F2014-AHF-054

DESIGN CONSIDERATIONS ON USER-INTERACTION FOR SEMI-AUTOMATED DRIVING

Van den Beukel, Arie P.*; Van der Voort, Mascha C.
University of Twente, Netherlands.

KEYWORDS – semi-automated driving, human machine interface, supervisory control, retrieving control, system awareness, mode changes

ABSTRACT – The automotive industry has recently made first steps towards implementation of automated driving, by introducing lateral control as addition to longitudinal control (i.e. ACC). This automated control is allowed during specific situations within existing infrastructure (e.g. motorway cruising). During these circumstances, the role of the driver changes from actively operating the vehicle to supervising the system. Due to being placed remote from the control-loop, vigilance and overreliance, performing supervisory tasks is something humans are typically not very good at. For this reason, Human Factors experts have often raised concerns about the implementation of semi-automation. Nonetheless, we observed that recommendations on how to design appropriate interaction between driver and automation, are rather scarce. Therefore, we reviewed Human Factors' literature and three existing interface examples to retrieve recommendations on desired driver-vehicle interaction. The most important design considerations were: (a) Avoid mode confusion by informing the driver appropriately about system state; (b) Support awareness of the system's operational envelope, i.e. helping drivers understand the boundary limits within which the automation is able to operate; (c) Provide instructions with respect to the required role of the driver. From the examples reviewed, we concluded that interfaces representing a road situation graphically, while depicting elements relevant for system functioning (e.g. detection of road lines and/or target vehicle), provide effective solutions to support driver's awareness of the system's operational envelope. Nonetheless, we observed that there is at this moment no univocal understanding of what kind of interface mechanism works overall best. No consensus has been reached on appropriate ways to communicate mode-changes and to effectively instruct drivers when a role-change is required (i.e. retrieving control). Because confusion might easily occur when needing to interpret mode-information in time-critical situations and revealing the associated driver's role, we strongly recommend more focus on drivers' instructions in the development of future interfaces.

1. INTRODUCTION

Automotive industry has recently made first steps towards implementation of automated driving for the consumer market through the market introduction of driver assistance which allow both lateral and longitudinal system control during specific situations within existing infrastructure (e.g. motorway cruising). The industry's choice to introduce the technology on a basis of semi-automation is, besides for legal and liability reasons, due to technical boundaries within which the introduced system is able to operate (e.g. automation is only possible when a target vehicle is detected). This requires human (driver) readiness to act as a back-up in case automation fails or exceeds her boundary limits. The role of the driver therefore changes from actively operating the vehicle to supervising the system during automation. Time and again, Human Factors experts have raised concerns about such implementation of semi-automation [1] [2] [3], since performing supervisory tasks is something humans are typically not very good at. This is due to low vigilance and because the supervisory role makes the driver being placed remote from the control-loop, causing e.g. slower reaction times and misinterpretation when intervention is needed [4]. Despite the expected advantages of automated driving, like raising comfort and road safety [5] [6], driver-interfaces need therefore to be designed carefully in order to support drivers in their additional role to supervise the automation and taking over control adequately when required. Nonetheless, we observe that recommendations on how to design appropriate interaction between driver and automation, are rather scarce. As first systems are now being introduced to the market we therefore reviewed existing literature and some field examples to retrieve recommendations on desired driver-vehicle interaction. Therewith this study serves as an attempt to explore effective interface mechanism as well as a means to gain insight in the associated requirements for adequate solutions. As the industry's current focus of semi-automation is on adding lateral control (i.e. steering assist) to existing solutions for longitudinal control (i.e. adaptive cruise control with stop & go functionality) our focus is on automation with the same profile. Furthermore, we consider the driving automation as 'soft' automation, meaning that the automation is user-initiated and can be overruled anytime [7]. Hence, for our application of driving automation the ultimate authority is at the human operator.

2. DESIGN CONSIDERATIONS FOR SEMI-AUTOMATED DRIVING

In this study semi-automation is defined within the context of *driving automation* as described by Young et al. [7]. In contrast to *vehicle* automation involving purely operational tasks without tactical aspects (e.g. choosing gear or activating wipers), *driving* automation refers to automation that also includes tactical aspects, like distance keeping (ACC), parking manoeuvres, or managing stop&go traffic. Compared to vehicle automation, automation of these kind of driving tasks require more in-depth environmental knowledge from road sensor data or GPS data and require more complex decision making. Furthermore, we define semi-automation as the automation-state where the vehicle has capabilities of fully automated driving (i.e. both longitudinal and lateral control) within existing infrastructure but under limited traffic circumstances and where the driver remains responsible for safe driving at any time. That is why we call it semi-automation. Those limiting circumstances relate to technical boundary conditions and choices in system design. Most of these choices are based on desired system's reliability. Examples are the inability to keep lateral control when either road lines or a target vehicle fails, or non-availability of automation when the vehicle is not on a motorway. Characteristic for semi-automation is therefore that transitions to take over control by the human driver are an inherent part of the system. Moreover, the environment is relatively uncontrolled with ad hoc and improvised interactions between road users. Therefore, required take-over of control might occur unexpectedly and in (time-)critical situations.

