility of the interface could lead to system clutter. A large amount of information projected on the windscreen could lead to misperception of the real traffic situation, because of system clutter, and therefore misinterpretation. A quick glance at the display should provide the driver with enough information (Information Presentation principles, Driver Focus Guidelines, 2006).

The interface shows the driver the system status. In critical TO situations it could be possible the driver is not able to see what exactly happened, for example because the driver was too busy taking over the driving task. The reason of an occurring TO is presented as a 'feed after' upon the center display (Help users recognise, diagnose and recover from errors, Molich &Nielsen, 1990). The display is normally used for entertainment so it is likely that the driver would use this display while driving automated. A small report of a TO situation is logged and could be shown at the display. The placement is visualised in figure 7.1 on the next page.

7.1.3 Driver Input

The steering wheel contains the controls for the system so the driver is able to keep his hands at the wheel while controlling TJA (Principles on Interaction with Displays/Controls, Driver Focus Guidelines, 2006). Here the division in longitudinal and lateral also comes into play. The longitudinal and lateral direction each have an own button for activation. The buttons have two functions: single click results in activation of the Inform state, double click in the Assist state. The buttons also work the other way around. A cycle of states is used. Single click while in Assist state results in deactivation, double click while in Assist state results in a transition to the Inform state. Both functions, Inform and Assist, are written down at the button (as abbreviations INF and ASS) in order to stimulate the learning effect of the buttons. The textual indication should help the driver in recognising the double function of the buttons.

Besides activation buttons, the steering wheel also contains two buttons for the regularly changed settings. Both following distance and desired speed, of importance while longitudinal Assist is active, are frequently changed. The driver could perceive the greatest following distance as very large at low speeds while it could be suitable for high speeds, the driven speed is critical in the perception of the following distance. The desired target speed is adjustable in km/h, the following distance ranges from probably two to eight seconds, in four steps. The button clicks are not time limited. The driver himself can decide at what pace the system is controlled, without the risk that the system menu 'resets' to its standby state because a period of no activity is detected. (Principles on Interaction with Displays/Controls, Driver Focus Guidelines, 2006).

Fig. **7.1:** Placement of the interface in the vehicle. The main system status is shown in the cluster display, 'feed afters' in the middle console display and controls are placed at the steering wheel.

This is a basic description of the interface placement and activation which suits the system concept best (Figure 7.1). Further on, the concept is focused upon the earlier mentioned system status; placement and button activation are not further detailed.

7.1.4 Situation Knowledge

The interface informs the driver about important changes in the situation. However, an overall picture of traffic could help even more in assessing situations. The more knowledge a driver has, the easier overtaking will be when the situations demands it. The interface shows the driver indications of possible threats as well as major threats. Besides, the presence of a lead vehicle is displayed, the interface shows these elements similar to the real presentation and placement of the objects on the road. (Knowledge in the world, Wickens, 2004; Match between system and the real world, Molich & Nielsen, 1990). The interface is focused on a minimal amount of information. When an object is not potentially dangerous it is not necessary to display it (Aesthetic and minimalist design, Molich & Nielsen, 1990).

7.1.5 Take over Knowledge

As mentioned above, in critical situations the driver is informed with just the necessary information to take over. The interface shows the changes in traffic which affect the take over. The direction in which the danger is present is also shown. Indicators below the interface (which are described in detail in chapter 7.3) tell the driver what to do for the requested TO. The indicators show a connection between the real action a drivers has to perform and a visualisation of it at the interface (Match between system and the real world, Molich & Nielsen, 1990).

In addition, the driver could want an explanation of the occurred TO. The center display should facilitate those messages (Figure 7.1). The display's system, normally used for entertainment, contains a report menu which logs data of TOs which the driver could read afterwards when the situations allows it and displays a short message with the reason for take over during a transition (Help users recognise, diagnose and recover from errors, Molich &Nielsen, 1990).

The driver has to be aware of both the traffic and system situation during take overs. The arrangement of elements and their shapes and overall placement in the interface are as close as possible to the real traffic situation to make sure the driver can quickly see what the interface 'tells' him about traffic (Proximity compatibility principle, Wickens, 2004).

7.2 CONCEPT EVOLUTION

Development of the interface has passed through multiple iteration steps. As mentioned in chapter 2, the interface is developed using a human approach. This results in multiple drafts, based on the idea generation which can be found in Appendix VI. The most significant modifications in the design process are described below.

7.2.1 Concept continuous feedback

The first draft introduces a top view of the ego vehicle, in line with other interfaces of Ford like ACC and LKA. The ego vehicle is placed in the center of the display and it will not move from its location. Other elements, like a lead vehicle, move relatively of the ego vehicle (Ford iconic language, 2013; Consistency and standards, Molich & Nielsen, 1990; Principle of consistency, Wickens, 2004). A clear distinction between the Inform and Assist state is visible (Similarity causes confusion: Use discriminable elements, Wickens, 2004). The Inform state is, in both longitudinal and lateral direction, visualised using 'cushions' (Figure 7.3 and 7.4) which represent the buffer around the car. The cushions show the monitoring function of the Inform system.

The Assist state is obviously divided in an longitudinal and lateral indication. The longitudinal Assist is visualised as a 'sonar like' set of bars which is placed between the ego vehicle and a (possible present) lead vehicle (Figure 7.2). There could be one to four bars visible (Ford iconic language, 2013). This goes together with the adjustable following distance. The four bars represent the four gaps the driver could set. The lead vehicle is a car equal to the ego vehicle which is visible in front of the longitudinal assist bars (when the lead vehicle is 'active'). The lateral Assist is visualised using two arrows, which 'fit in between' the road lines, accompanied with a steering wheel icon which is placed on top of the ego vehicle.

When the longitudinal Assist is active, the set target speed is displayed below the ego vehicle. In other states the speed is not displayed because it is only relevant when the longitudinal Assist is available.

Blue is the picked system colour. A consideration between multiple colours made. At first, green is a likely picked colour for safe situations. However, green could indicate the driver that everything is fine and no monitoring is required. Green symbolises health and safety (Morton, 1997). For example, green at a traffic light indicates it is safe to pass the intersection. Blue, a calm colour, would be a better choice. Calm colours are sedate in contrast to warm colours which provoke active feelings (Levy, 1984). Therefore a 'safe situation' is indicated with the main blue colour and dangerous situations are filled with red (a warm colour) elements.

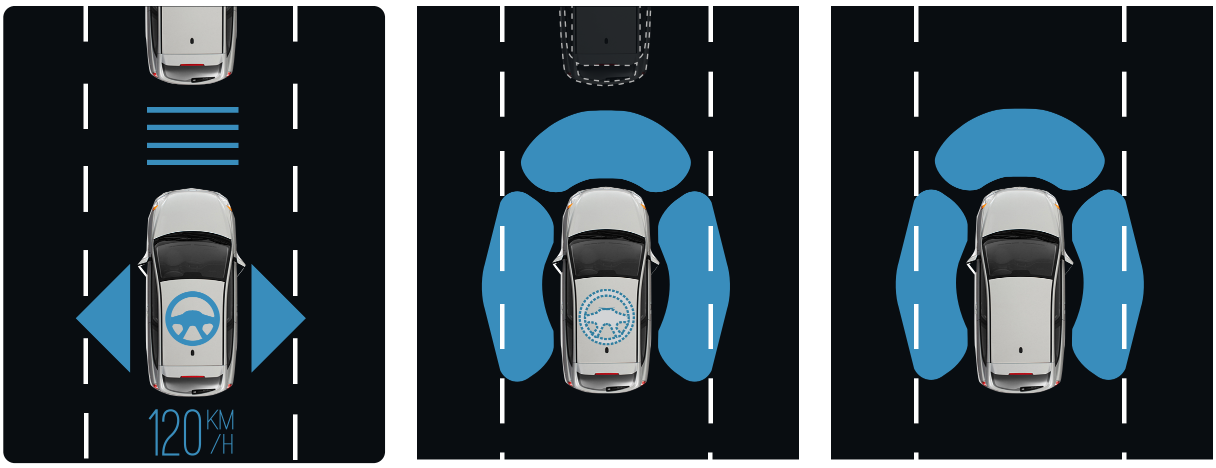

Fig. **7.2, 7.3 and 7.4:** The three basic states of the concept. From left to right, TJA active (Assist in both directions), Inform active plus Assist available (in both directions) and Inform active (in both directions).

The system is in control of (part of or the entire) driving task but the driver is still responsible. A TO request is possible at any time. Blue does not guarantee a completely safe situation, but the perception of an active system is likely. A clear distinction between the severity of situations is made in colours. As expected dangerous situations are displayed in bright red colours in contrast to the calm and blue 'normal' state (Make displays legible & Principle of pictorial realism, Wickens, 2004; Help users recognise errors, Molich & Nielsen, 1990;). Besides the colour changes, differing elements and element changes are used during state transitions of the interface (Redundancy Gain, Wickens, 2004).

The interface is (on purpose) visualised at a generic level according to the real traffic situation. The driver can use the mental proximity of the interface elements (in combination with the traffic situation) to quickly understand a take over situation. However, the interface should not provoke a complete visualisation of traffic. Other vehicles on the road (or relative placement of the ego vehicle on the road) is not visualised. Therefore, the ego vehicle does also not 'move along the road' at the interface. The interface is static in normal (inactive or active) situations.

Availability Indication

The transitions between the different LoAs each contain an available state besides the active state. All available states are visualised by dotted, non-filled versions of the active visualisations. For example, the Inform available state is visualised by dotted outlines of the cushions. The Assist available state is visualised by a dotted outline of respectively the four bars in longitudinal direction and the arrows and steering wheel in lateral direction. The longitudinal assist available state could also be accompanied by a dotted outline version of the lead vehicle, when it is availablehe driver can see what system states he could activate (Principle of predictive aiding, Wickens, 2004). Concerning the lateral states, the detection of road lines is also displayed. The lateral Inform and Assist state are only available when road lines are detected. Failure to detect road lines is visualised by incomplete lines.

7.2.2 Exploratory test results

The continuous feedback concept is evaluated with an expert review at Ford, multiple brainstorm sessions and an exploratory simulator experiment. In short, during the exploratory experiment participants were asked to experience the interface during three trials which are equal to the trials of the final simulator experiment. The trials are described in section 8.2.3. During the experiment the interface changes are simulated using the Wizard of Oz method. The continuous feedback concept is compared with the original Ford interface. The participants do not intervene; the moment a crash would occur the simulation is freezed. Just seeing the traffic and interface changes is part of the experiment. The complete experiment framework can be found in Appendix X. These results are a starting point for the changes, described in the following sections.

The following aspects are results of the experiment. Multiple participants thought the arrows of the lateral Assist state (as seen in figure 7.5, 7.6 and 7.7 on the right) indicated areas which could be used to 'escape' from a dangerous situation. Especially when a red cushion indicated danger on the left (in trial 2: Close Cut-In) and an arrow of the Assist state is visible on the right, the arrow is perceived as escape route.

Besides, some short remarks are of importance:

- The steering wheel on top of the ego vehicle is perceived as an indication of complete take over, in both directions, instead of the lateral direction it really indicates.
- The large amount of information visible at the interface is sometimes too much for the participants; especially in dangerous situations.
- The danger indication is perceived as a 'cushion' that detects danger of others but the possibility that danger of the ego vehicle is visualised is not recognised. This is described in detail in section 7.2.4.
- During the close cut-in (trial 2) the vehicle that inflicted danger crossed into the ego vehicle's road lane, in front of the ego vehicle. Therefore, the participants expected a warning in both the left side and front side area instead of just the left side.
- The target speed of CC and ACC, displayed below the interface, is not recognised. Most participants thought it could only mean their current speed is indicated.
- Disappearing elements of the interface should stand out more. For example, flashing of the elements should make the driver aware that an element is changing. By drawing the driver's attention the change is observed properly.
- At last, the participants prefer more feedback upon their task. They want to be guided in their take over task.

These results are used in the concept evolution, described in the following sections up to the interface that is tested in the final simulator experiment. The mentioned issues are redesigned.

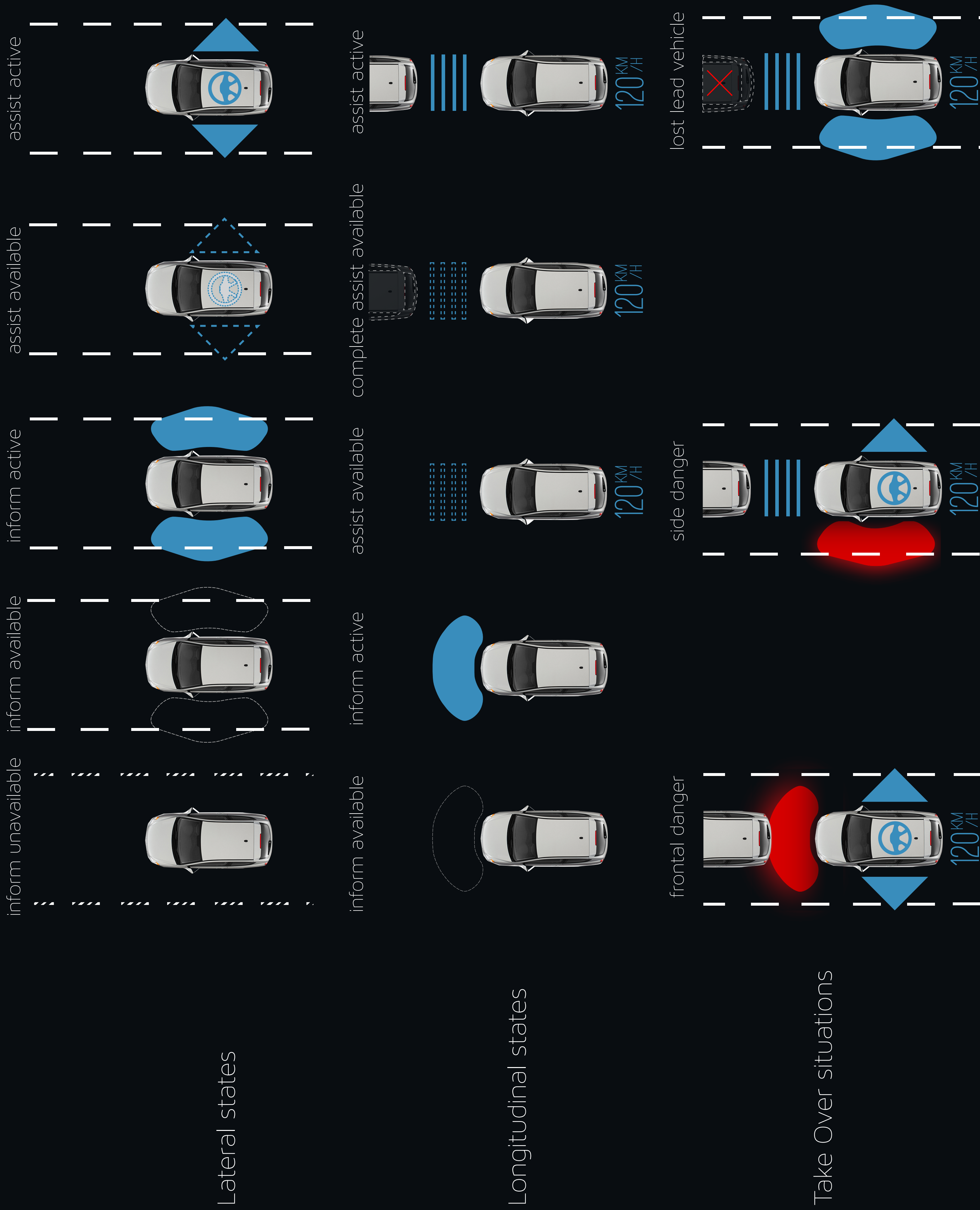

Fig. **7.5, 7.6 & 7.7:** The different states in lateral and longitudinal direction and take over situations.

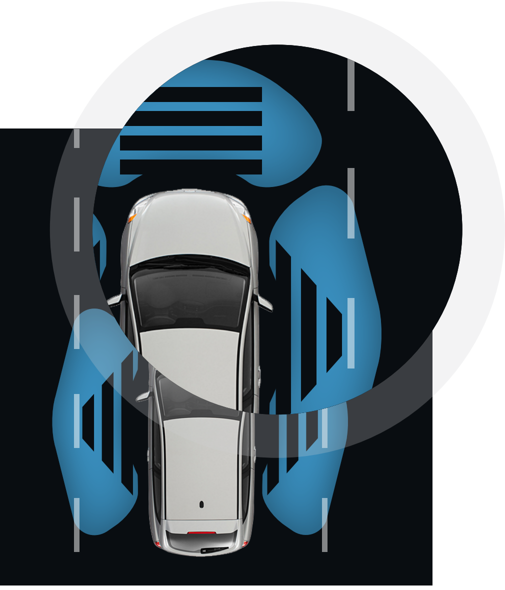

Fig. **7.8:** Assist available during Inform active, a combination of the elements is amde for this state.

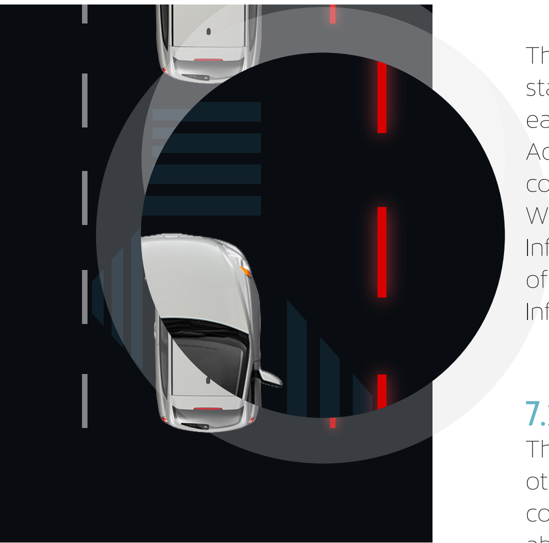

Fig. **7.9:** Selft inflicted danger (possible when the technology fails) is indicated by red road lines.

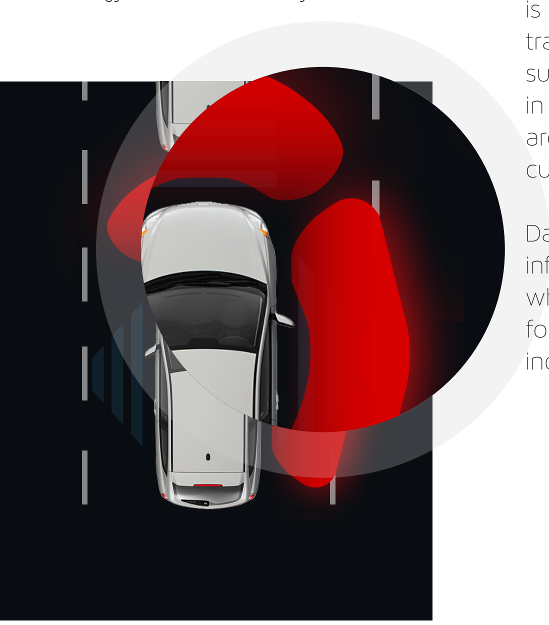

Fig. **7.10:** Danger of other traffic remains displayed by red cushions.

7.2.3 Transitions

The first iteration step is focused on state transitions. The simplification of state flow, described in chapter 6.4, is developed after the expert review of the interface by Ford. Main change that the simplification brought is the rigid manner of activation. The interface is activated in a rigid loop which looks the same in both longitudinal and lateral state. A rigid build up from Inform to Assist back to a deactivated system is used. This means that the system could (while in Inform state) only be deactivated by first activating Assist. However, in critical situations the system could deactivate itself. In this case, the deactivation is not driver initiated (and therefore done with the steering wheel buttons) but automation inititiated.

From this, it can be concluded that the assist available state could only occur while Inform (in the same direction) is active. Therefore, the transition between Inform and Assist states is remodelled because of the overlap it has to cope with.

The rigid loop tells the driver that the Assist state is an extension of the Inform state. After all the Assist state could only be active while Inform is active. For each element, the available state is displayed as a dotted outline version of the Active state of the element. With this consistency it is expected that the driver could predict the implication of the dotted elements (Principle of predictive aiding, Wickens, 2004). Concluding, the design choice is made to combine the states of Inform active and Assist available in a distinctive visual state (Figure 7.8). Results of the exploratory experiment showed it is not clear for the participants that the Inform state is active when only the Assist available state is visible.

7.2.4 Lateral Inform of danger

The lateral cushions have a double function; the cushions indicate danger from other traffic as well as danger from the ego vehicle itself. When another vehicle comes to close to the ego vehicle the cushions light up in bright red informing about a possible threat. Besides, the cushions indicate danger of the ego vehicle leaving its own lane. The exploratory experiment clarified that this double function is not clear to the driver. Therefore lateral danger is divided in danger of other traffic and 'self inflicted' danger, each represented with visualisations that should suit the driver's expectations; a red line is expected to be recognised as danger in crossing the line (Figure 7.9) and the cushions should represent a 'cushion around the car' (Figure 7.10) that indicates about dangers entering the area of the cushions (Knowledge in the world & Top-down processing, Wickens, 2004).

Danger of other traffic is in fact recognised by experiment participants while self inflicted danger is not linked to the cushions. The self inflicted danger only occurs when the system fails to stay within the road lane, because of bad markings or following a lead vehicle that does not stay in its lane, so the lane markings are an indication of the position of the ego vehicle and therefore this state of the system.

7.2.5 Danger highlighting

Analysis of critical situations, in brainstorm sessions and the exploratory experiment, made clear that dangerous situations were not standing out enough. The direction dependent warning makes clear that danger is looming, but the exploratory experiment showed that it is not directly clear to drivers that a TO is requested.

The approach of displaying danger is to draw the attention to the danger. This has to be achieved by minimalising distraction. Therefore, other elements in the interface are hidden or made less conspicuous. (Aesthetic and minimalist design, Molich & Nielsen, 1990; Minimising information access cost, Wickens, 2004). The severity of the situation is emphasised by an extra auditory signal, indicating that the driver has to take look at the interface/traffic situation. (Redundancy Gain & Principle of multiple resources, Wickens, 2004).

Firstly, the displayed set target speed, which misled participants multiple times during the exploratory experiment (see Appendix X for detailed results of the experiment), is pulled loose from the interface. The speed will be integrated in the speedometer.