As mentioned in the introduction, human factors experts have raised many concerns for semi-automation. Therefore this section with design considerations is mainly based on an human factors' perspective. Because, semi-automated control is also known within aviation for many years now, we include some design considerations that originate from this domain. We conclude with a list of desirable aspects for appropriate driver-interaction which we will use to review three existing solutions for semi-automation in the next section.

2.1. Design Considerations from a Human Factors' Perspective

Some of the concerns expressed by Human Factors experts, are caused directly by automation itself. Other concerns are the mere result of applying semi-automation. Meaning that during automation the driver is placed remote from the (control)-loop causing reduced situation awareness and erratic mental workload. The consequences of these issues are reduced driver's performance, in particular: slower reaction times, misunderstanding what corrective actions need to be taken [8] and skill degradation (loss of both psychomotor competence as well as reduced cognitive skills) [2]. All consequences that may lead to dangerous situations, especially for our application of semi-automation where the driver is required to function as a back-up and sometimes needs to take over control. Therefore these issues will now be explained and reflected upon, in order to gain insight how we can account for it with the design of interfaces for semi-automated driving.

Providing appropriate trust – Overreliance describes an operator's mind-set in which he or she trusts the system to such extent that counterchecks on automation performance and status are neglected. As a result situations in which automation performance is reduced might not, or too late, be detected. Sometimes an inappropriate level of trust could be the result from mode-confusion, like an operator believing the system is in a particular mode, but in reality it is not. Within aviation, mode-confusion is related to many incidents [7]. An automotive example of mode-confusion is often reported in association with ACC (e.g. [9]) where drivers in a reflex have pushed the brake without realizing that this also terminated ACC and are subsequently vainly waiting for the vehicle to accelerate again. To help avoiding overreliance and mode-confusion the interface should help with raising *awareness of the system's operational envelope* – A good awareness of the operational envelope allows a driver to anticipate beforehand on changes due to approaching system's boundary limits. As creating awareness of the operational envelope might reduce surprises, this is also likely to help driver readiness in case he or she is required to take over control. Most boundary conditions relate to sensor limitations and system design choices. The interface should help in communicating these conditions. An example is to indicate if road markings are registered or not. If a driver then enters a section with bad road conditions this awareness would help to anticipate and understand that the lane markings might be insufficient for the system to deal with. Hence, we recommend that the interface should provide insight in the system's operational envelope.

Avoiding behavioural adaptation – In low risk situations humans tend to adapt their behaviour to restore their target level of personally acceptable task-risk. Automation might easily be perceived as a low risk situation due to overreliance. Driver behaviour might therefore be adapted to being involved in more risk-full situations and therewith (partially) diminishing the safety advantages that the automation is trying to achieve. An example is that drivers with ABS and ESP equipped vehicles allow themselves to drive faster under bad weather circumstances than how they would with an unequipped vehicle. Also drivers have been observed [10] to adapt their lane-change behaviour to achieve higher cruise speeds when driving with ACC. Since behavioural adaptation is related to people's mid- to long-term experience with a system, it is difficult to make clear design recommendations. However, *awareness of the operational envelope* (as explained above) is intended to help gaining the right expectations and could therewith influence adaptation in a preferable manner. However, further research is needed on the relationship between design considerations and avoiding counter-productive behavioural adaptation.

Avoiding mode confusion – Due to automation a driver is placed remote from the control-loop. This reduced involvement in actual vehicle control also causes reduced awareness of the situations associated with performing these tasks. In the context of semi-automated driving, Situation Awareness relates to both traffic situations as well as automation state. While aviation has long experience in applying automation, a lack of mode-awareness (or confusion) has been linked with many accidents in that area [7]. Hence, *avoiding mode confusion* will be very important for semi-automated driving as well. Reduced mode-awareness might be due to several reasons. One reason is inappropriateness in which mode-information is being conveyed. With other words, an operator simply does not understand what the provided mode information means. With raising complexity and different available modes, mode confusion might easily occur, causing a mismatch between what an operator considers to be the mode the system is in and the actual mode. Another reason for confusion might be insufficient transfer of information when a mode-*change* occurs; in other words an operator simply doesn't notice a change. Thirdly, a reason could be inadequate possibilities to *check* status-information at any desired moment. Even when mode-information would be transferred in an efficient manner, for reasons of confidence and comfort (e.g. rather recognising status information than being obliged to recall information [11]), it is important that a semi-automated system allows to review status-information at any time.