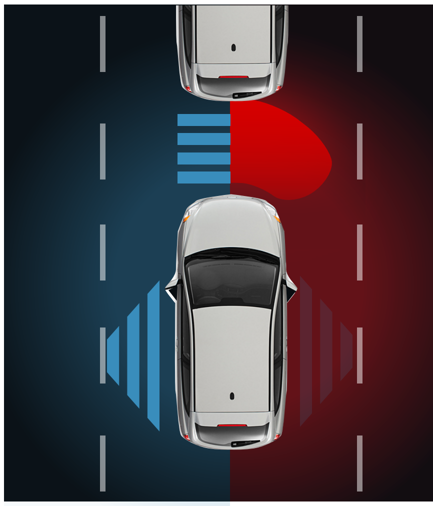

Fig. **7.11:** A blue glare (left) when a situation is 'safe' and a red glare (right) when a dangerous situation occurs to give an extra indication of system status.

Drawing more attention to the requested TO could be achieved in different ways. The overall appearance of danger is visualised by changing the tone of the entire interface, according to the situation. As seen in figure 7.11, a blue and red glare respectively represent a 'safe' and a 'dangerous' situation. As the level of automation increases the blue glare is gradually intensified.

A different approach is the use of flashing elements. Red flashing elements, that indicate the direction and Inform or Assist state in which the danger occurs, draw the driver's attention (Figure 7.12). In this way the danger is displayed at exactly the same place and as the same element (in a different colour/state) which should remind the driver that the danger is related to this highlighted element (Principle of consistency, Wickens, 2004).

At last, the target speed of ACC is not integrated in the final concept. As described in the exploratory test results this speed caused misinterpretation. The speed is not directly part of the interface and therefore left out.

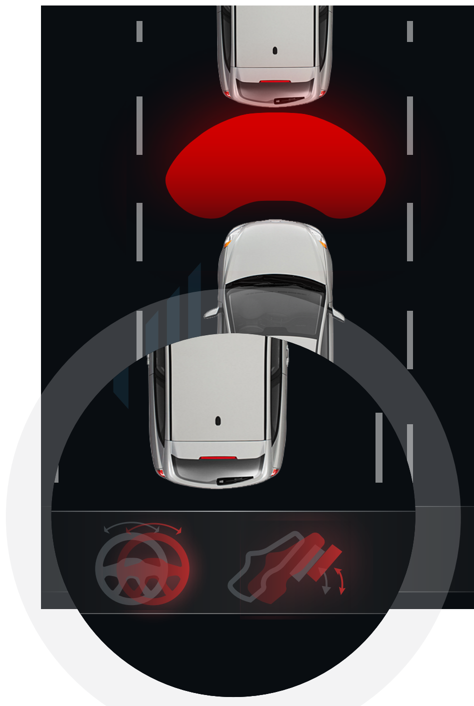

Fig. **7.12:** A visualisation of flashing status indicators. Grey visualises the indicator light when it is off, red indicates a light that is switched on.

7.3 INTERFACE PROPOSALS

The system was initially called an activation strategy, but during the iteration steps it gradually changed into a strategy to provide continuous feedback on system state. (Activation and arrangement issues of physical buttons, etc. are beyond the scope of the project.)

As described before in this chapter the interface is evolved and improved during multiple iteration steps. The main framework of system and interface is already described. The full concept is split in two different proposals in order to test the quality and suitability of the interface. The comparison test is described in detail in chapter 8.

The division is focused on the driver's perception of information about TOs. In critical situations the interface has to inform the driver about a possible TO and the required action of the driver when a TO is definitely requested. The division is made upon the point of view from where the system is approached. From automation perspective it makes sense to inform the driver about the active and available systems. From a driver's point of view, displaying the required activity of the driver could make sense. (Principle of predictive aiding, Wickens, 2004).

A division in two interface concepts from these two perspectives is made for the indicators. The indication of active system states is derived from the actual interface. A separated bar below the interface contains indicators of the system activity. This way the interface is divided from the indicators. The upper area, the actual interface, visualises system status on the basis of the current traffic situation and system boundaries. For example, cushions of an Inform state and lane markings or a lead vehicle are presented. The lower area contains the system indicators.

7.3.1 Automation Perspective

From an automation perspective the system could be active in two directions, longitudinal and lateral. Both directions are divided in an Inform and Assist state. An active Assist state in both directions results in an active automation which corresponds with an active TJA system. The longitudinal and lateral directions are visualised by arrows connected to text bars, in which the concerning active state is described. The automation interface is consciously focused on textual information. The three possible system states are described in words: INFORM, ASSIST and TJA (Figure 7.13, 7.14 and 7.15).

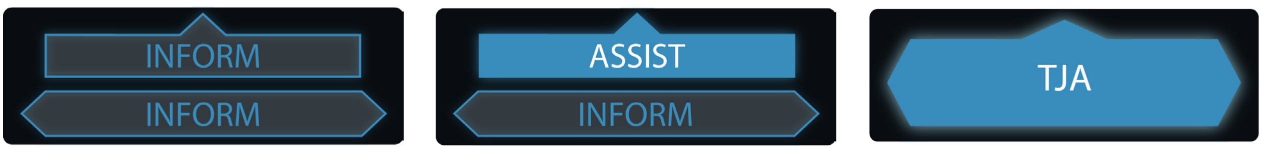

Fig. **7.13, 7.14 and 7.15:** The automation status indicators in Inform state (in both directions), longitudinal Assist plus lateral Inform state and complete take over state.

Building upon the actual interface, the indicators are also coloured in blue. As described earlier blue is perceived as system colour. The amount of blue in the indicators emphasises the active state. The Inform state is visualised by a translucent bar with blue lining and blue text, in Assist state the entire bar is blue. The TJA state combines both the longitudinal and lateral Assist state. The bars are merged into one blue bar. Available states are not displayed in the indicator area. The indicators are used just for the indication of active and inactive parts of the system. Availability is derived from the interface area. Inactive states are visualised by a translucent grey bar. The indicators turn red when a take over is required to make the driver aware of a dangerous situation (Principle of pictorial realism, Wickens, 2004).

7.3.2 Human Perspective

The human perspective is also divided in two parts, according to a driver's expectation of the car controls (Knowledge in the world, Wickens, 2004). A division in using the steering wheel and using the pedals is made. The indicators show which of these basic driving tasks has to be performed by the driver (Figure 7.16, 7.17 and 7.18). A clear distinction between the automation and human perception is made in the type of communication and system colour. The human perspective is based on the usage of icons for transmitting its message while the automation perspective uses text based messages.



Fig. **7.16, 7.17 and 7.18:** The human status indicators in Inform state (in both directions), lateral Assist plus longitudinal Inform state and complete take over state. The steering wheel represents the steering task and the pedal the task of handling the gas and brake pedal.

The human perspective converges with the automation perspective. In similar situations the indicators visualise an opposite state. For example, when TJA is active the human interface will show an inactive steering wheel and pedals while the automation interface shows an active TJA bar. To make a clear distinction between the two human interface does not use a blue colour for the active state. The icons will become bright white when active. On top of the converging matter, this is in line with the 'definition' of blue in the interface. Blue is determined as system colour and an active steering wheel or pedal is in the interface the opposite of an active system. Inactive states are displayed by a translucent grey icon, just like the automation inactive states. The indicators turn red when a take over is required to make the driver aware of a dangerous situation (Principle of pictorial realism, Wickens, 2004).

7.3.3 Final Concept

The division in two proposals with different indicators has led to a couple of changes in the final interface concept. Major change in the full concept is the longitudinal and lateral Assist available state. Originally, the lead vehicle (for longitudinal Assist) and steering wheel on top of the car (for lateral Assist) indicated an active or available Assist state. However, the steering wheel indication at the ego vehicle, representing the lateral available and active Assist state, would conflict with the steering wheel indicator of the human interface and placement in the automation interface is expected to lead to misunderstanding. The similar steering wheels could be exchanged when the driver perceives a system status or they could conflict with each other (Use discriminable elements, Wickens, 2004). The combination of an Inform active and Assist available state, as described in section 7.2.2, is the solution.

Referring back to the highlighting of danger, flashing elements are used for the visualisation of danger instead of a red glare. The indicators stroke excellent with a flashing state in danger, they attract the driver's attention in critical situations so the driver directly sees the indication of what the system does or what he, as driver, has to do. The red (and blue) glare are not used because of the amount of information in the interface. The aim of the interface is minimising the displayed information about the traffic and system situation. When a part of the system is inactive, or at any moment not important, it is faded or less prominent present. For example, the lateral Assist lowers in opacity while danger in longitudinal direction occurs. An occurring red glare during a dangerous situation would give the driver an extra element to assess while the indicators already include enough information for the driver to intervene.

The full final concept is visualised at the following page, in figure 7.19. A complete overview of the final concept and the visualisation of all system states can be found in Appendix IX.

Fig **7.19:** The final concept placed in the 2013 Ford Fusion cluster.

7.4 CONCLUSION

This chapter describes the actual interface concept design. The interactions between driver and vehicle are defined as well as the graphic language. The system uses three different types of information transfer: visual, auditory and haptic signals. Each signal is used for a different type of information: visual signals represent the different system states and displayed TO situations, auditory signals inform about danger in a TO situation and haptic signals are used for activation of the system. Situation knowledge is placed within the cluster display while TO knowledge, including 'feed after' information is displayed at the center display.

As described in chapter 5, the interface is designed with a human approach. The multiple iteration steps, build on human input, are described resulting in a final concept. The concept is always visible showing the current system status. The division in different automation levels and directions recurs in the visual aspects of the interface.

Based on the final concept, two different proposals are developed. A human and automation perception of the system are designed in the form of indicators. The indicators are icons which are placed below the interface, as an addition to the visualisation of the system status. These proposals are tested in comparison in chapter 8. By performing a final driving simulator experiment, within the human approach, it should become clear which of the perspectives suits best for further development.

8 CONCEPT TESTING

Chapter 8 validates the interface concept by describing the major simulator test. This includes a test plan, the simulator build and test results.

The driving simulator test should clarify in which degree the interface proposals fulfill the stated interface goals. The different questionnaires and findings should give an indication of the quality of the interface proposals concerning:

- providing information about system status and system capabilities
- understanding of drivers of system changes and the driver's role
- building up acceptance of the system by the driver

8.1 TEST PLAN

In line with the determined design approach, the final concepts are validated with a driving simulator experiment. The experiment examines the two concepts of continuous feedback system status of TJA, a comparison is made.

8.1.1 Goal

The test is aimed at a comparison of two interfaces types for TJA, with regard to their:

- comprehensiveness
- attractiveness
- contribution in gaining SA and retrieving control

The ease of understanding and clarity of the interface is an important aspect and the test should make clear which of the concepts fits this profile best. Results of the diverse set of measurements should indicate a preference of the participants for one of the interface concepts.

Besides, the test will serve as a pilot within the covering University Research Project (URP). The experiment should indicate major issues in the interface, in the test setup or in the driving simulator which could affect the test results. By testing a small set of participants in this 'pilot' these issues could be rectified before a large scale experiment will be performed in the URP.

8.1.2 Setup

As mentioned before, the test serves as a pilot for a large scale examination of the TJA interface concept. Therefore, the test group exists of ten participants, differing in gender, age and background (five men, five women, age ranging from 20 till 43). All participants have a driving license.

The test is divided in two parts, the two interface concepts are tested apart from each other. The order of testing of the concepts is varied so it has a minimised effect upon the results. The test takes place in the driving simulator, which is described in chapter 8.2. The participant takes place in the simulator and he or she experiences each interface in three different situations. The interface informs the driver about the traffic and system status and therefore informs the driver about possible TOs. The participant will perform a secondary task while TJA is active at the start of each situation. This simulates a situation in which the system controls the car and the driver is able to perform other tasks.

In the described experiment measurements and results the terms first and second interface session are used. These terms stand for the order of execution of the interface tests of the participants. A first interface session means the driver first tested this interface and afterwards the other one.

8.1.3 Measurements

The situations/trials are rigid in time and occurrence, no variation is made in order to minimise external effects at the perception of the different participants. Each participant experiences the same conditions during the test, only the order of testing of interface 1 and 2 is varied to take account for possible learning effects.

<table>
<tr><td colspan="3">Interface session 1</td><td rowspan="4">Questionnaire</td><td colspan="3">Interface session 2</td><td rowspan="4">Questionnaire</td><td rowspan="4">Comparison between interface concept</td></tr>
<tr><td colspan="3">Random order of conditions
EB; CI; CO</td><td colspan="3">Random order of conditions
EB; CI; CO</td></tr>
<tr><td>Trial 1</td><td>Trial 2</td><td>Trial 3</td><td>Trial 1</td><td>Trial 2</td><td>Trial 3</td></tr>
<tr><td>RT</td><td>RT</td><td>RT</td><td>RT</td><td>RT</td><td>RT</td></tr>
</table>

Fig. **8.1:** A schematic overview of the test setup.

The participants are questioned at three different moments. After each trial the participant is asked whether it was clear what the interface displayed with regard to the active driving support. The participant has to choose one of five multiple choice answers. This questionnaire should give an objective indication of the driver's perception of the situation and the recognition of this situation in the interface. The complete experiment is described in figure 8.1

After the attendance of all three trials for one interface, the driver is asked to choose between a set of statements. With the help of a Likert Scale the participant has to choose between statements like helpful and pointless or cautiousness enlarging and sleep inducing. The used scale is divided in five options, for example: very helpful, helpful, neutral, pointless and very pointless. The set of answers for these statements gives an indication of the degree in which the participant thinks the interface is pleasurable, practical, reliable and advanced. An example is shown below, in figure 8.2.

progressive ☐ ☐ ☐ ☐ ☐ conventional

Fig. **8.2:** A example of the options for questionnaire 2.

A comparison between the two interface concepts is made after the participant performed the three trials for both experiments. First, the participant is asked which interface is preferred and which interface the participant thinks the average car driver prefers. Further, for five different aspects a decision between interface 1 and 2 has to be made. The participant has five options: completely matches interface 1, matches interface 1, matches interface 2, completely matches interface 2 or no opinion. The statements are aimed at the differences in displaying system status and driver role. An example is shown below, in figure 8.3.

Clarity of instructions about the role of the driver

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ no opinion

Fig. **8.3:** An example of the options questionnaire 3.

At last, the participant will be asked upon what reasons their answers for the five statements are based. The participant is given the opportunity to make comments about the interfaces, about both general and detailed aspects. The complete questionnaires are found in Appendix XI.

Besides these questionnaires, the driver's reaction time is measured. In each trial the interface will indicate a TO request at a critical moment. The driver is supposed to take over (part of) control of the driving task in these trials. The reaction time is measured, a clear difference between the interfaces (in the same traffic situations) could indicate a 'better' functioning interface concept in relation to the other concept.

8.1.4 Variables

The to be determined, dependent variables in the test are:

- understanding of information distribution
- attractiveness
- clarity of instruction

The different questionnaires should give an indication of these variables for each interface. Questionnaire 1 mainly indicates in which degree the information distribution of the interface is understood. An objective measurement of the understanding is made. Questionnaire 2 gives an indication of the attractiveness, a comparable value for the statements pleasurable, practical, reliable and advanced is measured. This is a subjective measurement. Questionnaire 3 is aimed at both examining the attractiveness and the clarity of instruction by asking the participant which interface he or she prefers.

An independent variable in the experiment is the order of the interfaces during the experiment. A conscious decision is made to vary the order so a possible learning effect during the experiment (influencing the results) is minimised.

The environmental variables are kept unaltered during the experiment. Each participant experiences the same rigid situations/trials. Both traffic simulation and interface simulation are the equal in timeline changes during each trial. The driving simulator is also not changed during the different trials and experiments. Each participant is subject to the same conditions.

8.2 SIMULATOR BUILD

Fig. **8.4:** During the experiment the interface and simulator are constantly monitored. Steering wheel and pedal activity is measured as well as reaction times.

Fig. **8.5:** During the experiment the interface is shown at the dashboard (behind the steering wheel). The middle console is used by the participant to perform a secondary task.

8.2.1 Simulator specifications

The experiment is performed in the driving simulator of the University of Twente.
The simulator consists of a roll cage which is placed in front of a three-part screen. The screen partial encapsulates the roll cage. The front view and a significant part of the side views of the traffic situation are covered by the screen, as seen from the roll cage. The simulation is displayed using three beamers. The roll cage is comparable with the body of a regular car, except the windscreen, doors and a passenger seat are missing. The interior of a car is completely reverse engineered. The driver sits in a bucket seat with the middle console next to him. The virtual car (of the simulation) is controlled by an actual steering wheel and braking and gas pedal. The setup is shown in figure 8.4 and 8.5.

Interesting aspect for the interface experiment is the dashboard. The dashboard is emulated by four displays. The middle console also contains a fifth display.

8.2.2 Traffic simulation

The traffic is simulated by using three rigid trials. The ego vehicle and other traffic are both pre-programmed. The timeline of the trials is always the same so the participants all have to handle a TO request at the same time in the same trial. The times at which a TO occurs is altered per trial so the participants could not react better because they are expecting a TO request based on the amount of time at which the simulation is running. The simulations will freeze when the driver is unable to prevent an accident; in this case the participant has to perform the trial again. When the TO is successful, the simulation plays on for a couple of seconds after the TO.

Trial 1: Emergency Brake

The trial starts while the TJA system, which takes over in both directions, is active. The ego vehicle drives at the right lane. The driver has the opportunity to settle in the situation. After 80 seconds danger occurs. The lead vehicle makes an emergency brake. The hard braking results in a TO request by the system. The driver has to take over steering and the gas/brakes. After the dangerous situation (when the TO was successful) the system warnings fade away and the Inform status of the system is active in both ways. After 4 seconds the Assist status will be available again in both directions.

Trial 2: Close Cut-In

The Close Cut-In is quite similar to the Emergency Brake. The simulation starts while TJA is active. The ego vehicle drives at the right lane. After 60 seconds danger occurs. A vehicle merges in from the left lane and brakes hard (for example to reach an exit that traffic has almost past). The hard braking results in a TO request by the system. The driver has to take over steering and handling gas and brake pedal. After the dangerous situation (when the TO was successful) the system warnings fade away and the Inform status of the system is active in both ways. After 4 seconds the Assist status will be available again in both directions.

Trial 3: Merge Out

The ego vehicle starts the simulation at the left lane while TJA is active. After 70 seconds the lead vehicle merges out to the right lane leaving an (almost) empty lane in front of the driver. The interface requests a TO of steering while the gas and brakes is still controlled by the automation system. The simulation goes on for 10 seconds to give the driver the opportunity to experience the state transition.

8.2.3 Interface simulation

The interface is simulated in the same manner as the traffic simulation; the same timeline is used. The instants at which a transition in the traffic occurs are also used for the timing of the interface transitions. The interface is programmed using Adobe After Effects. Each trial is encapsulated in a movie clip, a visual timeline of each trial is shown at the following page (figure 8.6, 8.7 and 8.8). The test is focused on deactivations which occur as a result of changes in the traffic simulation. Therefore, the interface simulation could also be rigid. It is not effected by the driver. To visualise the simulations on paper, a visual timeline of each trial is presented further ahead.

The trials all follow a similar timeline. After some time a dangerous traffic situation occurs, the driver is requested to take over. Afterwards, danger fades away and the system will display the system status that is active afterwards. The trials differ in running-in time at which the dangerous traffic situation occurs. In trial 1, 2 and 3 the dangerous situation occurs after respectively 80, 60 and 70 seconds.

Placement in the Driving Simulator

The interface concepts are displayed at the middle right display of the driving simulator dashboard. Placement at the display just behind the steering wheel, the usual place for the cluster display, would hamper the view of the driver upon the interface because the steering wheel covers a significant part of the display. This way the driver has the most truthful view upon the interface during the simulations. While driving with TJA activated the driver performs a secondary task. This task, reading the news at www.nu.nl, is performed at the fifth display, in the middle console.

Trial 1: Emegrency Brake

The interface changes as follows during the simulation.

SIMULATION CHANGES	TRANSITION TO STATE
Start	TJA active
Dangerous situation might occur	Direction dependent warnings (inform cushion in longitudinal direction)
Dangerous situation occurs, TO request	Indicators show danger, TO request
Danger fades away	Inform in both directions active

Fig. **8.6:** A visual timeline of the first trial.: Emergency Brake.

Trial 2: Close Cut-In

The interface changes as follows during the simulation.

SIMULATION CHANGES	TRANSITION TO STATE
Start	TJA active
Dangerous situation might occur	Direction dependent warnings (inform cushions in longitudinal and left lateral direction)
Dangerous situation occurs, TO request	Indicators show danger, TO request
Danger fades away	Inform in both directions active
Full system available again	Assist in both directions available

Fig. **8.7:** A visual timeline of the second trial.: Close Cut-In

Trial 3: Cut Out

The interface changes as follows during the simulation.

SIMULATION CHANGES	TRANSITION TO STATE
Start	TJA active
Dangerous situation occurs, TO request	Indicators show danger, TO request
Danger fades away	Assist in longitudinal direction & Inform in lateral direction active

Fig. **8.8:** A visual timeline of the third trial: Cut Out.

8.3 TEST RESULTS

The test results could be interpreted in two groups, objective and subjective measurements. Because of the small group of participants no hard evidence can be found but obvious differences between the interfaces could be changed before the general experiment (performed outside of this project, in the URP) will start.

8.3.1 Objective measurements

The objective results are divided in two categories:

- Understanding of the situation change corresponding with the interface (questionnaire 1)
- Reaction Time (each simulation)

Questionnaire 1

Corresponding to the earlier described goals of the interface, questionnaire 1 describes in which degree the participant realises and understands system status changes. The answers they gave showed if they understood the change from the automated driving state to the state according to the simulated situation. The results are separated per type of situation which results in the following values (Figure 8.9):

first interface session EB	first interface session CI	first interface session CO
60%	30%	10%

second interface session EB	second interface session CI	second interface session CO
80%	60%	40%

Fig. **8.9:** The results of the answers for questionnaire 1, divided in first and second session answers for each trial.

It is clear that the test results indicate a significant learning effect. This is stimulated by the test plan. The participants only knew that they started a simulaton while driving automated and that they were asked top pay attention for the system when an auditory and visual signal was transferred. Multiple participants told that they gained basic knowledge of the interface within the first interface session which they could use in the second session The learning effect is clearly visible in the amount of right answers for questionnaire 1 (Figure 8.10).

first interface session HC	first interface session AC
33,3%	33,3%

second interface session HC	second interface session AC
46,7%	73,3%

Fig. **8.10:** The results of the answers for questionnaire 1, divided in first and second session answers for each interface proposal.

In overall view of the results per interface, the learning effect is also visible. Both interfaces are interpreted better in a second interface session. The automation control is even more than doubled in good answers which indicates that the participants were able to determine the status change better while using the AC interface.

Reaction time

The test results show no clear difference in reaction times (RTs). In both, first and second interface sessions the two interface proposals score equal (Figure 8.11). A distinction between a first and second interface session with the concerning proposal is made in order to detect a possible learning effect. It is likely that a participant was able to react more easily to a situation during a second session because of the knowledge about situations, build up in the first session.

first interface session HC	second interface session HC	
6	6	
		Equal reaction times:
		6
first interface session AC	second interface session AC	
6	6	

Fig. **8.11:** Quickest reaction times for each interface proposal, divided in first and second interface sessions.

Looking at the reaction times per specific trial, there are differences visible. The emergency brake trial resulted in quite equal results per interface proposal. Human and Automation Control were reacted faster upon respectively four and three times. The differences were quite small, varying from 0,70 to 0,10 seconds. For the Close Cut-In trial, the same differences are visible. However, in this trial the AC interface was reacted faster upon five times, the HC interface upon three times. The Cut-Out trial resulted in significantly bigger differences. Faster RTs for the interfaces were: five times HC and four times AC. The maximum difference was four seconds (Figure 8.12).

Emergency Brake:	Faster RT	max difference (s)	min difference (s)	avg difference (s)
Human Control	4	0,40	0,10	0,30
Automation Control	3	0,70	0,10	0,47
Equal	3		average RT:	0,73 s

Close Cut-In:	Faster RT	max difference (s)	min difference (s)	avg difference (s)
Human Control	3	0,70	0,10	0,30
Automation Control	5	0,30	0,10	0,20
Equal	2		average RT:	0,65 s

Cut-Out:	Faster RT	max difference (s)	min difference (s)	avg difference (s)
HC	5	4,00	0,10	1,16
AC	4	2,70	0,20	1,58
Gelijk	1		average RT:	1,74 s

Fig. **8.12:** Quickest reaction times per trial with the measured differences and average reaction time.

According to the average RTs per trial a big difference between EB and CI in relation to CO is noticed. The average human reaction time is 0,215 seconds (Human Benchmark, 2012). This is the reflex of a driver, the difference between these 0,215 seconds and the average RT per trial could be spend on building up awareness of the traffic and system situation. The CO trial needs a lot more time of the driver before intervention.

The used reaction times are derived from situations which participants successfully performed. When a participant failed to prevent a crash, the simulation was started over again. The last reaction time, during a successful take over, is used in order to minimise the influence of a learning effect when the participants performed the same trial for the second interface. The knowledge gained from the earlier trials is in this case equal to the first session, as the participant already knew what was coming during the first session because of starting over when crashed.

8.3.2 Subjective measurements

The subjective results are also divided in two parts:

- Rating of the interface as a whole (questionnaire 2)
- Comparison of the interfaces (questionnaire 3)

Questionnaire 2

After a complete interface session the participants rated the interface by valuing nine statements using a 5-point Likert Scale (Figure 8.13 and 8.14).

Statement / Rating		2	3	4	5	
useful	1	5	0	3	1	useless
pleasurable	0	4	6	0	0	unpleasurable
good	1	5	3	1	0	bad
effective	1	3	2	3	1	unnecessary
nice	3	0	7	0	0	tedious
desirable	1	6	2	1	0	undesirable
pleasant	1	5	4	0	0	unpleasant
helpful	0	5	5	0	0	worthless
wariness enlarging	0	4	4	1	1	sleep inducing
progressive	1	6	3	0	0	conventional
inspiring trust	3	4	2	1	0	inspiring distrust

Fig. **8.13:** The Likert scorecard for all participants for the Human Contol interface.

Statement \ Rating	1	2	3	4	5	
useful	3	3	1	2	1	useless
pleasurable	2	3	4	1	0	unpleasurable
good	2	4	3	1	0	bad
effective	3	2	2	1	2	unnecessary
nice	2	0	7	1	0	tedious
desirable	0	3	5	2	0	undesirable
pleasant	0	4	6	0	0	unpleasant
helpful	2	3	3	2	0	worthless
wariness enlarging	0	4	6	0	0	sleep inducing
progressive	1	4	5	0	0	conventional
inspiring trust	2	5	2	1	0	inspiring distrust

Fig. **8.14:** The Likert scorecard for all participants for the Automation Contol interface.

The values of enjoyable and practical are determined by averaging the ratings for respectively pleasurable, nice, pleasant and desirable and useful, good, effective, helpful and wariness enlarging. The lower the rating, the better the statement is judged.

Statement	Human Control	Automation Control
enjoyable	2,40	2,65
practical	2,72	2,52
progressive	2,20	2,40
inspiring trust	2,10	2,20

Fig. **8.15:** The average ratings derived from the Likert scorecards for both interfaces.

Based on the results of questionnaire 2 the interface build from human perspective scored best. On three of the four statements its score is better (Figure 8.15).

Questionnaire 3

The third questionnaire enquires the participant to make a choice between the two interfaces. First, a personal preference is given, afterwards a perception of the interface which the average driver should prefer.

	Automation Control	Human Control
personal	5	5
average driver	5	5

Fig. **8.16:** The explicit choice for one of the interfaces that all participants made during questionnaire 3.

The explicit choices of the participants give no decisive answer (Figure 8.16). Besides these explicit choices, the participants are enquired to give their preference based on five statements. A neutral choice was not possible.

An overall look at the comparison between the two interfaces shows a little advantage for the human control interface. The HC interface is determined as more clear in displaying the driver role while the system status is valued as slightly more clear at the AC interface. The AC interface is also valued higher in evoking trust in the system. The HC interface is valued much more attractive. The effectiveness of the warning lights (the actual difference between the interfaces) is valued equal (Figure 8.17). One of the possible reasons for this fact is the way the participants used the interface during the critical situations.

Statement							no opinion
Clarity of the instructions about the role of the driver	Automation Control	2	1	1	5	Human Control	1
Clarity of the visualisation of the current system status	Automation Control	2	3	1	3	Human Control	1
Attractiveness of the interface	Automation Control	0	1	6	3	Human Control	0
Degree in which the interface evokes trust in the system	Automation Control	1	3	1	2	Human Control	3
Effectiveness of the 'warning lights' of the system	Automation Control	1	3	4	1	Human Control	1

Fig. **8.17:** The choices for the five statements of questionnaire 3 for which the participants had to make a choice between the two interfaces.

Questionnaire 3 - Discussion

In conclusion, the participants were asked to give their opinion on three open questions:

- What signal triggered you to (partially) take over driving?
- Do you think the status indicators are of added value?
- Which perspective of building up a system like TJA makes sense to you/what do you expect, a human or automation approach? And did this thought influence your preference?

Slightly more participants (six) mentioned that they when they were triggered by the auditory signal, they first took a look at the road and corresponding traffic situation. Four participants first took a look at the red danger cushions at the interface.

Three of the participants thought the status indicators are of added value as addition to the interface. Most important statements are the learning effect it comes with and the clear instructions. When the participant got to know the basics of the interface it was clear what the indicators stand for and especially, how they indicated the driver role in the Human Control interface. Seven participants thought the indicators were not of added value, the red danger cushions were more interesting for them as a warning element. Three of them did not notice the indicators while intervening during the simulation.

Seven participants expected a system build up from human perspective. They thought a user centered design approach was meant to be used; the fact that the driver could quickly see what he has to do was a major contribution in this thought, the instructions are clear and simple. Six participants said their preference for an interface was influenced by their expectations of the build up approach of the interface.

Other Findings

Besides the measured ratings some other findings were made during the experiment, both from observation and participant's remarks. Main remark is the placement of the 'entertainment display'. The secondary task, reading the news, was performed at a screen in the middle console, at the height of the gear-lever. This resulted in a big change of the field of view in TO situations. Three participants commented that placement near the windscreen could improve the perception of situations and reaction times. Contrary, three participants commented about the interface display. Placement 'at the road', with the help of a HUD, would change their behaviour and let them take a glance at the display instead of directly at the road.

Other remarks:

- It could be wisely to take in consideration the influence of previous experiences of drivers with assistance systems, ranging from CC or an automatic gearbox to ACC or LKA.
- An overlay of the interface on top of the entertainment display would remedy the extra change of scope from entertainment display to interface display. Only the change of scope from entertainment display to the actual road is needed.
- Letting the participant practice before the experiment with Stop&Go traffic could enlarge the understanding of the purpose of the system. Now the participant only experiences the extreme situations in which the interface is used while Stop&Go traffic is an essential aspect of TJA.
- Drivers did not recognise the term TJA in the automation interface proposal as an abbreviation of Traffic Jam Assist. Mainly, it was read as the dutch word 'tja'. Therefore the term should be written in full as 'Traffic Jam Assist'.

8.4 CONCLUSION

This chapter describes the execution of the final driving simulator experiment and the corresponding results. The participants were asked to take over driving when necessary and to determine the occurring system status change in three different situations. A comparison between the two interface concepts is made by questioning the participants about their experiences in three different questionnaires.

Overall, the results show a slight preference for the HC interface but the small size of the participants group should be taken into account. Questionnaire 1 shows a significant learning effect for both interfaces. A second interface session resulted in much better scores, mainly for the AC interface. The HC interface results show a small growth while the correct answers for the AC interface are more than doubled. The reaction times show no big differences between the interfaces. Explicit conclusions cannot be made from these results. However, it is noticeable that the CO trial requires significant more reaction time of the participants. It is expected that this was a result of the confusion that the take over situation gave. Making the vehicle accelerate could clarify to the driver that the longitudinal take over is still active.

The total results of questionnaire 2 indicate a preference for HC. AC scores better as practical interface while HC is valued better for enjoyable, progressive and inspiring trust. The last statement is striking because questionnaire 3 shows a preference for AC for evoking trust. However, this measurement could be seen as more subjective, in Q3 the participants were asked to choose between the interfaces while Q2 valued them separately. In comparison, HC is a clear favourite in clarity of the driver's role and attractiveness while the effectiveness of status indicators and clarity of system status is rated more ore less equally. An explicit choice between the interfaces resulted in five votes for both.

Falling back on the main goals of the interface the following conclusions can be made:

- Both interfaces are providing equal adequate information about system status
- AC helps the driver better in realising and understanding system changes
- Both interfaces help gaining acceptance, i.a. by providing the driver to gain knowledge about system capabilities
- HC helps the driver better in recognising information about the required role of the driver

The objective measurements show an indication that AC works better in letting the driver know the system status, while subjective ratings made by the participants indicate a preference for HC. From the ratings it could be said that the participants like the HC interface more and are more likely to use it. But the contradiction indicates more findings and a more clear preference could be measured in further research about the system status. On the basis of understanding system changes a clear choice for AC could be made while, on the basis of understanding the driver's role, a clear choice for HC could be made.

In general, from the test results no premature decisions could be made. It is desirable to further investigate both interfaces. The small experiment showed some indications of related variables that could significantly influence the interface and its performance. For example, according to the participants the placement already played a role in their decisions. It would be wisely to take these variables in consideration in decisions about the two interfaces.

9 CONCLUSION & RECOMMENDATIONS

Chapter 9 concludes with an evaluation of system and interface. Furthermore recommendations for future research and overall conclusions are handled.

The interface is improved multiple times during the design process. The iteration steps that come along with the human approach resulted in multiple evaluations and improvements. After the execution of the final driving simulator experiment, the system and interface could be evaluated. The system and interface are evaluated based on the, in chapter 4, stated design requirements. The system is evolved multiple times based on the design approach as explained in chapter 5. During the development of the two interface proposals the stated guidelines were used in designing. The human factors issues which were important in the design, combined with the test results are used in evaluation. Besides, reflection upon the stated main goals of the interface is made.

In chapter 4, the main goals of the interface are defined. In evaluating the interface, these goals are a lead to determine in what degree the interface fulfills the stated requirements. In general, the interface is defined in the following goals:

- providing adequate information about system status
- help drivers realise and understand system changes
- (indirectly) help drivers to gain acceptance
- help drivers to gain knowledge about system capabilities
- provide information about required driver's role

9.1 SYSTEM EVALUATION

The system concept provides the driver with the option to use part of the system. The user decides at which degree he or the automation system is in control. The concept allows the user to familiarise with the system by trying out different levels of automation and therefore different states of the system. System knowledge could be build up faster because it is driver initiated.; no system initiated forced walkthrough or installation menu is used. The test results show a significant raise in correct interpreted take over situations during the experiment which could indicate the system accelerates gaining system knowledge.

The build up framework of the system also helps in acceptance of the system as can be concluded from the test results. The user could choose for partial take over while getting to know the technology. While building up trust, the level of automation could also be raised. The amount of information a driver has to absorb in these situations is decreased when the system takes over part of the driving task.

The system is build up from the perspective of solutions instead of errors. For example, failure to detect lines results in a degradation in the level of automation which is accompanied by a state transition. Lateral assistance is no longer available in this case. Instead of giving a warning, the system requests a soft take over and offers the user to stay in assistance state in longitudinal direction, combined with lateral inform. As results of the test show, this could be one of the main reasons why the participants accept the system.

The system is presented as an assistance system to the driver, instead of an automation system. The system could take over the driving task, but the driver always stays responsible for the vehicle. The stepwise build up should make sure this matter is clear for the driver. The status indicators show the driver what he has to do or what the system does, according to the different interface proposals. The test shows that participants have a desire to be assisted in their choices in traffic. The Human Control proposal, which 'tells' the driver what to do, is preferred.

9.2 INTERFACE EVALUATION

The test results give an indication that the interface provides adequate information about system status. Especially, the learning effect of the interface stands out. The participants started the test without prescience, they did not get to know what to do or what the system exactly does, before performing the experiment. The learning effect that occured because of this 'lack of guidance' showed a significant raise in correct answers for both interfaces during the second interface session. The correct answers could partial be referred to the participants correctly 'reading' the traffic situation but there is no doubt a learning effect, which should most likely be derived from the interface, is visible.

The measured reaction times were quite short for the traffic situations. As described in chapter 8, human need an average of 0,245 seconds to react with a reflex. The average reaction times of the first two trials, emergency brake and close cut-in which needed a quick reaction, varied around 0,70 seconds. This means the participants needed half a second to decide what to do. It is expected that the interface gave participants an indication of what to do or at least in what direction an intervention was necessary. As stated in the discussions, most participants said they were triggered by the interface in terms of the direction of the danger. The interface clearly indicated system changes and information about a change in the driver's role in this case.

Mainly, the objective measurements of the experiment give an indication of the interface in general, as described above. However, subjective measurements also show some interesting signs. The test questionnaires show that the participants have quite an amount of trust in the system. Especially the Human Control proposal is valued as provoking trust. This shows that the interface is accepted by the participants. The usefulness is also valued significantly good.

Most participants (six) first take a look at the road. However, a quick glance at the interface gave them an idea of the direction in which danger is occurring and intervention is necessary. The placement of the interface is of influence in this case. This subject is further detailed in section 9.3. As indicated in the test results, especially the Human Control proposal clearly provides adequate information about the driver's role. Seven participants stated that the HC proposal was in according with their expectations of the build up of the interface. A 'user centered design approach' was mentioned as substantiating.

However, in discussion seven of the ten participants said they do not think the status indicators have an added value. In intervening during take over situations, they used the direction dependent indications in the interface (the red cushions) to determine where the danger occurred. Further on, their actual intervention was based upon their driving experience and own assessment. The usefulness of the status indicators should be investigated in further research.

According to the Driver Focus guidelines, the interface is properly designed. The system is designed bearing in mind the standards of Ford. Concerning installation, the interface could be placed more closely to field of view of the driver. A Heads-Up Display could guarantee that the driver does not have to take his eyes of the road while looking at the interface.

The distinctive system states, and minimised amount of information per state, make sure the driver could derive the required information for take over or awareness of the system and traffic situation with sequential glances.

In the field of interaction with displays and controls, the concept is not extensively developed (because of the focus upon system status). However, the generated controls make sure that the driver could keep his hands on the steering wheel while controlling Traffic Jam Assist. Besides, the buttons are designed without the need of time limited response; it is not necessary to click through a menu that will disappear after a couple of seconds without activity.

According to system behaviour, the interface continuously informs the driver with information about system status. When one of the system states is active or available the interface is visible.

The system instructions are kept at a simple, direct level. Instructions are given in text (automation interface) or icons (human interface) that describe only the required action of the driver. In automation perspective an extra thinking step is added because the active system status is communicated while the human perspective directly indicates the necessity of the driver handling the steering wheel and gas and brake pedal. At last, the generic top view should make sure the driver does not have unrealistic expectations of what is displayed at the interface. For example, the relative position on the motorway or in the road lane is not visualised.

9.3 FUTURE RESEARCH & RECOMMENDATIONS

As mentioned earlier, this project is part of a covering University Research Project. The (in terms of participants) small experiment is meant to be a 'pilot' for the covering project. The early test results give an indication of possible helpful changes for further research.

The basis of the system concept should be left more or less intact. The system build up was accepted well and most transitions were dealt with well by the participants. However, the test results show that the understanding of the system's capabilities could be improved. The partial loss of automation during the Cut-Out trial (longitudinal Take over is still active while lateral just Inform is active) is taken over correctly but multiple participants also used the throttle afterwards. A possible reason for this failure is the test build up. It was not possible (due to technical reasons) to make the ego vehicle accelerate when the lead vehicle merged out in the trial so the driver did not experience the entire traffic situation as it is desired to be. In fact, the ego vehicle should accelerate to a (set before starting the trial) target speed. The driver's experience of acceleration of the vehicle would prevent confusion about the status of the longitudinal support.

As mentioned in section 9.2, most participants used the interface itself, without the status indicators, in order to take over. It is recommended to take this fact into account in further research. Comparison of an interface with the preferred Human Control proposal and an interface without the status indicators is possible. However, the small differences between the two proposals is not negligible. It is highly recommended to take both proposals into account in further research.

Most participants first took a look at the road before taking over or having a quick glance at the interface. Multiple participants stated that the placement of the interface was of influence in this case. A Heads Up Display could make sure the driver has the opportunity to take a quick look at both the traffic situation and in the interface before a considered decision is made in take over situations. This variable (as well as other environmental variables like ambient sounds and distraction in the vehicle) is worth examining in further research.

In the field of placement, another important remark is derived from the test results. The driver has to change his field of view twice while using the interface. First, a change from the entertainment display (at which the secondary task was displayed) in the middle console to the interface display in the cluster and thereafter from interface display to the real traffic situation. An overlay of the interface (or just the critical part which transfers the warning) upon the entertainment display is a welcome improvement.

Experiment specific recommendations are more detailed. It could be wisely to take in consideration the influence of previous experiences of drivers with assistance systems, ranging from Cruise Control or an automatic gearbox to Adaptive Cruise Control or Lane Keeping Aid. This could influence the way and speed in which a participants picks up the system build up an recognises elements of the interface. Besides, it could be desirable to let the participants practice with the driving simulator and interface in less critical situations. The simulator experiment gave the participants an idea of the boundaries of the system but it would be used significantly more in situations like Stop&Go traffic. Letting the participants practice in Stop&Go traffic before the real test, gives them a more broad idea of the system purpose. Besides, the critical situations they will suffer in the real trials are not revealed in advance in this case.

In measuring the experiment variables, the mental workload is an interesting aspect. While taking over in dangerous situations, in fact the participants have to handle more information because of the interface. Without the interface they would just have to handle the traffic situation. The interface informs the driver about the danger but it is not guaranteed and proved in the experiment that this extra chunk of information makes the decision making easier. Therefore, examining the driver's mental workload during the experiment could help in assessing the contribution of the interface during critical situations. At last, drivers did not recognise the term TJA in the interface an read the dutch word 'tja'. Therefore the term should be written without abbreviation as 'Traffic Jam Assist' in further testing.

9.4 CONCLUSION

This chapter evaluates both system and interface concept. The system concept is evaluated on the basis of the design requirements, stated earlier in the report. The interface is reflected upon using the earlier defined main goals of the interface. Besides, the test results are an important source in evaluating the interface.

At last, further research in the covering University Research Project and recommendations for this future research are described on the basis of the system and interface evaluation and results from the simulator experiment.

X. ABBREVIATIONS AND DEFINITIONS

AC	Automation Control
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
BLIS	Blind Spot Information System
CI	Close Cut In
CO	Cut Out
CTA	Cross Traffic Alert
EB	Emergency Brake
HAD	Highly Automated Driving
HC	Human Control
HMI	Human Machine Interface
HUD	Heads up display
IVIS	Intelligent Vehicle Information System
LKA	Lane Keeping Aid/Alert
LoA	Level of Automation
OOTL	Out-of-the-loop
PO	Primary Object
RT	Reaction Time
SA	Situation Awareness
TJA	Traffic Jam Assist
TO	Take Over
TTC	Time To Collision
URP	University Research Project (between the University of Twente and Ford Technology)

Ego vehicle	The vehicle of the driver, as displayed in the center of the interface.
Interface session	The execution of three trials for one interface in the driving simulator experiment, the order (first or second) of these interface sessions varies per participant.
Lateral	Of or pertaining to width; extending in the direction of the width of an object
Lead vehicle	The vehicle that is followed while longitudinal Assist is active
Level of Automation	A unit to determine in which degree a human or machine is in control. The LoA rises when the system automation increases.
Longitudinal	Of or pertaining to length; extending in the direction of the length of an object
Mental Workload	The amount of information and tasks a driver has to handle at a certain moment
Out-of-the-loop	Not having knowledge of or involvement in something (in this case the driving task)
Reference Tool	Usage of a system by the driver in order to learn to make better estimations or in order to avoid any unwanted effects due to their perceptual limitations.
Road lane	The lane in which the vehicle is driving, part of the motorway. The interface does not visualise the amount of road lanes at the concerning motorway.
Situation Awareness	Perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future
Skill decay	Degradation of skills for a certain task as result of extensive abstention.
Slave System	Usage of a system by the driver while allocating their attention to other in-vehicle tasks or to overcome their own limitations and enjoy the freedom of driving to the limit
Status indicators	The elements that vary per interface proposal. For human perspective the indicators are the steering wheel and pedal visualisation, for automation perspective the bars that indicate the state of Inform, Assist and TJA.
Tell Tales	an indicator, signal, or sign that conveys the status of a situation, mechanism, or system.

X. REFERENCES

1. Papers

Ben-Yaakov, A., Maltz, M. and Shinar, D. (2002) Effects of an in-vehicle avoidance warning system on short- and long-term driving performance. In: Human Factors.

Campbell, J.L., Richard, C., Brown, J.L. and McCallum, M. (2007) Crash Warning System Interfaces: Human Factors Insights and Lessons learned. In: Tech. Rep. NHTSA.

Dorrestijn, S. (2011) Gedragsbeïnvloedende techniek en usability. In: Tijdschrift voor Ergonomie.

Driel, C. van (2007) Driver Support in Congestion: An assesment of user needs and impacts on driver and traffic flow. Enschede.

Endsley, M. (1988) Design and evaluation for situation awareness enhancement. In Proceedings of Human Factors Society.

Endsley, M. (1996) Automation and situation awareness. In: Automation and Human Performance: Theory and Applications. Parasuraman, R. and Mouloua, M. Eds. Mahwah, NJ: Erlbaum.

Endsley, M. R. and Kiris, E. O. (1995) The Out-of-the-Loop Performance Problem and Level of Control in Automation. In: Human Factors.

Fairclough, S.H., May, A.J. and Carter, C. (1997). The effect of time headway feedback on following behaviour. In: Accident analysis and Prevention.

Hancock, P.A. and Parasuraman, R. (1992) Human Factors and safety in the design of Intelligent Vehicle-Highway Systems (IVHS). In: Journal of Safety Research.

Hoedemaeker, M. (1999) Behavioural reactions to advanced cruise control: results of a driving simulator experiment. In: R.E.C.M. van der Heijden & M. Wiethoff (eds.) Automation of car driving – Exploring societal impacts and conditions. Delft University Press, Delft.

Hoedemaeker, M. (1996) Behoeften, rijstijlen en meningen ten aanzien van Automatische Voertuig Besturing (Needs, driving styles and opinions towards Automated Driving). Technical University Delft, Delft, The Netherlands.

Hoedemaeker, M. and Brookhuis, K.A. (1998) Behavioural adaptation to driving with an adaptive cruise control (ACC). In: Transportation Research Part F.

Kaber, D. B. and Endsley, M. R. (1997) Out-of-the-loop performance problems and the use of intermediate levels of automation for improved control system functioning and safety. In Process Safety Progress.

Kaber, D.B. and Endsley, M. R. (1999) Level of automation effects on performance, situation awareness and workload in a dynamic control task. In Ergonomics.

Kessel, C. and Wickens, C. D. (1982) The transfer of failure detection skills between monitoring and controlling dynamic systems. In Human Factors.

Kienle, M., Damböck, D., Kelsch, J., Flemisch, F. & Bengler, K. (2009) Towards an H-Mode for highly automated vehicles: driving with side sticks. In: Proceedings of the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications. Essen, Germany.

Levy, B.I. (1984) Research into the psychological meaning of color. In: American Journal of Art Therapy.

Martens, M.H. and Beukel, A.P. van den (2013) The road to automated driving: dual mode and human factors considerations. University of Twente, Enschede

Nielsen, J. and Molich, R. (1990) Heuristic evaluation of user interfaces. In: Proc. ACM CHI'90 Conf. Seattle.

Parasuraman, R., Sheridan, T. B. and Wickens, C. D. (2000) A Model for Types and Levels of Human Interaction with Automation. In: IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans.

Parasuraman, R., Molloy, R. and Singh, I.L. (1993) Performance consequences of automatin-induced 'complacency'. In: Int. J. Aviation Psychology.

Parasuraman, R. and Riley, V.A. (1997) Humans and automation: Use, misuse, disuse, abuse. In: Human Factors.

Parasuraman, R., Mouloua, M. and Molloy, R. (1996) Effects of adaptive task allocation on monitoring of automated systems. In: Human Factors.

Rose, A.M. (1989) Acquisition and retention of skills. In: Application of Human Performance Models to System Design. G. McMillan Ed., New York: Plenum.

Saad, F. and Villame, T. (1999) Integration of a new driver support system in drivers' activity. In: Safety and Cognition.

Saffarian, M., De Winter, J. C. F. and Happee, R. (2012) Automated Driving: Human-Factors Issues and Design Solutions. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2012.

Sarter, N. and Woods, D. D. (1995) Strong, silent, and out-of-the-loop: Properties of advanced (cockpit) automation and their impact on human-automation interaction. In: Technical Report CSEL 95-TR-01. Cognitive Systems Engineering Laboratory, Ohio State University, Columbus.

Shinar, D. and Schechtman, E. (2002) Headway feedback improves intervehicular distance: a field study. In: Human Factors.

Stanton, N. A. and Young, M. S. (2000) A proposed psychological model of driving automation. In: Theoretical Issues in Ergonomics Science.

Taieb-Maimon, M. and Shinar, D. (2001) Minimum and comfortable driving headways: Reality versus perception. In: Human Factors: The Journal of the Human Factors and Ergonomics Society.

Wickens, C. D. (1992) Engineering Psychology and Human Performance. Harper Collins, New York

Wickens, C.D. (1994) Designing for situation awareness and trust in automation. In: Proc. IFAC Conf. Integrated Systems Engineering. Baden-Baden, Germany.

Wickens, C.D., Mavor, A., Parasuraman, R. and McGee, J. (1998) The Future of Air Traffic Control: Human Operators and Automation. Washington, DC: National Academy Press.

Wiener, E.L. (1981) Complacency: Is the term useful for air safety?. In: Proc. 26th Corporate Aviation Safety Seminar. Denver, CO.

Wiener, E.L. (1988) Cockpit automation. In: Human Factors in Aviation, E.L. Wiener and D. C. Nagel. Eds. New York: Academic.

2. Reports

Rieth P.E. (2010) Contiguard – Continental's Way to Enhance Future Vehicle and Traffic Safety. Helmond, High Tech Automotive Campus

Ford Internal Documents:
TJA Functional Spec, Ford Technology Internal Document, 28-10-2011.
TJA HMI State Diagram, Ford Technology Internal Document, 15-01-2013.

AIDE:
Parameters and indicators of behavourial adaptation to ADAS/IVIS for inclusion in DVE model for preliminary design of AIDE system. deliverable 1.1.3, 1-03-2004.

CityMobil:
Human Factors' aspects in automated and semiautomatic transport systems: State of the art. deliverable 3.2.1, 27-07-2007.

interactIVe:
Accident avoidance by active intervention for intelligent vehicles. deliverable 2.2, 31-07-2012.

Principles of Display Design:
Wickens, C.D. Lee, J.D., Liu, Y. and Gordon Becker, S.E. (2004) An Introduction to Human Factors Engineering. Pearson Education, New Jersey.

Driver Focus Guidelines:
Statement of Principles, Criteria andVerification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems. 26-06-2006.

3. Internet sources

Google Driverless Car, last visited 12-04-2013
http://www.ted.com/talks/sebastian_thrun_google_s_driverless_car.html

Ford Traffic Jam Assist, last visited 12-04-2013
http://media.ford.com/news/
forddevelopstrafficjamassistandnewparkingtechnologytohelpaddressfuturemobilitychallenges.htm

2013 Ford Fusion User Manual, last visited 20-04-2013
http://www.motorcraftservice.com/pubs/content/~WODFSN/~MUS~LEN/42/13fsnom3e.pdf

Adaptive Cruise Control, last visited 28-04-2013
http://www.youtube.com/watch?v=UpUMLsc0xxE
http://media.ford.com/images/10031/Adaptive_Cruise.pdf

Lane Keepig Aid, last visited 28-04-2013
http://www.youtube.com/watch?v=I_mUyQmxJQY
http://media.ford.com/article_display.cfm?article_id=35776
http://media.ford.com/images/10031/Lane_Keeping_Tech.pdf

Blind Spot Information System, last visited 28-04-2013
http://media.ford.com/images/10031/BLIS.pdf

SYNC technology, last visited 28-04-2013
http://www.ford.com/resources/ford/general/innovations/sync/features/command_center/image01.jpg?v=1345516060000
http://www.ford.com/resources/ford/general/innovations/sync/features/navigation/image01.jpg?v=1359436081000
http://media.ford.com/images/10031/Vehicle_Health_Report.pdf

Mercedes technology, last visited 28-04-2013
http://techcenter.mercedes-benz.com/en/distronic_plus_steering_assist/detail.html

BMW technology, last visited 28-04-2013
http://www.bmw.com/com/en/insights/technology/connecteddrive/2010/future_lab/index.html#/2/10
http://www.youtube.com/watch?v=laewq8ZULEk

Audi technology, last visited 28-04-2013
www.youtube.com/watch?v=JnPJse5yYbc

CityMobil Project, last visited 28-04-2013
http://www.citymobil-project.eu/

AIDE Project, last visited 28-04-2013
http://www.aide-eu.org/background.html

Perception and attention, last visited 28-04-2013
http://en.wikipedia.org/wiki/The_Magical_Number_Seven,_Plus_or_Minus_Two

Intelligent car initiative, last visited 28-04-2013
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006DC0059:EN:NOT

Driver Focus Guidelines, last visited 7-7-2013
http://www.autoalliance.org/about-the-alliance/principles

Likert Scale, last visited 7-7-2013
https://en.wikipedia.org/wiki/Likert_scale

Nielsen's Heuristics, 16-7-2013
http://www.nngroup.com/articles/ten-usability-heuristics/

Human Benchmark: Average Reaction Times, 20-7-2013
http://www.humanbenchmark.com/tests/reactiontime/stats.php

A guide to color symbolism, last visited 20-07-2013
http://www.rainbow-mouse.net/ebooks/selfimprovement/art/color/Jill%20Morton%20-%20COLORCOM%20-%20COLOR%20SYMBOLISM.pdf

4. Illustrations

Illustrations which are not mentioned in this list of references are produced by the author of this project.

2.1: ADAS,	http://assets.knowledge.allianz.com/img/ford_allsensores_51467.jpg
2.2 & 2.3:	http://www.motorcraftservice.com/pubs/content/~WODFSN/~MUS~LEN/42/13fsnom3e.pdf
2.4 & 2.5:	Ford Lane Keeping Tech http://media.ford.com/images/10031/Lane_Keeping_Tech.pdf
2.6:	Ford BLIS technology, http://www.youtube.com/watch?v=PZameuDpT0A
2.7:	Ford veiligheid, http://www.ford.nl/cs/BlobServer?blobtable=MungoBlobs&blobcol=urldata&blobwhere=1214384345977&blobkey=id
2.8:	http://www.ford.com/resources/ford/general/innovations/sync/features/color_coded_touch_screen/image01.jpg?v=1351737833000
2.9:	http://www.ford.com/resources/ford/general/innovations/sync/features/command_center/image01.jpg?v=1345516060000
2.10, 2.11, 2.12 & 2.13:	TJA Functional Spec, Ford Technology Internal Document, 28-10-2011.
2.14:	bmw.com/com/en/insights/technology/connecteddrive/2010/future_lab/index.html#/2/10
2.15, 2.16 & 2.17:	Audi Traffic Assist Demo, www.youtube.com/watch?v=JnPJse5yYbc
2.18:	www.techcenter.mercedes-benz.com/en/active_lane_keeping_assist/detail
2.19:	Parameters and indicators of behavourial adaptation to ADAS/IVIS for inclusion in DVE model for preliminary design of AIDE system. deliverable 1.1.3, 1-03-2004.
2.20:	Human Factors' aspects in automated and semiautomatic transport systems: State of the art. deliverable 3.2.1, 27-07-2007.
2.21 & 2.22:	Accident avoidance by active intervention for intelligent vehicles. deliverable 2.2, 31-07-2012.
3.1:	Kaber, D.B. and Endsley, M. R. (1999) Level of automation effects on performance, situation awareness and workload in a dynamic control task. In Ergonomics.
7.1:	http://www.ford.com/cars/fusion/gallery/photos/
7.19:	http://rwshiftinggears.files.wordpress.com/2012/04/12-ford-fusion-hybrid-dash.jpg http://www.cartype.com/pics/8421/full/ford_explorer_cluster_11.jpg

APPENDICES

INTERFACE DESIGN

FOR THE TAKE OVER OF AUTOMATED DRIVING

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CURRENT TJA TAKE OVERS

TJA's technical and system boundaries result in required take overs. These take overs are divided in subgroups (TO1-TO5), according their cause.

TO1: Take Over without Take Over Request
When the driver overrides the system a take over will be processed. In this case the driver will not receive a message TJA is deactivated because it is likely the driver knows he has taken over control himself. The situation could occur in both longitudinal (left figure and lateral control (right figure).

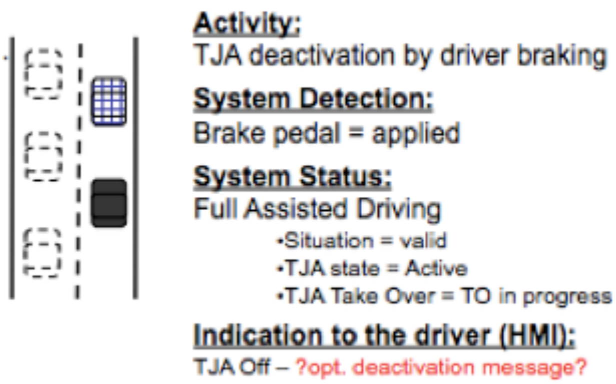


Fig. 1: TO1, deactivation by driver braking.

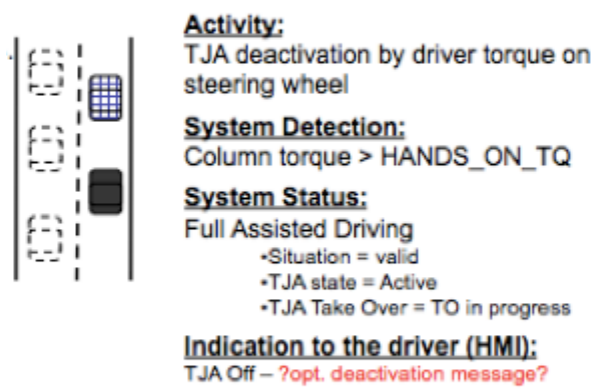


Fig. 2:: TO1, deactivation by driving steering.

TO2: Take Over with Soft Take Over Request
When the system fails at one of its conditions it will ask for a take over of the driver. When the situation is not critical a soft take over (yellow) is indicated. This happens e.g. when the system fails to detect road lines.

TO3: Take Over Request without Take Over
It is possible that the driver does not react when a take over is requested. The uncertain situation then turns into a possible dangerous situation. A soft TO request will be followed by a hard TO request. When a driver reaction is not occurring the car will smoothly decelerate to standstill and it will activate hazard lights.

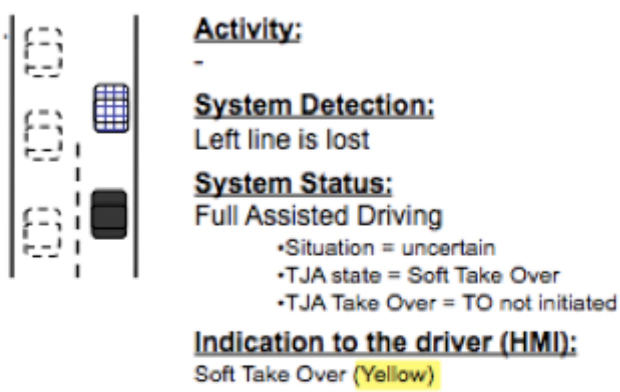


Fig. 3:: TO2, take over with soft take request

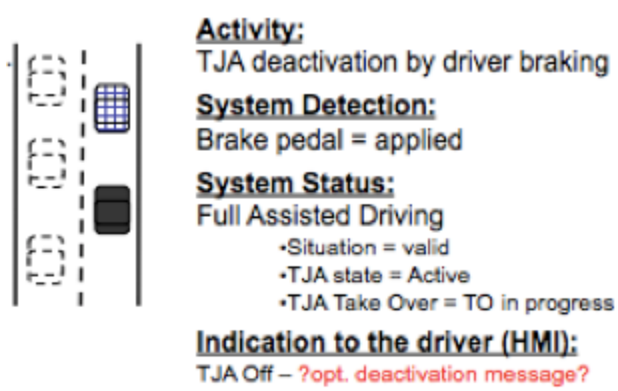


Fig. 4: TO3, take over request without take over

TO4: Take Over on Traffic Jam Ends

When a traffic jam ends, multiple situations are possible. The driver could react himself by taking over control (no indication is given) or the system has to ask for a (soft or hard) take over. When the lead vehicle accelerates above 60 km/h the system will be deactivated an will indicate the traffic jam is over. When the driver is not in the loop and therefore does not react a hard take over request will be indicated.

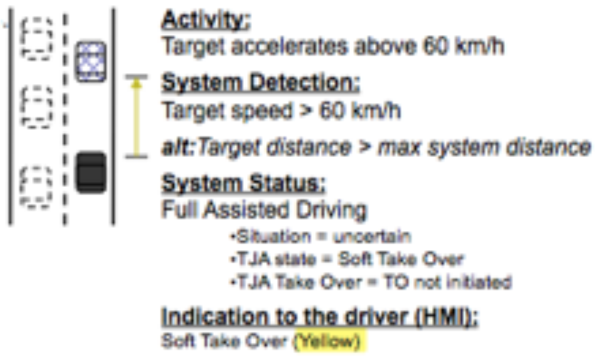


Fig. 5: TO4, a soft TO because the lead vehicle exceeds system boundary speed.

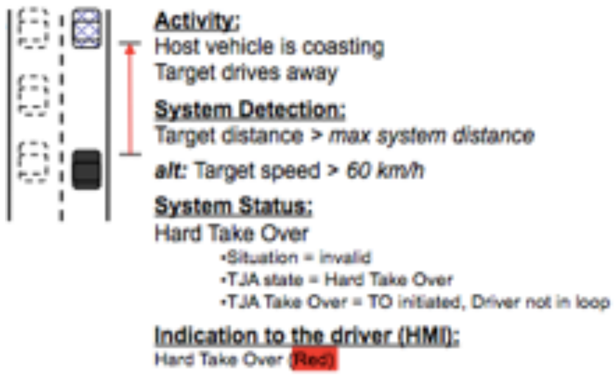


Fig. 6: TO4, a hard TO because the lead vehicle exceeds the maximum following distance.

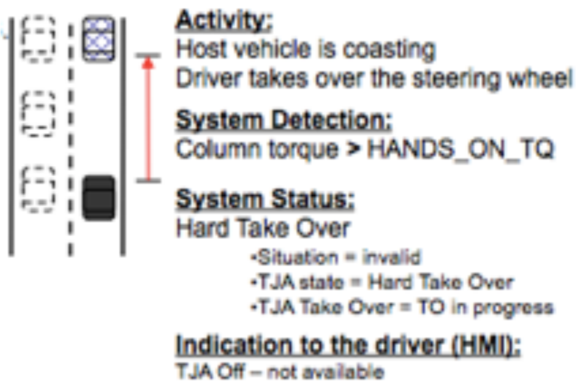


Fig. 7:: TO4, a hard TO request, the driver takes over and TO is in progress.

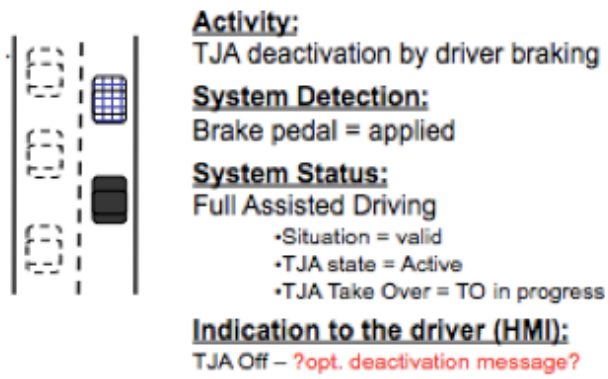


Fig. 8: TO5, The driver is requested to take over because the maximum system braking capacity is exceeded.

TO5: Take Over with brake capacity warning

When the target vehicle brakes, the system will react with the desired brake pressure. When the maximum deceleration of 0,3G is exceeded a hard TO request with Brake Capacity Warning is indicated. This is a critical situation which desires a more direct approach of the driver. Therefore, it is a special subgroup.

It is clear that some cases, like a traffic jam end, could activate ACC instead of a complete deactivation of driver assisting systems. The earlier described table could be used as guide to activate or deactivate certain parts of the TJA system; the level of automation is a key figure.

II OTHER INTERFACES

Besides competitive systems and projects, a couple of other interface designs use interesting methods. The following described systems could lead to ideas for TJA.

II.1 Vehicle Driver Interaction

Volvo – Intelligent Driver Information System (IDIS)

IDIS is an intelligent information system designed by Volvo. Goal of IDIS is to avoid distraction of the driver as much as possible. The system tracks certain functions of the car for activity, like steering wheel and pedal movements and indicator control. When IDIS assesses a situation as potentially dangerous or likely to require the driver's full attention, the system suppresses information signals. Incoming phone calls (via hands free) or cluster display messages are delayed until the situation allows the driver to divide its attention again. An example is shown below: an upcoming turn (turn indicator is activated) or passing manoeuvre is detected by IDIS (the driver's car is red). When the situation has passed, messages are passed on again (driver's car is green). Warnings are labelled with a priority. Certain situations should delay a soft warning but should pass on a hard warning (like situation three, green/red car).
TJA could use this way of passing on information in take over situations. When the driver has to take over control only simple, necessary information should be passed on, in this case the hard warning. Afterwards, or beforehand when IDIS thinks a take over could occur, a soft warning could be passed on because the driver has the opportunity to process it.

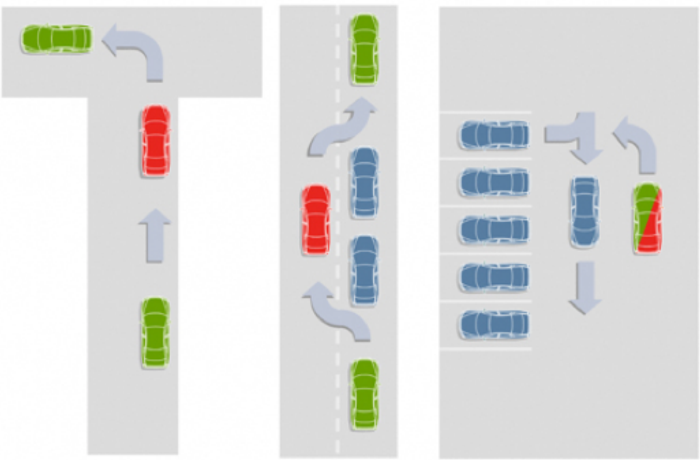


Fig. 9: Volvo's IDIS with the different states it could be in.

Fig. 10: The 'safe' indication of Driver Alert.

Ford – Driver Alert

Driver Alert measures how alert a driver is. The system uses technology comparable with Traffic Jam Assist. A front camera and radar determine the position of the car in the driving lane.

Fig. 11: A soft warning of Driver Alert.

Fig. 12: A hard warning of Driver Alert.

Situations which could point at a driver that is not concentrated or alert are detected by the system. For example, sudden and heavy steering corrections are detected. The system remembers earlier situations of low alertness and provides the driver with a soft or hard warning according to this information. It is possible to show the amount of alertness of the driver in the cluster display.

The soft warning consists of an audible warning which should trigger the driver to take a look at the cluster display. An advise to take a break is displayed. The hard warning consists of a stronger, more penetrating audible warning. The warning gets stronger and more penetrating when the system detects that the driver is less alert.

II.2 Information Distribution

Mercedes – Distronic Plus

Besides the earlier described Distronic Plus system with Steering Assist of Mercedes, its core Distronic Plus system includes an interesting approach of the interface. The situation is visualised through a side view. A detected lead vehicle and the driver's vehicle are projected on a line, accompanied by distance measures. The speed of lead vehicle and driver's vehicle are also shown. When the driver is closing in on the lead vehicle the side view visualises this situation. Distronic Plus uses warnings similar to LKA when the driver has to be aware of the situation or he has to intervene.

Fig. 13: The side view that Mercedes uses for Distronic Plus.

Fig. 14: The top view interface of Active Blind Spot Assist.

Mercedes – Active Blind Spot Assist

Another system of Mercedes worth mentioning is its Active Blind Spot Assist. The system itself does not differ significantly from Ford's technology but the interface contains a different approach. The top view projected at the cluster display within the speed gauge shows the driver's vehicle and surrounding vehicles, looming in the blind spots of the car.

This approach could be used to show surrounding traffic in TJA. The way information is transferred to the driver does not differ. An indicator light is present in the side mirrors and an audible warning is given when the driver decides to switch lanes (detected by the usage of the turn indicator) while a vehicle is present in the blind spots.

III FORD ICONIC LANGUAGE

Simultaneously to the development of the digital dashboard, manufacturers tried to create an iconic language to communicate with the driver. Graphical information should transfer its message more quickly in contrast to text. The driver could see in a glance what is asked. Besides, icons use less space. In contrast to these benefits a learning process is added. The driver has to have knowledge about the meaning of the icons. Therefore manufacturers tried to create a connection between the real world and the icons, earlier described knowledge of the world was used to transfer the message.

It is quite odd that there are no guidelines or standards that describe the meaning and usage of dashboard icons. Each vehicle has quite the same messages to transfer and could therefore use the same icons. However, most manufacturers use identical (or similar) icons. The mimicking of the real world used in these icons could be used in the TJA interface. Therefore, a brief explanation of common used icons is welcome.

The most interesting icons (in case of TJA) have a relation with the entire car or connected systems like Cruise Control. Most indicator lights are only visible when they require the drivers' attention (which sounds quite logically). When a problem (or activation) occurs the light will illuminated. Red corresponds with something critical (recommended to stop immediately), orange is a warning and green means there is something is activated. Unique color is blue, used only for fog lights. For example:

Active Cruise Control
Illuminates in white when ACC is turned on. When it is engaged, it turns green. When ACC is turned off, the tell tale is also turned off and not visible.

Cruise Control
Illuminates when CC is turned on.

Door Ajar
Illuminates when engine is running and one of the doors is not completely closed. The corresponding door will be highlighted.

Bonnet Ajar
Illuminates when engine is running and one of the bonnet is not completely closed.

Lane Keeping Aid
Illuminates when LKA is activated.

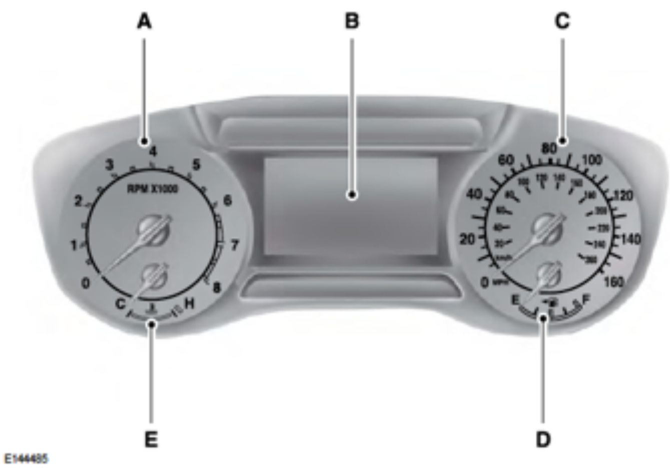
Blind Spot Information System
Illuminates when BLIS is turned off or a BLIS related message appears at the cluster display. So, this tell tale works in the opposite way of the others.

Both ACC and LKA tell tales are an extra indicator on top of the earlier described information displays (in chapter 2 of the design report).

Audible language
The iconic language can be extended in current audible indicator usage. Most cars are equipped with a an audible warning for the following occasions:

Headlamps on warning chime
Sounds when the key is removed from the ignition and the driver's door is opened while the headlamps or parking lamps are still on.

Parking brake on warning chime
Sounds when the parking brake is left on while driving.



A Tachometer
B Information Display (Type 2 shown Type 1 similar)
C Speedometer
D Fuel Gauge
E Engine Coolant Temperature Gauge

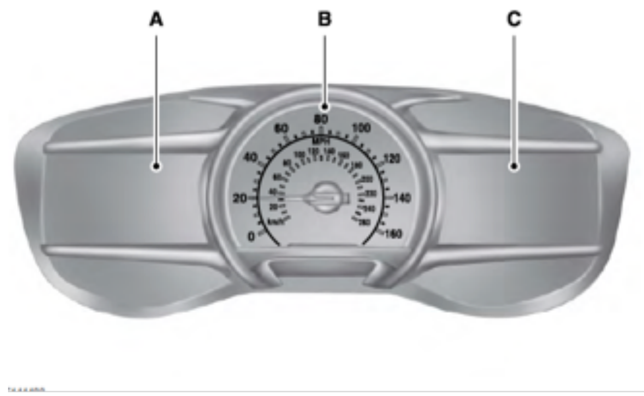


Fig. 15 & 16: A generic visualisation of the two versions of the Ford cluster display. Left, the normal version with one center display and right the new Fusion cluster, with two display one each side of the speedometer.

Extended iconic language
Following example has no direct connection with in-vehicle interface design and Ford's iconic language but the extension of the 'iconic language' is worth mentioning and a possible addition to the Ford language.

An interface design which takes the knowledge of the world even a step further is build twenty years ago. The first generation Fiat Panda interface uses the placement of tell tales to give an extra hint about what message the displayed icon should transfer. For example, activated headlights are indicated by a light that is placed at the front of the mimicked car, the battery indicator 'under the bonnet' and fuel indicator back right, where you are supposed to refuel.

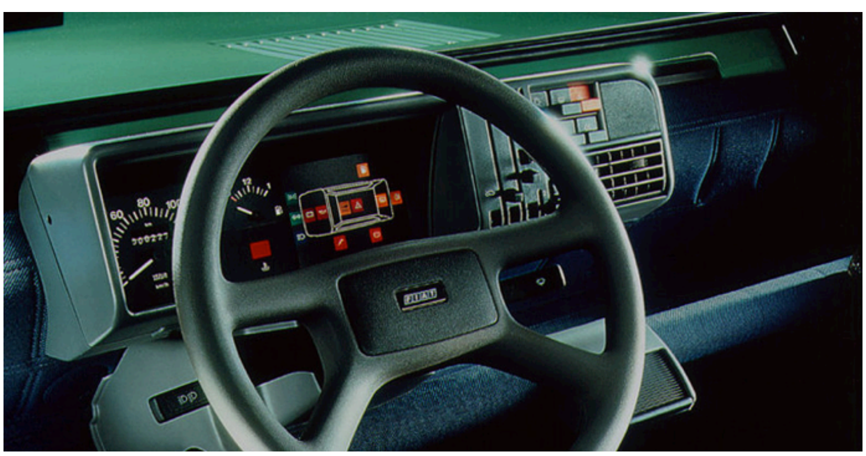


Fig. 17: The representation of the Fiat Panda at the cluster display with integrated tell tales.

IV COGNITIVE ASPECTS

Cognitive ergonomics focus on the clarity of product designs. Being able to find, read/percept and understand presented information is essential. An important aspect of cognitive ergonomics is the way information is processed. There is a division in perception between bottom-up and top-down processing.

Bottom-up: what you expect to see is what you will in fact see.
Top-down: the clarity is subjective: what you think you see is not real.

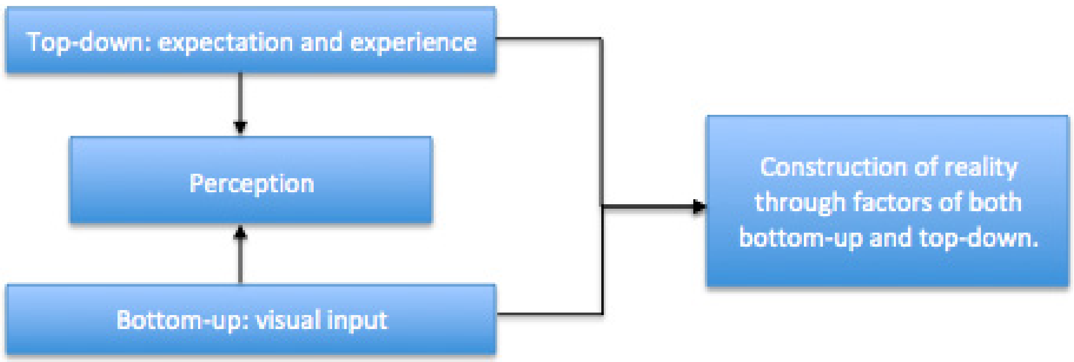


Fig. 18: A visual representation of the perception and related influences of drivers.

An example of the differences in perception is the human ability of estimating distance towards another car while in traffic. In the United States more road accidents occur with small cars because American drivers are used to drive with and along big cars. Top-down processing results in a wrong perception of distance to smaller cars which results in a higher risk of accidents.

IV.1 The visual system

This knowledge could help in steering a drivers' visual attention. Example is target search, an existing formula describes the time you should need to find a couple of B's in a field with a lot of P's and those couple of B's. However, conspiciuity influents the time needed, this is bottom-up processing. An extra eye-catcher like different colors decreases the search time significantly. In the same way visual attention of the driver could be steered.

Top-down processing is also of importance. Expectancies are affected by earlier interaction between driver and vehicle. Similar situations create experiences that influent the drivers' attention. Visually steering the driver with the interface could result in shorter times of setting things up but as well in reacting to requested TOs.

Besides, some rational aspects are of importance. The eye can be misled by visual information. Brightness is processed top-down. Similar colors could create an illusion and could mislead the interpretation of the brain. In this case the visual interface has to be made with clearly different objects and colors; contrast is important. A quick look should result in the right interpretation. In this case it is desirable to rely on bottom-up processing. Under normal circumstances, the eyes' rods and cones (used for respectively seeing brightness and color) can see the right information. As long as there is no room for misinterpretation no problems will occur. Subsequently, it is important to make use of redundancy gain. Color-blind drivers should be able to interpret the information and therefore just a difference in color is not enough. Example is a traffic light: color-blind people will know the light turns green when the bottom light is illuminating.

IV.2 Perception and attention

It is astonishing how much information human miss while observing; selective attention is the main cause. When human focus on a certain object/movement/etc. attention capture or salience is occurring. For example, in a clip with people who a throwing a ball the viewer get the task of counting the amount of throws between white shirted players. A moonwalking black bear can walk right through the center of the view without the viewer even noticing something happened, but each participant in the test looked for a brief moment at the bear. In this case, the Inattentional Blindness is catalysed by the difference between the focus of the viewer on white objects and the black bear, a red bear probably had been noticed.
The eye has a filtering function. Each point with information it is focused on is processed but for the

information in between, looked at while moving, the eye is 'blind'. Looking at something does not mean it is perceived. So, minimalising the amount of information and the required eye movement to look at it is desirable. A Heads Up Display (HUD) could be an option. However, inattentional blindness and clutter should be avoided. Too much overlaying information leads to missed information behind the display, in the 'real world'.

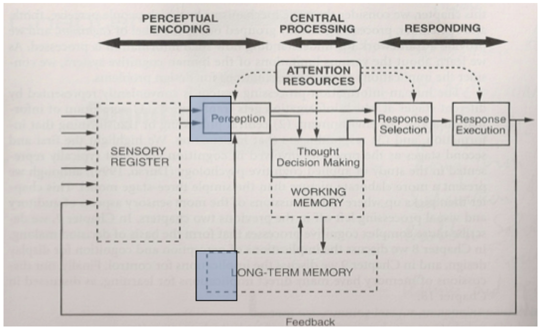


Fig. 19: The long-term memory influences driver's perception.

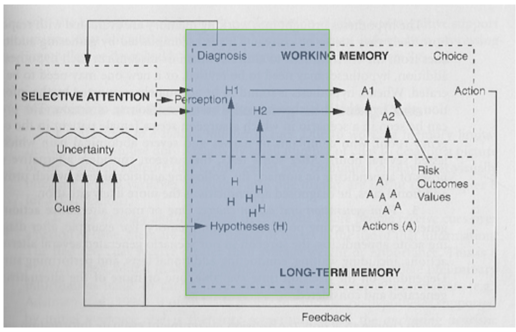


Fig. 20: Decision making uses knowledge of both long-term and working memory.

Expect the unexpected. Human behavior is not predictable, therefore consequence is essential. Denial in used text leads to misinterpretation. Simple, short and 'positive minded' quotes leave little room for wrong interpretations.

Attention can be aimed at more crucial aspects by 'enlarging' the working memory of a human brain. Normally only seven different subjects (according to G.A. Miller, 1956) can be handled by the working memory. By 'helping' the memory more can be dealt with, for example by hinting to certain situations or 'storing' information in the long-term memory. Second is putting knowledge in the head, but even easier is putting knowledge in the world. By mimicking the real world in the interface it is easier to recognise certain situations or objects.

IV.3 Auditory signals

Auditory signals are often used for warnings because they are independent of the direction. However, auditory signals are harder to supply with information. Therefore usage should be kept to a minimum. An division in auditory warnings for soft and hard TOs is feasible. Too loud and too much auditory signalling has an effect in the opposite way of the desired direction. Too much could lead to an overkill; the users will mainly try to stop the noise instead of reacting to it. Too loud sounds could startle the user; overexcitation will disturb in undertaking the desired action.
Some criteria for warning are as follows:

- The warning should be audible in contrast to background noise (minimum of 15dB on top of background noise, 30dB on top of 'noise-level' to guarantee detection).
- The warning should not exceed danger zone for hearing (85-90dB, however previous criterion is more important).
- The warning should not start or end too abrupt.
- The warning should not disturb the reception or understanding of other signals (for example a horn of other traffic or emergency vehicles).
- The warning should be informative. A clear contrast with other signals should easily be detected.

Differences in pitch of auditory signals, instead of melodies, make it unnecessary for the user to know what a signal means. The severity of the tone 'steers' the user unconsciously. A preamble phase could be desirable to let the user know danger could be close. Situation Awareness will rise in these situations.

IV.4 Decision making

Human decisions are mainly made on the basis of a limited amount of information. The first cue is very important. Users will remember the first cue and will take it into account in further considerations. This is called cue primacy/anchoring. Besides, it is said that the more reliable, the more important a cue is (Cue salience).

However, this not always right. Under normal circumstances, people can handle 1 to 4 hypotheses. Under time pressure 1 hypothesis is the maximum. Decisions can be influenced by the availability of a hypothesis. Often used hypotheses are used again more easily while it is not more likely they are right.
At last, cognitive tunneling, retaining the belief in a generated hypothesis, is of importance. Conformation bias amplifies this thought; only affirmative information is noticed. These aspects are of importance in influencing driving behaviour while using TJA. Less room for decisions, in critical situations, compensates the risk of wrong hypothesis generation.

V DESIGN GUIDELINES

V.1 Nielsen's Heuristics - 10 Usability Heuristics for User Interface Design

Summary: The 10 most general principles for interaction design. They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines.

Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

I originally developed the heuristics for heuristic evaluation in collaboration with Rolf Molich in 1990 [Molich and Nielsen 1990; Nielsen and Molich 1990]. I since refined the heuristics based on a factor analysis of 249 usability problems [Nielsen 1994a] to derive a set of heuristics with maximum explanatory power, resulting in this revised set of heuristics [Nielsen 1994b].

V.2 Thirteen principles of display design

Christopher Wickens et al. defined 13 principles of display design in their book An Introduction to Human Factors Engineering. These principles of human perception and information processing can be utilized to create an effective display design. A reduction in errors, a reduction in required training time, an increase in efficiency, and an increase in user satisfaction are a few of the many potential benefits that can be achieved through utilization of these principles. Certain principles may not be applicable to different displays or situations. Some principles may seem to be conflicting, and there is no simple solution to say that one principle is more important than another. The principles may be tailored to a specific design or situation. Striking a functional balance among the principles is critical for an effective design.

Perceptual principles

1. Make displays legible (or audible). A display's legibility is critical and necessary for designing a usable display. If the characters or objects being displayed cannot be discernible, then the operator cannot effectively make use of them.
2. Avoid absolute judgment limits. Do not ask the user to determine the level of a variable on the basis of a single sensory variable (e.g. color, size, loudness). These sensory variables can contain many possible levels.
3. Top-down processing. Signals are likely perceived and interpreted in accordance with what is expected based on a user's past experience. If a signal is presented contrary to the user's expectation, more physical evidence of that signal may need to be presented to assure that it is understood correctly.
4. Redundancy gain. If a signal is presented more than once, it is more likely that it will be understood correctly. This can be done by presenting the signal in alternative physical forms (e.g. color and shape, voice and print, etc.), as redundancy does not imply repetition. A traffic light is a good example of redundancy, as color and position are redundant.
5. Similarity causes confusion: Use discriminable elements. Signals that appear to be similar will likely be confused. The ratio of similar features to different features causes signals to be similar. For example, A423B9 is more similar to A423B8 than 92 is to 93. Unnecessary similar features should be removed and dissimilar features should be highlighted.

Mental model principles

6. Principle of pictorial realism. A display should look like the variable that it represents (e.g. high temperature on a thermometer shown as a higher vertical level). If there are multiple elements, they can be configured in a manner that looks like it would in the represented environment.
7. Principle of the moving part. Moving elements should move in a pattern and direction compatible with the user's mental model of how it actually moves in the system. For example, the moving element on an altimeter should move upward with increasing altitude.

Principles based on attention

8. Minimizing information access cost. When the user's attention is diverted from one location to another to access necessary information, there is an associated cost in time or effort. A display design should minimize this cost by allowing for frequently accessed sources to be located at the nearest possible position. However, adequate legibility should not be sacrificed to reduce this cost.
9. Proximity compatibility principle. Divided attention between two information sources may be necessary for the completion of one task. These sources must be mentally integrated and are defined to have close mental proximity. Information access costs should be low, which can be achieved in many ways (e.g. proximity, linkage by common colors, patterns, shapes, etc.). However, close display proximity can be harmful by causing too much clutter.
10. Principle of multiple resources. A user can more easily process information across different resources. For example, visual and auditory information can be presented simultaneously rather than presenting all visual or all auditory information.

Memory principles

11. Replace memory with visual information: knowledge in the world. A user should not need to retain important information solely in working memory or retrieve it from long-term memory. A menu, checklist, or another display can aid the user by easing the use of their memory. However, the use of memory may sometimes benefit the user by eliminating the need to reference some type of knowledge in the world (e.g. an expert computer operator would rather use direct commands from memory than refer to a manual). The use of knowledge in a user's head and knowledge in the world must be balanced for an effective design.
12. Principle of predictive aiding. Proactive actions are usually more effective than reactive actions. A display should attempt to eliminate resource-demanding cognitive tasks and replace them with simpler perceptual tasks to reduce the use of the user's mental resources. This will allow the user to not only focus on current conditions, but also think about possible future conditions. An example of a predictive aid is a road sign displaying the distance from a certain destination.
13. Principle of consistency. Old habits from other displays will easily transfer to support processing of new displays if they are designed in a consistent manner. A user's long-term memory will trigger actions that are expected to be appropriate. A design must accept this fact and utilize consistency among different displays.

V.3 Driver Focus Guidelines

For years automakers have worked to help drivers focus on the road. In fact, by 2003 Alliance member companies voluntarily developed and began implementing guidelines for integrated advanced information and communications systems. These Driver Focus – Telematics (DF-T) Guidelines were developed in consultation with ITS America, the Consumer Electronics Association, the National Safety Council, the Society of Automotive Engineers, AAA and as observers, the National Highway Traffic Safety Administration and Transport Canada. The complete guidelines can be found at www.autoalliance.org/driverfocus and www.autoalliance.org/driverfocusfacts (media information page).

These are highly-developed design and performance guidelines for in-vehicle systems, and the industry is committed to updating them as we continue learning more about driver behavior. The guidelines cover the design, use and installation of telematics systems through 24 principles focused on helping drivers keep their "eyes-on-the-road."

Data is essential, and through continued research and ever-evolving understanding of how drivers visually and manually interact with their vehicles, each principle in the guidelines includes examples, evaluation criteria, verification procedures and citations to supporting peer-reviewed research. The DF-T guidelines address many factors in ways that optimize auto features for use in one, single, environment: the driving environment.

Installation Principles

1.1 The system should be located and fitted in accordance with relevant regulations, standards, and the vehicle and component manufacturers' instructions for installing the systems in vehicles.
1.2 No part of the system should obstruct the driver's field of view as defined by applicable regulations.
1.3 No part of the physical system should obstruct any vehicle controls or displays required for the driving task.
1.4 Visual displays that carry information relevant to the driving task and visually-intensive information should be positioned as close as practicable4 to the driver's forward line of sight.
1.5 Visual displays should be designed and installed to reduce or minimize glare and reflections.

Information Presentation Principles

2.1 Systems with visual displays should be designed such that the driver can
complete the desired task with sequential glances (a glance should not exceed 2 seconds) that are brief enough not to
adversely affect driving.
2.2 Where appropriate, internationally agreed upon standards or recognized
industry practice relating to legibility, icons, symbols, words, acronyms, or
abbreviations should be used. Where no standards exist, relevant design

guidelines or empirical data should be used.
2.3 Available information relevant to the driving task should be timely and accurate under routine driving conditions.
2.4 The system should not produce uncontrollable sound levels liable to mask warnings from within the vehicle or outside or to cause distraction or irritation.

Principles on Interaction with Displays/Controls

3.1 The system should allow the driver to leave at least one hand on the steering control.
3.2 Speech-based communication systems should include provision for hands-free speaking and listening. Starting, ending, or interrupting a dialog, however, may be done manually. A hands-free provision should not require preparation by the driver that violates any other principle while the vehicle is in motion.
3.3 The system should not require uninterruptible sequences of manual/visual interactions. The driver should be able to resume an operator-interrupted sequence of manual/visual interactions with the system at the point of interruption or at another logical point in the sequence.
3.4 In general (but with specific exceptions) the driver should be able to control the pace of interaction with the system. The system should not require the driver to make time-critical responses when providing input to the system.
3.5 The system's response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.
3.6 Systems providing non-safety-related dynamic (i.e., moving spatially) visual information should be capable of a means by which that information is not provided to the driver.

System Behavior Principles

4.1 Visual information not related to driving that is likely to distract the driver significantly (e.g., TV, video, and continuously moving images and automatically scrolling text) should be disabled while the vehicle is in motion or should be only presented in such a way that the driver cannot see it while the vehicle is in motion.
4.2 (a) System functions not intended to be used by the driver while driving should be made inaccessible for the purpose of driver interaction while the vehicle is in motion.
(b) The system should clearly distinguish between those aspects of the system, which are intended for use by the driver while driving, and those aspects (e.g. specific functions, menus, etc) that are not intended to be used while driving.
4.3 Information about current status, and any detected malfunction, within the system that is likely to have an adverse impact on safety should be presented to the driver.

Principles on Information about the System

5.1 The system should have adequate instructions for the driver covering proper use and safety-relevant aspects of installation and maintenance.
5.2 Safety instructions should be correct and simple.
5.3 System instructions should be in a language or form designed to be understood by drivers in accordance with mandated or accepted regional practice.
5.4 The instructions should distinguish clearly between those aspects of the system that are intended for use by the driver while driving, and those aspects (e.g. specific functions, menus, etc) that are not intended to be used while driving.
5.5 Product information should make it clear if special skills are required to use the system or if the product is unsuitable for particular users.
5.6 Representations of system use (e.g. descriptions, photographs, and sketches) provided to the customer with the system should neither create unrealistic expectations on the part of potential users, nor encourage unsafe or illegal use.

VI IDEA GENERATION

These visualitions show the first ideas for the system and interface concept. A morphologic scheme is made in order to make fundamental design choices upon interface elements and possible activation methods.

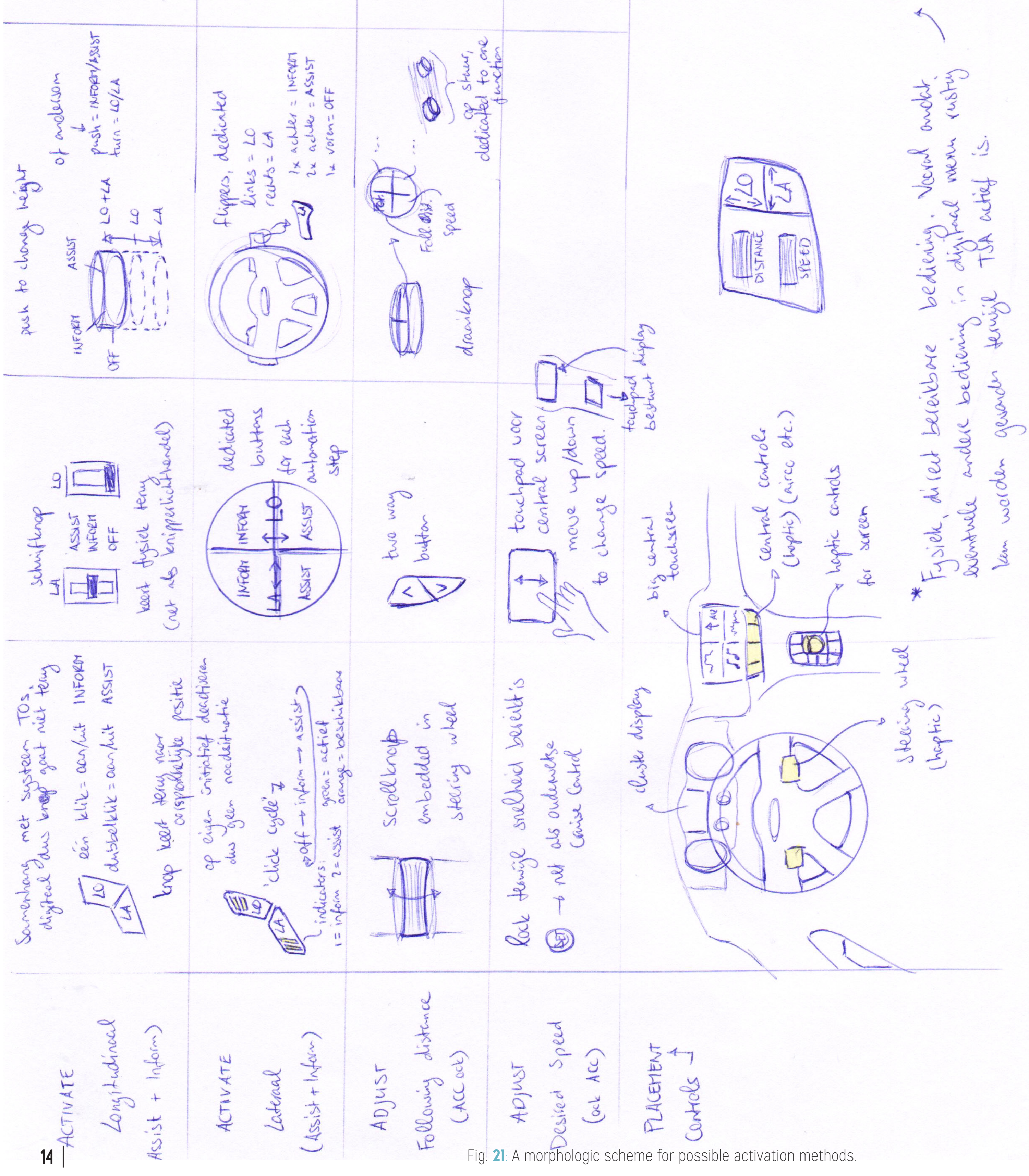


Fig. 21: A morphologic scheme for possible activation methods.

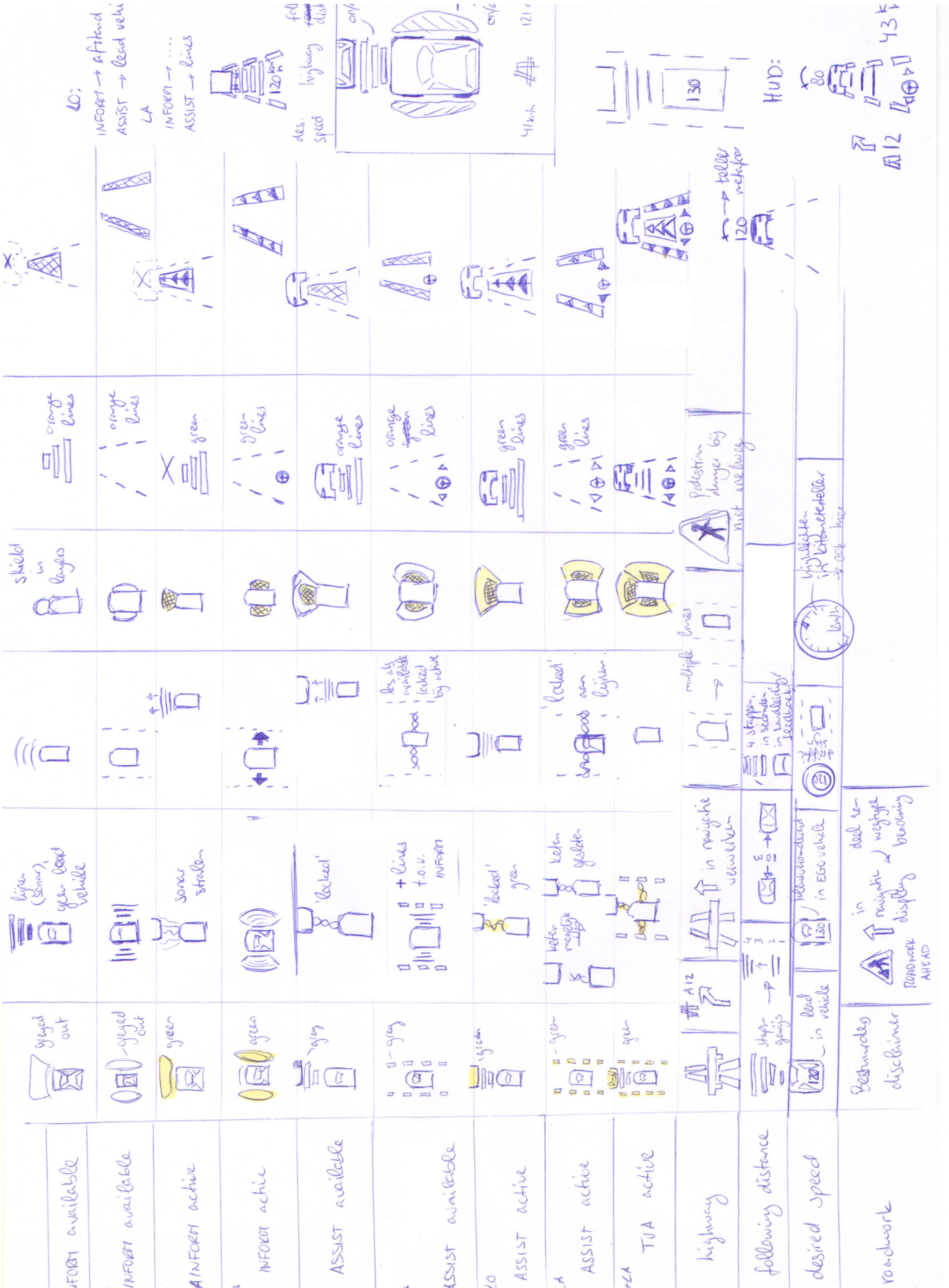
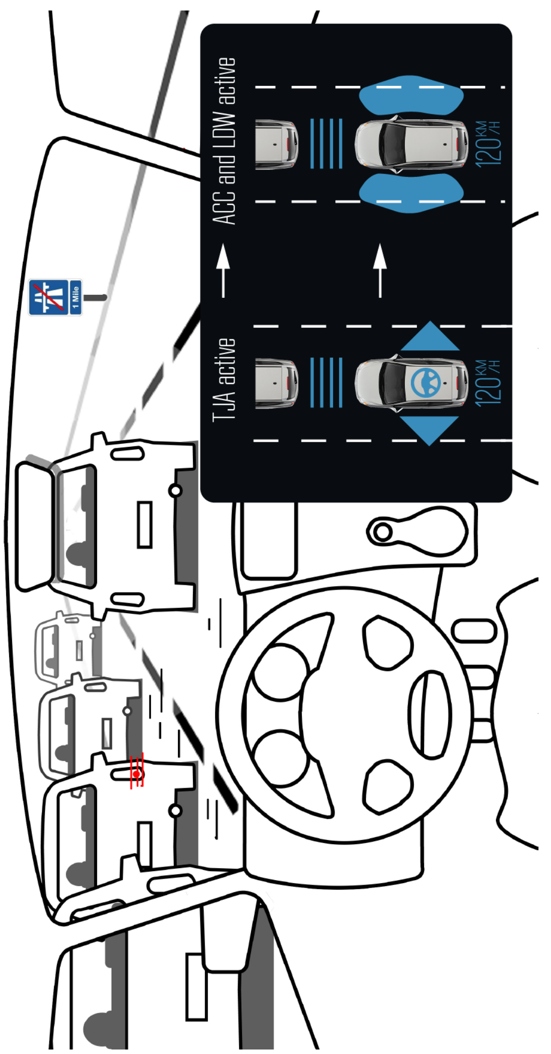


Fig. 22. A morphologic scheme for the different system states as derived from the initial activation strategy.

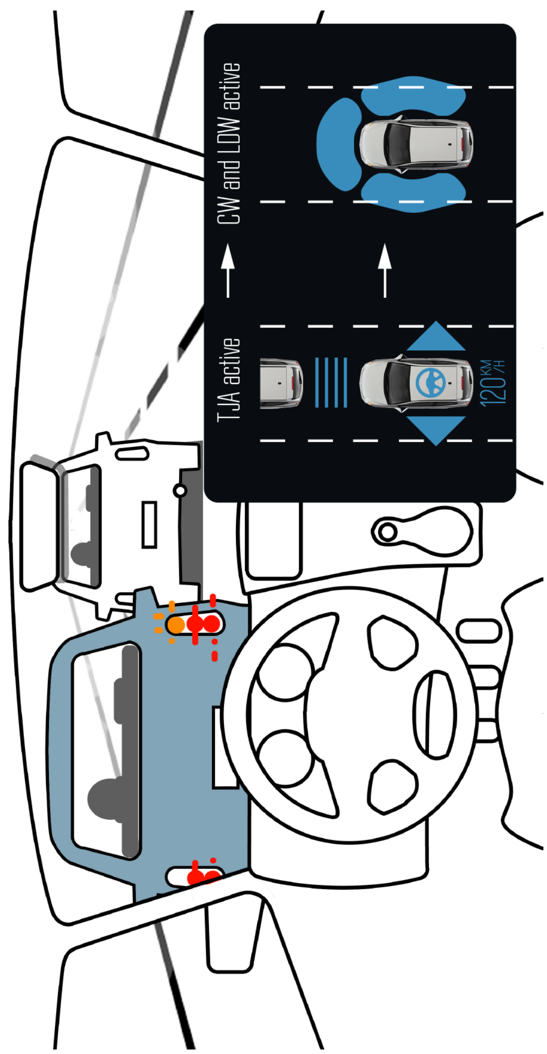
VII TRANSITION SCENARIOS

These scenarios are used during the expert review with Ford to present the continuous feedback concept. The scenarios clarify some critical situations (and the corresponding system state transition) which a driver could experience frequently in traffic.



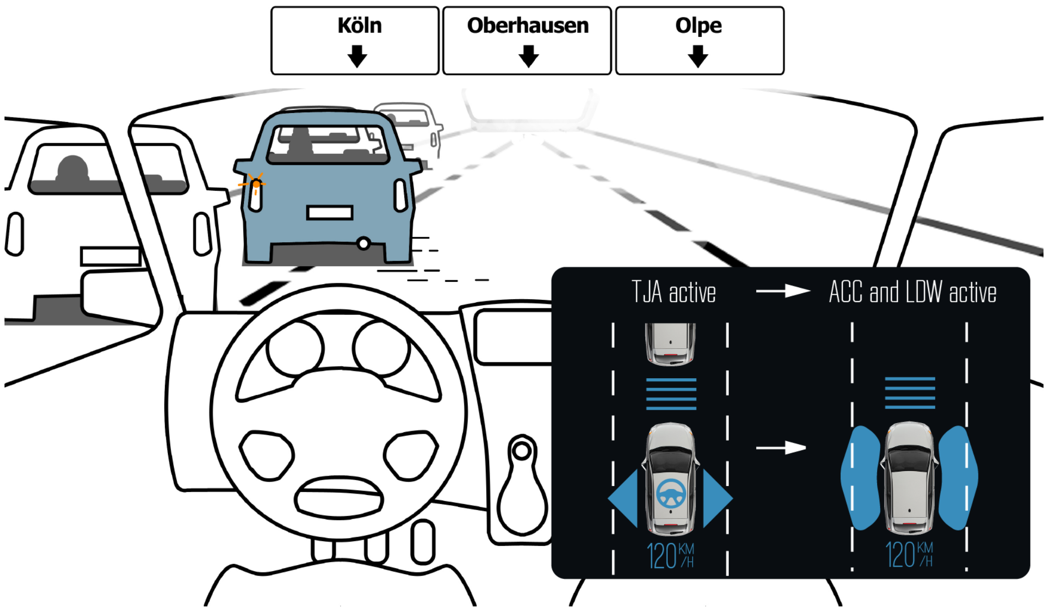
PO = 'target' vehicle

End of Motorway
TJA is intended to be only operated on motorways. When the motorway ends, this should be observed by the driver or the system should **request to take back control.**



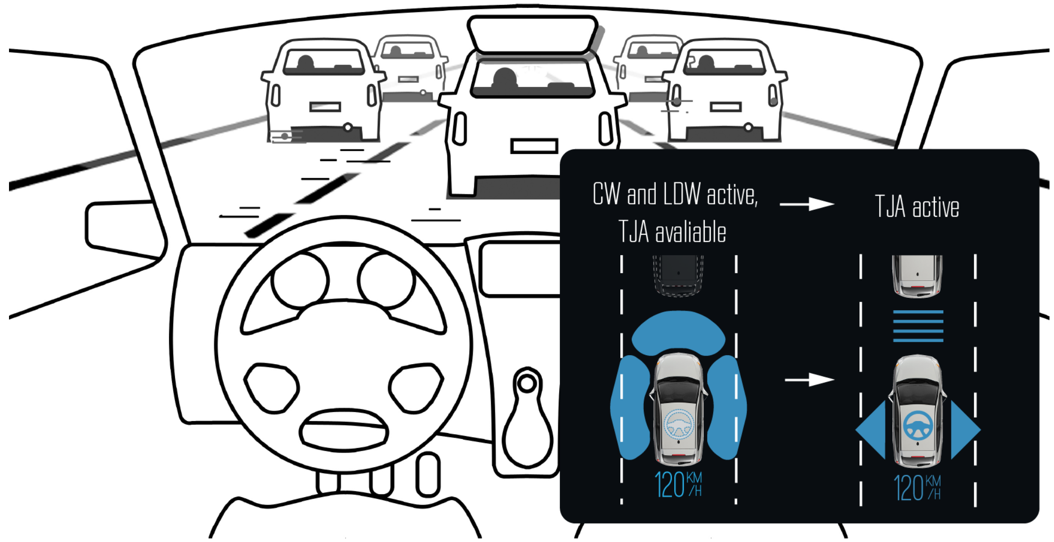
PO = 'target' vehicle

Close cut-in
Car from neighbouring lane cuts in between PO and host vehicle; violating minimum distance: **driver required to take-over control**

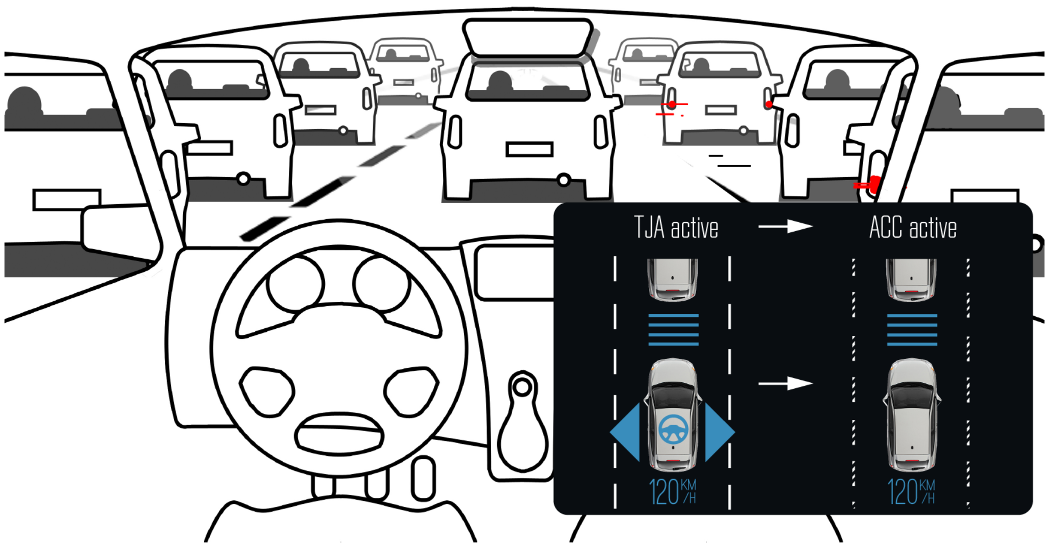


Target vehicle changes lane; no new PO
The target vehicle pulls over to the left as he goes in the lane of his preferred direction. There is no new PO in the existing lane: **driver required to take-over control;**

PO = 'target' vehicle

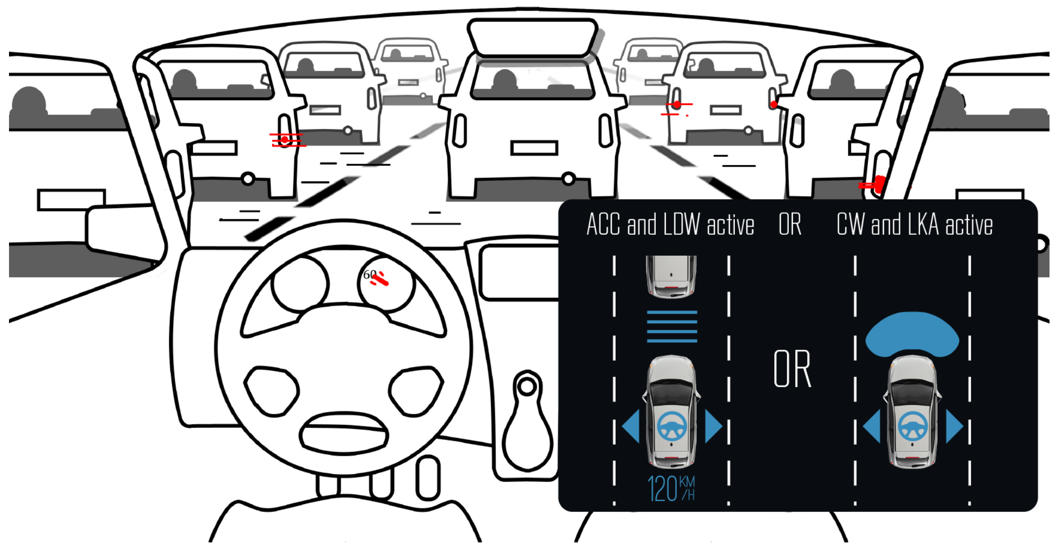


Entering traffic
Average speed of traffic drops below 60 km/h, a traffic jam is occuring: **TJA is available**.



No lane detected
The system is not able to detect a lane to drive in. Lateral control has to be taken over.

PO = 'target' vehicle



Traffic speed oscillates around threshold
Average speed of jammed traffic oscillates around 60km/h (max. speed for TJA), resulting in: **frequently requests to take back control.**

PO = 'target' vehicle

VIII STATE FLOW DEVELOPMENT

Initiating transitions is only possible when the next stage is available. Therefore each stage is divided in an available and active state. This adds a lot of complexity to the possibilities considering the possibility of simultaneous changes in longitudinal and lateral stages. Each of these six stages now has two states which results in a total of twelve stages. There are several ways of 'walking through' these states. Graph 3.X below shows the entire State Flow diagram. All possible 'walkthroughs' are included in the diagram. An important feature of the described concept is already visible in this diagram. It is not possible to activate the assist stage (of either longitudinal or lateral direction) while the inform stage is not active. The walkthrough requires the steps of inform available, inform active and assist available before the assist could be activated.

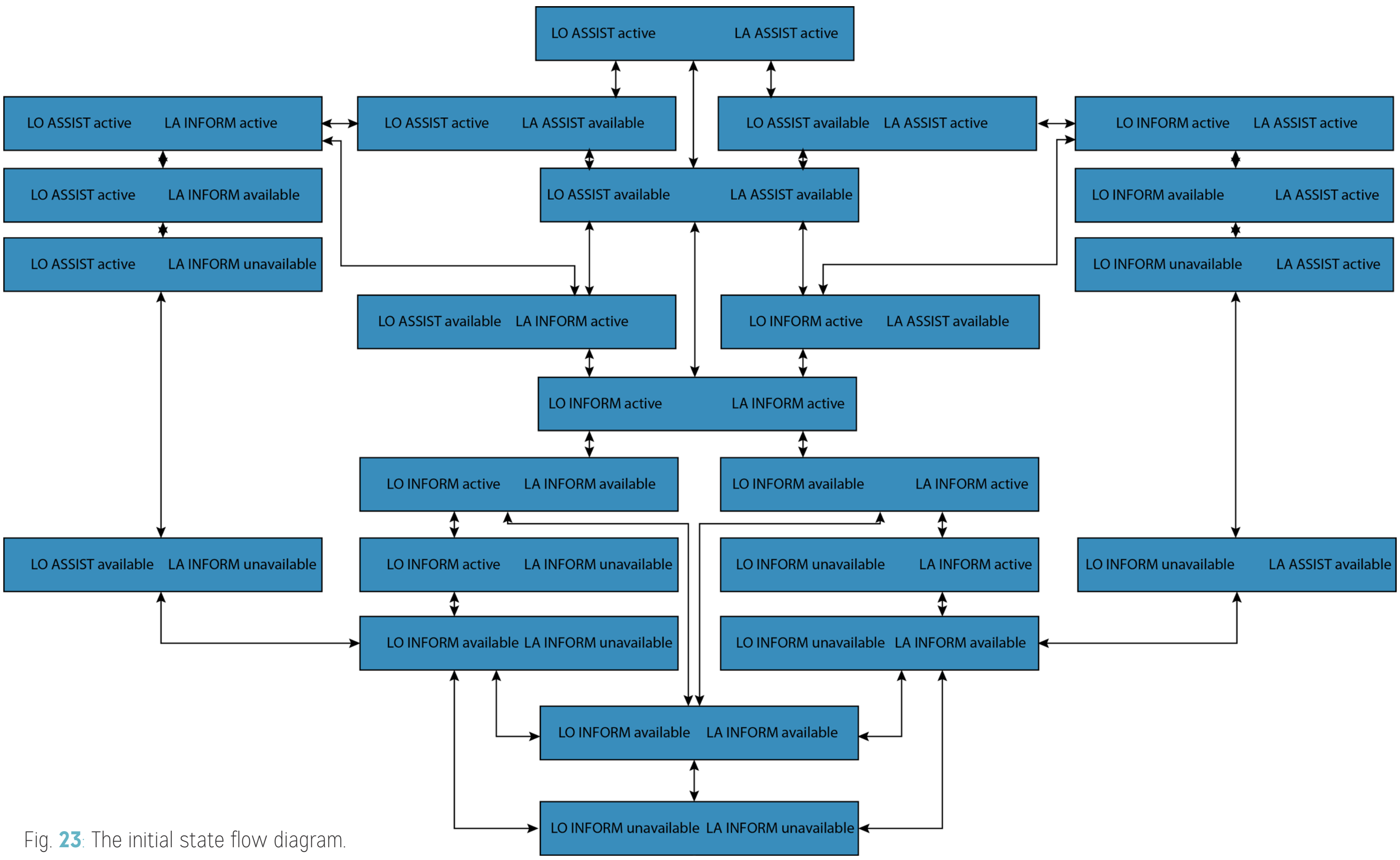


Fig. **23**: The initial state flow diagram.

Result is a quite complex diagram with a lot of states. However, there are some states which are probably rarely used. For one thing, beyond the occurrence of a technical defect, it is not possible that the longitudinal inform stage is unavailable. This results in leaving out three states which are marked in red in graph 3.X.

States which would be quite unusual in common use of the system are marked in translucent blue blocks. The assist stage of a direction is rarely used without the inform stage of the other direction besides it. An average user would not use these states.

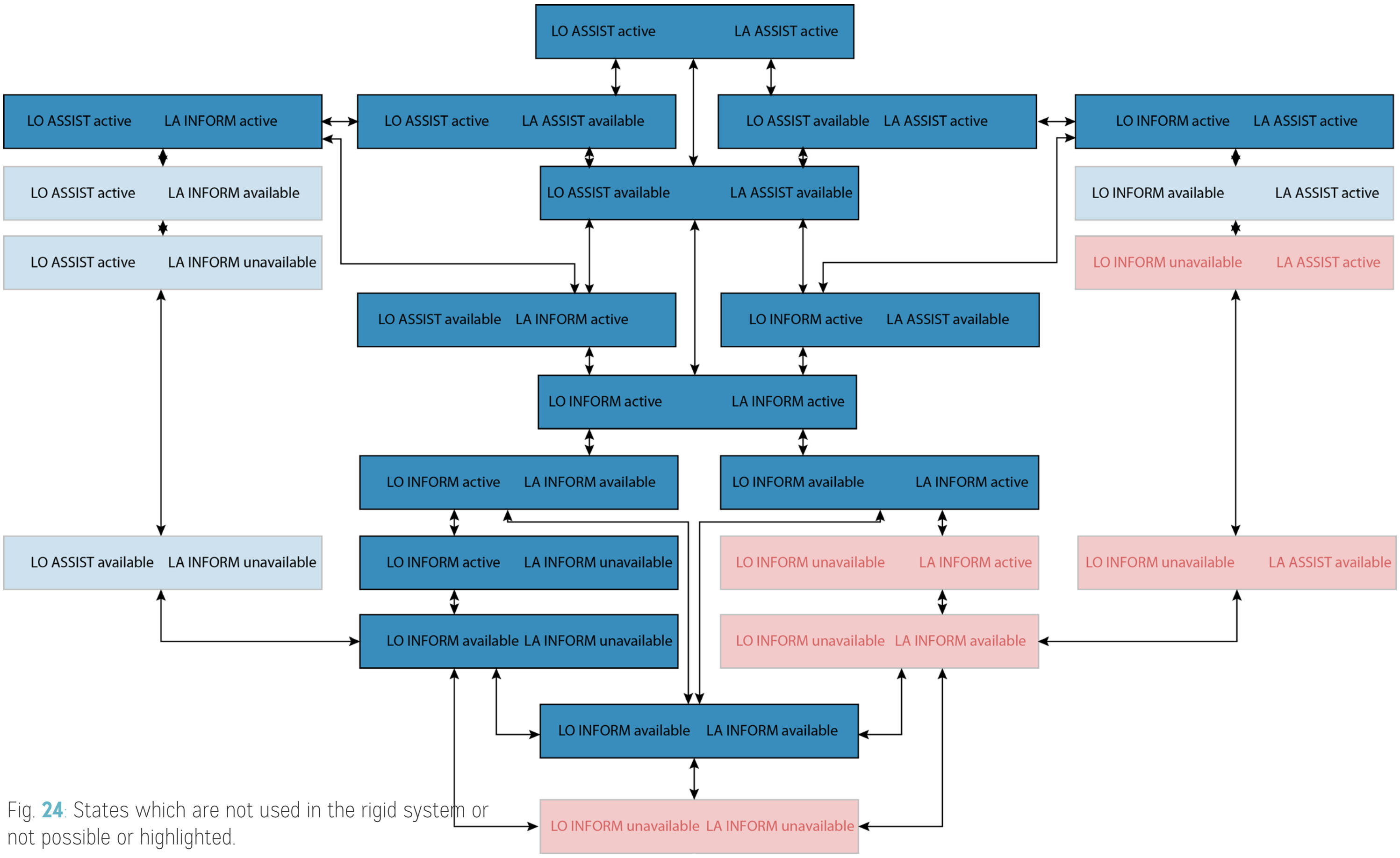


Fig. **24**: States which are not used in the rigid system or not possible or highlighted.

Leaving out these states results in a simplified State Flow diagram as shown in graph 3.X. This simplified set of states is used for the elaboration of the interface concept which will be described in chapter 4.

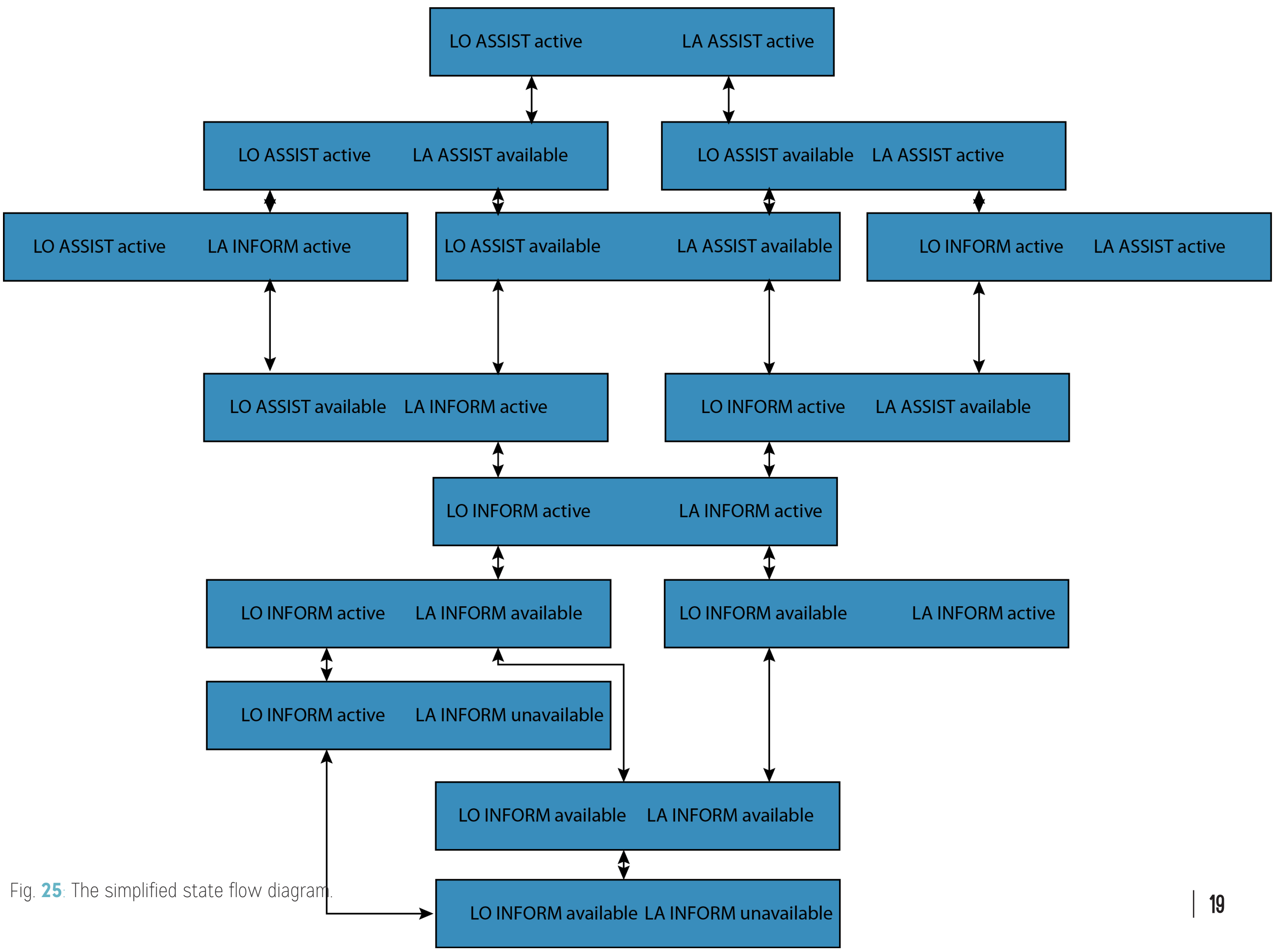


Fig. **25**: The simplified state flow diagram.

IX INTERFACE STATE FLOW

With the complete state flow an overview of the different interface states, and transitions between these states, is made. The danger states could be activated from any state which is active in an inform state (either longitudinal, lateral or both). The shown state flow is based on the human control interface. The states for the automation control interface are identical, only the status indicators differ.

In the overview the following abbreviations are used:

LO	longitudinal
LA	lateral
INF	inform
ASS	assist

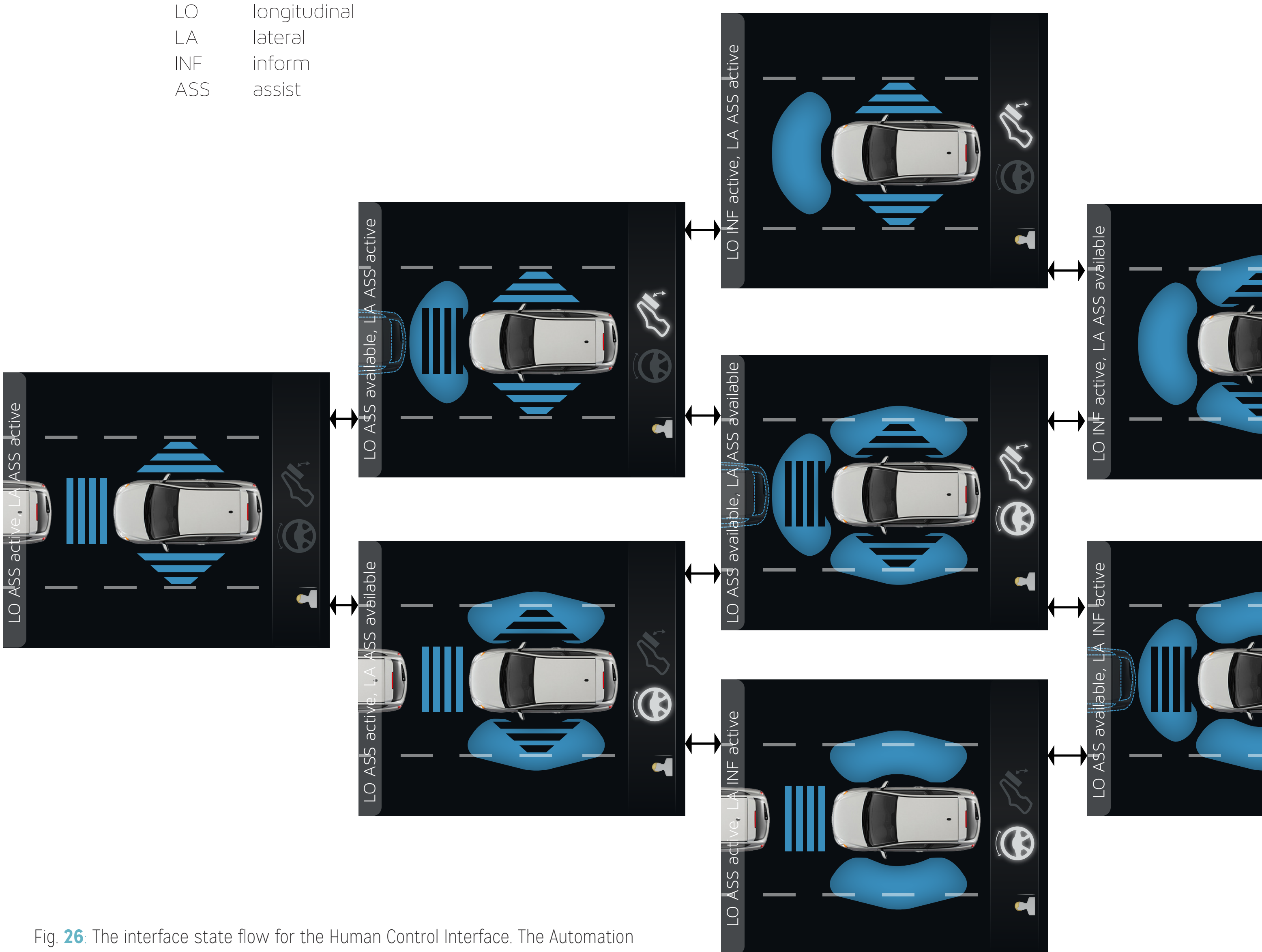
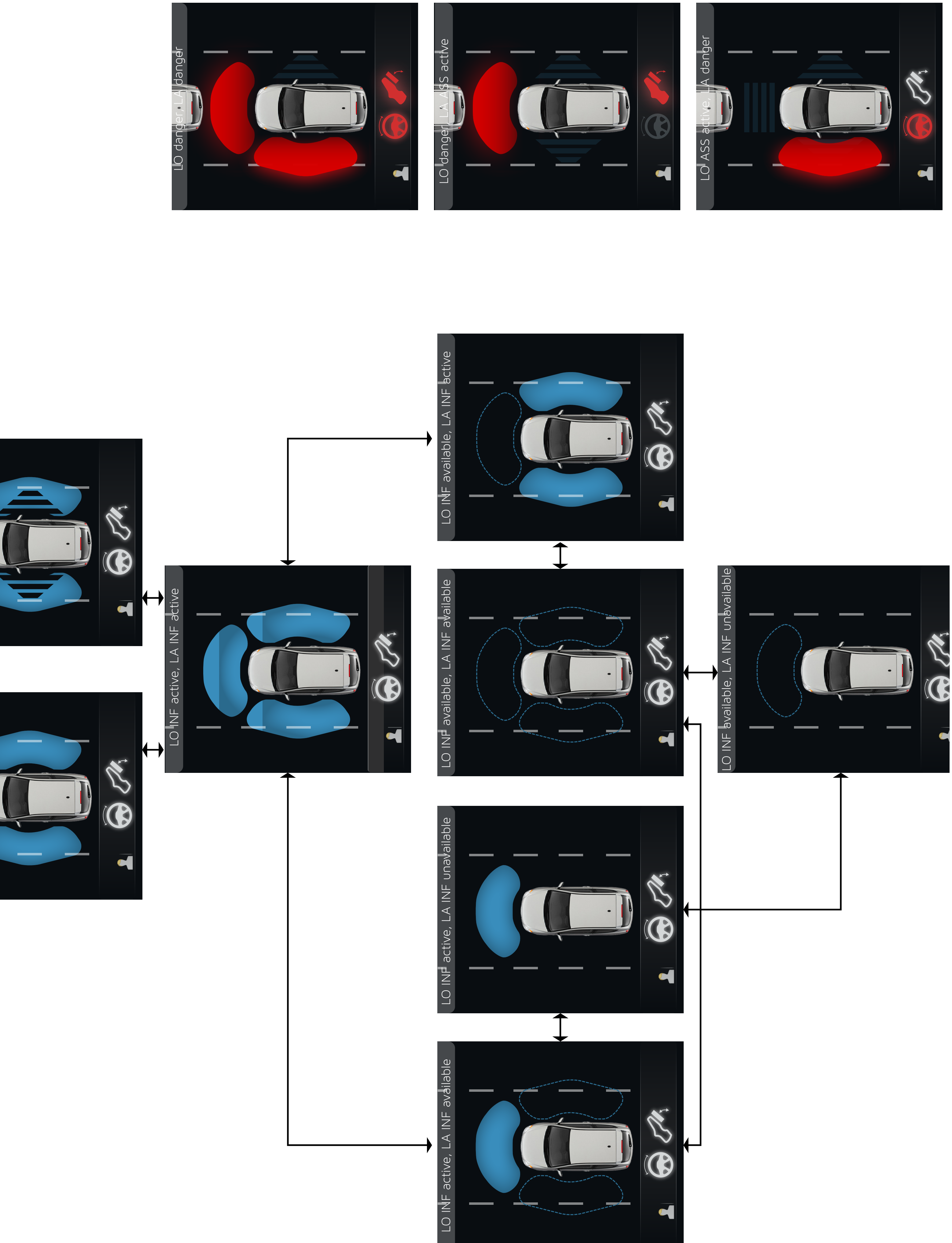


Fig. **26**: The interface state flow for the Human Control Interface. The Automation Control interface exists of the same states and representations, only the status indicators beneath the interface differ.


LO danger, LA danger
LO danger, LA ASS active
LO ASS active, LA danger
LO INF available, LA INF active
LO INF active, LA INF active
LO INF available, LA INF available
LO INF available, LA INF unavailable
LO INF active, LA INF unavailable
LO INF active, LA INF available

X EXPLORATORY EXPERIMENT FRAMEWORK

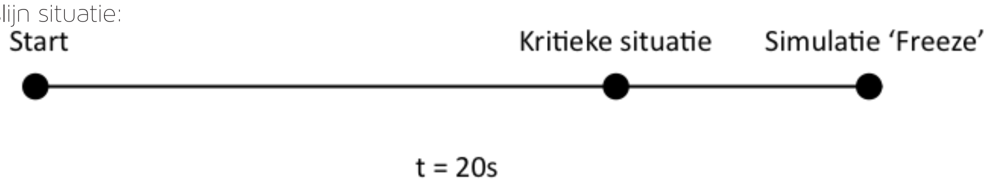
Instructies voor de proefpersoon

Dit interview dient ter optimalisatie van het ontwikkelde interface concept voor het (de)activeren van Traffic Jam Assist, een Highly Automated Driving System van Ford.

Tijdens dit interview zal u als proefpersoon plaatsnemen in de rijsimulator alvorens u een drietal situaties te zien krijgt. Voor iedere situatie wordt afgespeeld krijgt u uitgelegd waar u op dient te letten. Op het kritieke moment in de situatie wordt de simulator gefreezed. De verandering qua interface die hier mee gepaard gaat, wordt op papier gevisualiseerd met behulp van de originele interface en de in dit project ontwikkelde interface. De situatie wordt dus tweemaal doorlopen.

Na iedere situatie zal u een aantal vragen worden gesteld over de interface. De bedoeling hiervan is niet een strikte ondervraging, het ontstaan van een discussie is gewenst.

tijdslijn situatie:



Het interview bestaat uit twee delen:

1) ervaringen aan de hand van getoonde scenario's
   - Als start krijg u de status van beide interfaces te zien. Vervolgens wordt de simulatie gestart, de situatie duurt +- 20s.
   - Observeer alsof u in een echte auto zit. Denk er echter aan dat u een monitorende (ipv actieve) functie hebt, de auto rijdt zelf in de file.
   - Het interview is bedoeld voor het optimaliseren van de interface, uw reactievermogen of manier van ingrijpen is in deze test niet van belang.

2) uitleg en brainstorm aan de hand van getoonde statussen van de interface
   - U zult een aantal statussen van de nieuwe interface te zien krijgen. Doel van dit deel is inzage krijgen in de duidelijkheid van (onderdelen van) de interface en de mate van herkenning door de proefpersoon.
   - Dit onderdeel wordt na het bespreken van de drie situaties (en discussie) uitgevoerd.

Afname test

Na iedere situatie zijn de volgende vragen gesteld om te controleren of de proefpersoon de overgang in de interface (en het verkeer) begrepen heeft.

Vraag 1: Is het duidelijk welke automatisering (het niveau in zowel laterale als longitudinale richting) na de transitie beschikbaar is?

Vraag 2: Naar welke interface gaat je voorkeur in deze situatie uit?
   a) Heeft de stap in automatisering hier mee te maken?
   b) Heeft de weergave van voorwaarden/condities hier mee te maken?

Een lijst met mogelijke vragen voor de brainstorm is hieronder weergegeven. De proefpersoon is uitgedaagd om zijn of haar mening te geven over de interfaces en te onderbouwen waarom dit zo is.

Vragen met betrekking tot deel 1:

- Welke automatisering is bij de 'freeze' actief?
- Is dat idee gebaseerd op de simulatie of op de getoonde interface op het beeldscherm?
- Vind je dat dit duidelijk is weergegeven?
- Bij welke interface ligt je voorkeur?
- Is deze keuze gemaakt op basis van de ervaring in automatisering of puur op basis van het grafische aspect?
- Is het je duidelijk waar de waarschuwing op slaat?
- Vind je de additie van een richtingsafhankelijke waarschuwing in de nieuwe interface van toegevoegde waarde?
- Wat vind je van de implementatie van de voorwaarden/condities (waaraan het systeem moet voldoen)(in de nieuwe interface) in de statusweergave?

Vragen met betrekking tot deel 2 (aan de hand van de getoonde lateral en longitudinal states):

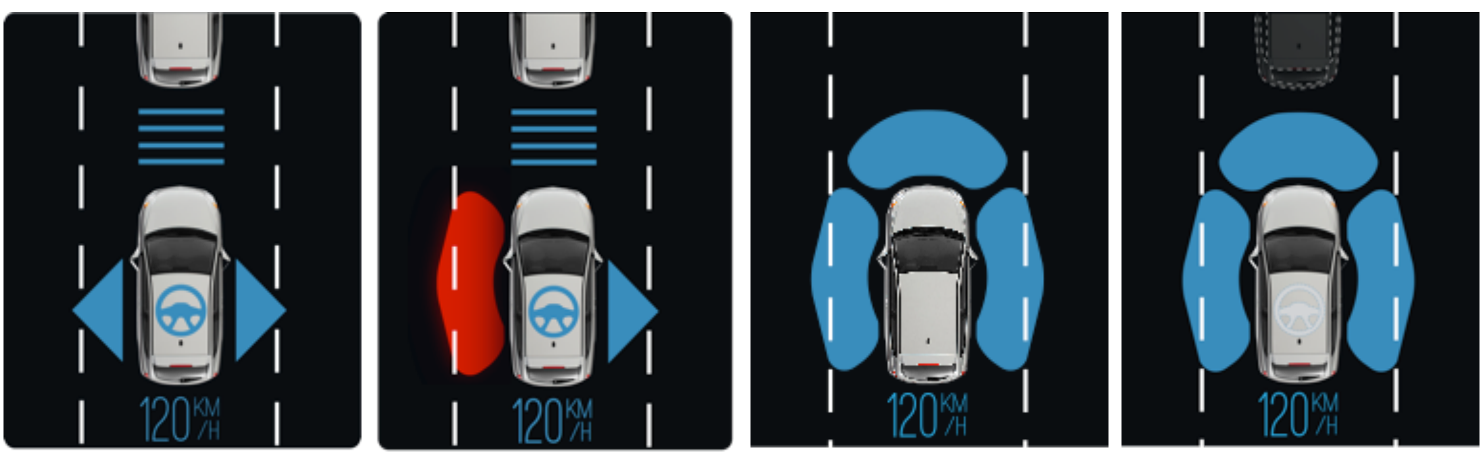
- Wat vind je in het algemeen van de activatie strategie, mbt tot de opdeling in richting (lateraal/longitudinaal) en automatisering (inform, assist, automation)?
- Begrijp je de opbouw in statussen per richting nu je ze voor je hebt liggen? Zitten er onlogische stappen tussen?
- Vind je dat de iconen duidelijk weergeven voor welk niveau van automatisering ze dienen?

Situatie 1: Emergency Brake

Transitie interface 1

1) Voor | 2) Kritieke situatie | 3) Na | 4) Na x aantal seconden

Transitie interface 2

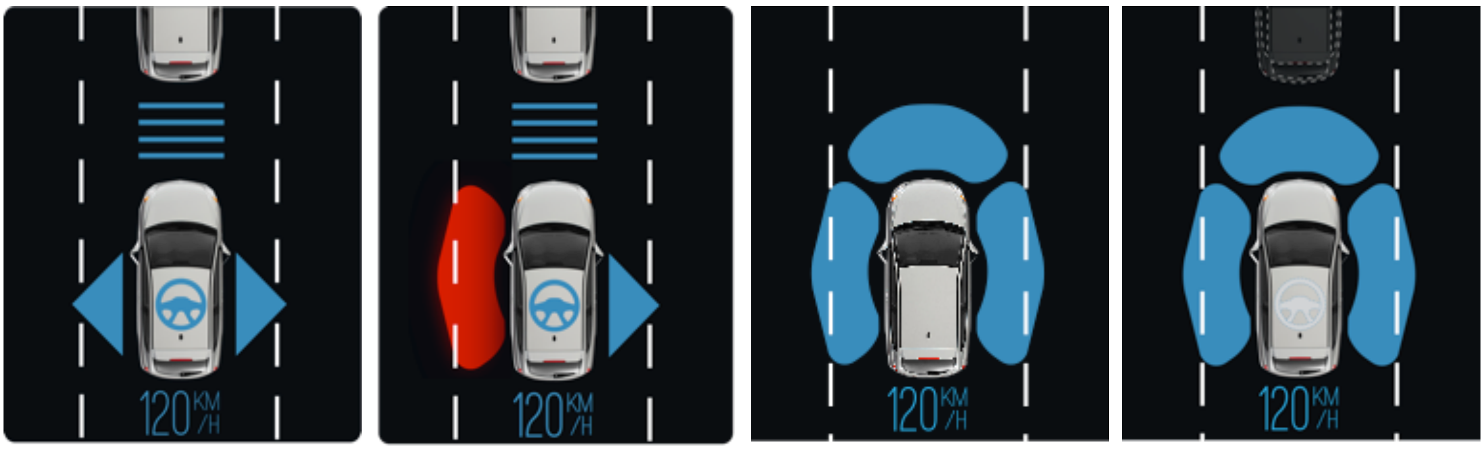


Situatie 2: Close Cut-In

Transitie interface 1

1) Voor | 2) Kritieke situatie | 3) Na | 4) Na x aantal seconden

Transitie interface 2

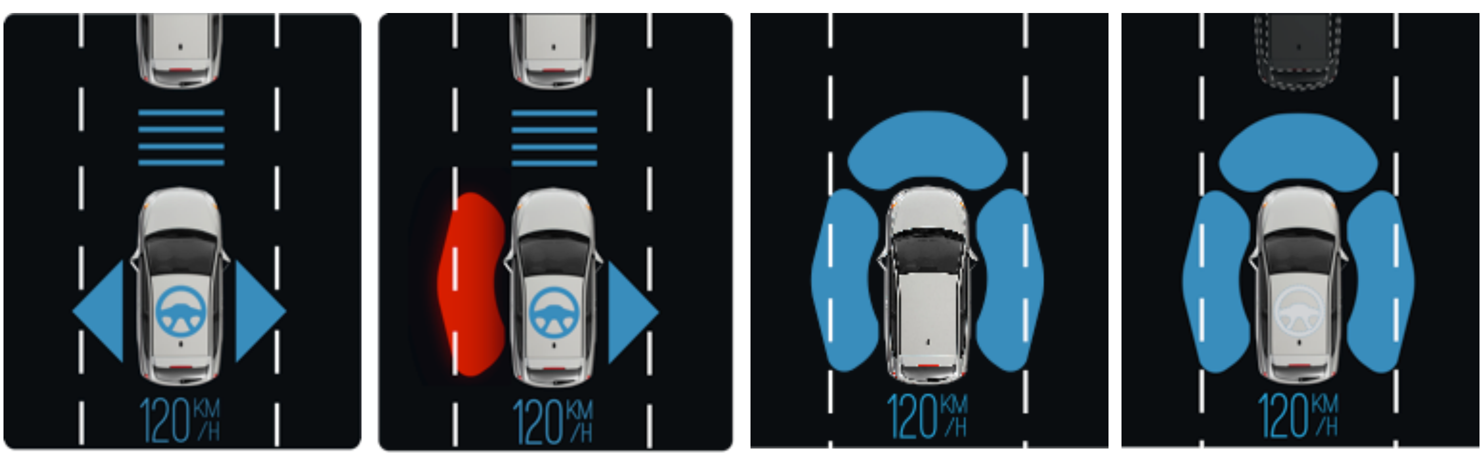


Situatie 3: Cut-Out

Transitie interface 1

1) Voor | 2) Kritieke situatie | 3) Na | 4) Na x aantal seconden

Transitie interface 2



XI DRIVING SIMULATOR EXPERIMENT FRAMEWORK

Test Interface concepts of continuous feedback system status TJA

Scope
Comparison of two interface types for TJA with regard to their comprehensiveness (i.e. ease of understanding), attractiveness and contribution in gaining S.A. and retrieving control.

Background
Robin Vermeulen has developed two interface concepts for providing continues (graphical) feedback on system status. The aim with this interface is that the driver can see and easily understand what state the system is in (at any moment), e.g. whether longitudinal support is active in terms of informing or actively assisting and likewise for lateral support. Besides, at the moment it is required to take over control, the interface should inform about the changed role of the driver.

One interface concept, called 'Automation control' (AC) emphasizes the role of the automation and the concept tries to explain this role with graphics and text labels as explicit as possible. Based on reasoning and learning, a driver needs to discover what role he has (see graph 1). The other interface concept is called 'Human control' (HC) and emphasizes the role of the driver by visualizing the driver's role, i.e. it uses an avatar and symbols for steering (lateral control) and using the pedals (longitudinal control)(see graph 2).

Interface 1: Human Control indicators

Interface 2: Automation Control indicators

Driving Simulator Conditions
Because the scope is to assess the interface concepts with respect to the ease in which they bring across the state the system is in and the role of the driver, the simulator is programmed with different situations of automated driving, which evoke change of system state. These situations are:
(1) EB – Emergency brake:
The lead vehicle makes an emergency brake manoeuvre. The system is programmed to require a TO of the driver when deceleration exceeds 0,3G which is the case in this situation.
(2) CI – Cut in:
A vehicle, leaving the left lane, merges in too closely in front of the ego vehicle at the right lane and brakes hard. It emulates a situation where the vehicle which cuts in has to reach an exit which is almost past. The ego vehicle has to decelerate with more than 0,3G resulting in a requested take over of the driver.
(3) CO – Merge out
The lead vehicle merges out to the right lane leaving an (almost) empty left lane in front of the ego vehicle. Result is a step back in automation, complete automation is no longer possible, the driver has to partly take over.

Setup & Order of Trials

<table>
<tr><td colspan="4">Interface session 1</td><td colspan="4">Interface session 2</td><td rowspan="4">Comparison between interface</td></tr>
<tr><td colspan="3">Random order of conditions
EB; CI; CO</td><td rowspan="3">Questionnaire</td><td colspan="3">Random order of conditions
EB; CI; CO</td><td rowspan="3">Questionnaire</td></tr>
<tr><td>Trial 1</td><td>Trial 2</td><td>Trial 3</td><td>Trial 1</td><td>Trial 2</td><td>Trial 3</td></tr>
<tr><td>RT</td><td>RT</td><td>RT</td><td>RT</td><td>RT</td><td>RT</td></tr>
</table>

To account for learning effects during the experiment, the order of using concepts AC and HC within the first and second session will be alternated.

Measurements

- The contribution in retrieving control will be measured with Reaction Time.
- The ease of understanding and attractiveness will be measured by using Likert scales (The aspects on the Likert scale t.b.d.)
- Ease of understanding will be assessed within a short interview (qualitative assessment of the likes and dislikes per concept and the under laying reasons/causes)
- Concept preference will be measured by a score card (maybe for multiple aspects)

Enquête 1: Herkenning van situatie in interface

Deze vraag wordt direct na iedere trial gesteld. In totaal zal de vraag dus 6 keer beantwoordt worden.

1) Is het duidelijk wat de interface weergeeft met betrekking tot de actieve rijondersteuning?

A. De actieve rijondersteuning is het volgen van de voorligger.

B. De actieve rijondersteuning is het binnen de lijnen houden van de auto.The

C. De actieve rijondersteuning is het volgen van de voorligger én het binnen de lijnen houden van de auto.

D. De actieve rijondersteuning is het waarschuwen voor ander verkeer voor en naast de auto.

E. Geen idee

Enquête 2: Beoordeling van de interface op basis van de drie trials

Deze vragenlijst wordt direct na het uitvoeren van 3 trials, een complete interface, afgenomen.De vragenlijst komt dus twee keer, voor iedere interface, voorbij.

nuttig	☐	☐	☐	☐	☐	zinloos
plezierig	☐	☐	☐	☐	☐	onplezierig
goed	☐	☐	☐	☐	☐	slecht
effectief	☐	☐	☐	☐	☐	onnodig
leuk	☐	☐	☐	☐	☐	vervelend
gewenst	☐	☐	☐	☐	☐	ongewenst
aangenaam	☐	☐	☐	☐	☐	irritant
behulpzaam	☐	☐	☐	☐	☐	waardeloos
waakzaamheidverhogend	☐	☐	☐	☐	☐	slaapverwekkend
vooruitstrevend	☐	☐	☐	☐	☐	conventioneel
betrouwbaar	☐	☐	☐	☐	☐	onbetrouwbaar

Driving Simulator Conditions Enquête 3: Vergelijking tussen interfaces

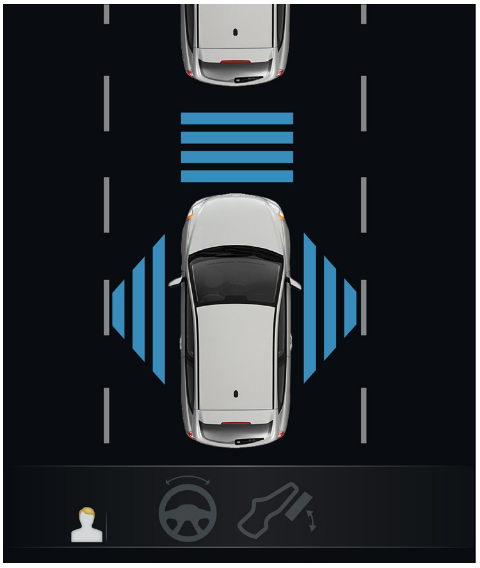
Deze vragenlijst wordt na het uitvoeren van alle trials voor beide interfaces afgenomen.

Geef voor de volgende stellingen aan wat je voorkeur is en waarom.

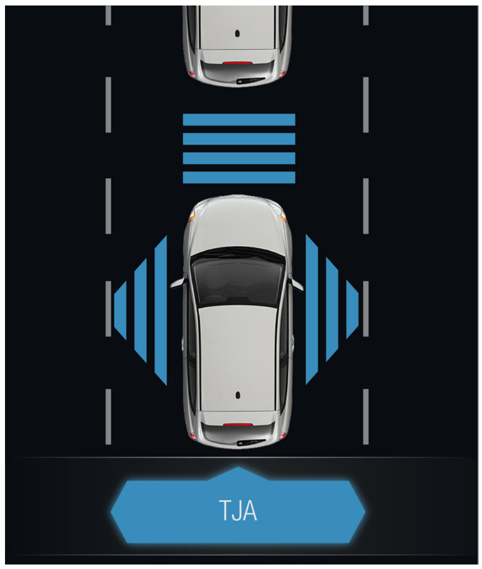
1) Mijn persoonlijke voorkeur gaat uit naar interface 1 / 2
2) Ik verwacht dat de gemiddelde automobilist een voorkeur heeft voor interface 1 / 2

Maak voor de volgende begrippen een keuze tussen beide interfaces. De vakjes representeren de mate waarin u interface 1 of 2 het meest toepasselijk vindt waarbij het meest linker vakje totaal bij interface 1 past en het meest rechter vakje totaal bij interface 2 past.

Interface 1: Human Control



Interface 2: Automation Control



Duidelijkheid van instructies rol bestuurder

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ geen mening

Duidelijkheid van actieve systeem status

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ geen mening

Aantrekkelijkheid van de interface

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ geen mening

Vertrouwen in systeem

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ geen mening

Effectiviteit indicatoren van de interface

Interface 1 ☐ ☐ ☐ ☐ Interface 2 ☐ geen mening

Aansluitend op antwoord op deze punten zal in een korte discussie getracht worden te achterhalen waarom de proefpersoon deze keuze hebben gemaakt en waarom hun voorkeur bij de betreffende interface ligt.

REFERENCES

I TJA take overs
TJA Functional Spec, Ford Technology Internal Document, 28-10-2011.

II Other interfaces
Volvo IDIS, last visited 28-04-2013
http://www.volvedia.com/inf-58.html
http://www.volvocars.com/nl/sales-services/services/volvo-van-a-z/pages/i.aspx#intelligent
http://www.roadsafe.com/news/article.aspx?article=210
Mercedes Distronic Plus, last visited 28-04-2013
www.youtube.com/watch?v=qECD4GivF_8
http://techcenter.mercedes-benz.com/en/active_blind_spot_assist/detail.html
http://techcenter.mercedes-benz.com/en/active_lane_keeping_assist/detail.html
http://www.daimler.com/dccom/0-5-1210218-1-1210321-1-0-0-1210228-0-0-135-0-0-0-0-0-0-0-0.html
Illustration Distronic Plus, last visited 28-04-2013
www.youtube.com/watch?v=qECD4GivF_8
Driver Alert, last visited 28-04-2013
http://nl.euroncap.com/nl/rewards/ford_driver_alert.aspx
Illustration Driver Alert, last visisted 20-04-2013
http://nl.euroncap.com/nl/rewards/ford_driver_alert.aspx

III Ford iconic language
2013 Ford Fusion user manual, last visited 20-04-2013
http://www.motorcraftservice.com/pubs/content/~WODFSN/~MUS~LEN/42/13fsnom3e.pdf
Autoblog Italia, last visisted 23-07-2013
http://www.autoblog.it/galleria/30-anni-fiat-panda/24

IV Cognitive Aspects
Perception and attention, last visited 20-04-2013
http://en.wikipedia.org/wiki/The_Magical_Number_Seven,_Plus_or_Minus_Two
Wickens, C.D. Lee, J.D., Liu, Y. and Gordon Becker, S.E. (2004) An Introduction to Human Factors Engineering. Pearson Education, New Jersey.

V Design Guidelines
Nielsen's Heuristics
Molich, R., and Nielsen, J. (1990). Improving a human-computer dialogue, Communications of the ACM 33 , 3 (March), 338-348.
Nielsen, J., and Molich, R. (1990). Heuristic evaluation of user interfaces, Proc. ACM CHI'90 Conf. (Seattle, WA, 1-5 April), 249-256.
Nielsen, J. (1994a). Enhancing the explanatory power of usability heuristics. Proc. ACM CHI'94 Conf. (Boston, MA, April 24-28), 152-158.
Nielsen, J. (1994b). Heuristic evaluation. In Nielsen, J., and Mack, R.L. (Eds.), Usability Inspection Methods, John Wiley & Sons, New York, NY.

Thirteen principles of display design
Wickens, Christopher D., John D. Lee, Yili Liu, and Sallie E. Gordon Becker. An Introduction to Human Factors Engineering. Second ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2004. 185–193.
Brown, C. Marlin. Human-Computer Interface Design Guidelines. Intellect Books, 1998. 2–3.

Driver Focus Guidelines
Statement of Principles, Criteria andVerification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems. 26-06-2006.