Avoiding confusion about the driver's role – Providing mode-information is important because it allows drivers to gain insight in who is doing what. However, mode-information typically indicates the state of the automation while only indirectly explaining the driver's role. From deduction the driver needs to reveal what task is left and this again leaves room for misinterpretation ("if the system does lane keeping, does that mean that I am responsible for longitudinal control?"). Moreover, mode-changes are often the result from exceeding system's boundary limits and are therefore likely to appear suddenly and unexpectedly. Hence, these circumstances hamper the ability to interpret the mode-information correctly. Therefore we conclude that an appropriate interface should *explain the role of the driver*, meaning that it should communicate the desired tasks of the driver explicitly, especially at moments when a transition in control is desired.

Avoiding erroneous counter-reactions – As mentioned before, mode confusion has been linked with many aviation accidents and is especially disastrous if the confusion causes inappropriate counter-reactions with the operator or system erroneously assuming that the other is operating according to a specific mode, but in reality is not. Within the automotive field an example of such erroneous counter-reactions is reported by Schmidt & Young [12], i.e. situations in which a driver with automated transmission unintendedly hits the acceleration pedal in an attempt to brake. As the vehicle doesn't stop, the driver pushes stronger and this causes the system's perception of a request for extra power and subsequently the kick-down is being activated. Although other examples are scarce, we cautiously recommend to let the automated system *not provide counter-reactions* after mode-changes. Consequently, if an operator is required to take over, then he/or she should take over completely without the system still operating to some extent. An example is a congestion assistant being designed to rely on detection of a target vehicle for providing lateral control. As mentioned in the introduction, lateral control is often an addition to longitudinal control. If detection suddenly fails (e.g. because the target vehicle changes its lane and no new target is present), the driver would be requested to take over. However, if at the same time the system falls back to longitudinal control (i.e. ACC) and the set speed is high, the vehicle would start accelerating. It is likely that such behaviour would interfere with the intentions of the driver, causing a dangerous situation.

Influence mental workload to be at a moderate level – During automation workload is typically low because the driver is placed remote from the control loop. Low levels of workload are related to vigilance, reduced situational awareness and behavioural adaptation. Although these consequences are issues in themselves and despite the fact that automation is intended to relieve human task operation, automation causes (compared with completely human operation) also instances of extra workload or even *over*load if human tasks to take-over control are required in unexpected and/or critical situations. Therefore it is a misunderstanding that semi-automation naturally makes the driving task easier. If everything goes smooth, it raises comfort. The complex interaction between human and system operation might however in critical situations cause moments with high levels of workload and stress. Therefore we recommend the interaction to be designed to influence mental workload at a moderate level (not too high and not too low). Within European projects (e.g. AIDE) concepts for a workload manager have been developed that reduce or take away the availability of secondary tasks in moments that are likely to require extra or full driver's attention. Nonetheless, solutions to avoid overload when taking over control in critical driving situations are not readily available.

Directing attention to vital information – Situations of high workload are likely to occur in critical situations where the driver is required to take over control very suddenly. Due to the driver being placed remote from the control loop, intervention after automation it is even more difficult to manage. Therefore the identification of hazardous situations and providing directional information on the location, distance and criticality of such situation is assumed to be key for the interface in helping the driver to react appropriately and timely. We therefore recommend that the interface supports the *moment of take-over* and stimulates *driver readiness.* As the relevant information and cues about the traffic situation are retrieved from the environment around the vehicle, support should be aimed at directing the driver's attention to the correct locus outside the vehicle. Interface mechanism to steer the driver's attention are still in a preliminary and experimental stage. However solutions with LED-strips around the windscreens seem promising [13] while differentiation in location, size and intensity of lid up LEDs, provide cues about location and urgency of an event. Moreover, Martens & Van den Beukel [4] proposed to take away secondary tasks and subsequently 'force' a change towards attention outside the vehicle. Furthermore, mechanisms based on force-feedback seem worthwhile to investigate further, since information transferred via the neuro-muscular system is transported faster and enables quick cognitive throughput [14].

Sharing authority – Furthermore, Young et al. [7] pose the consideration to implement driving automation as 'shared automation'. Within this concept the ultimate authority is still at the driver, but the automation and driver are intended to work as 'teammembers' and complement one another for managing the driving task as a whole. The interface should then serve as a means for cooperating and sharing the authority. Other researchers have proposed similar ideas, like Norman's [15] reflection on automation acting as a human co-driver and Schutte [16] refers to the roles of driver and automation as 'complemation'. With this approach, we would try to be using the capabilities of technology to exploit the human's strengths while compensating for their weaknesses. Or in other words, combining the best of both 'worlds' to improve the driving task as a whole. Nonetheless, for directions on how the interface could help achieving this idea of 'shared authority' further research is needed.

2.2. Summarizing: Desirable Aspects of User-Vehicle Interaction for Semi-Automated Driving

The considerations from the previous section are combined to compile the following list we consider base-line for achieving appropriate driver-interaction:

- *Avoid mode confusion* by informing the driver appropriately about system state. In addition, an interface needs to enable drivers to check the automation state any moment.
- *Provide instructions* with respect to the required role of the driver, especially at moments of mode-changes in order to avoid confusion about the required driver's role.
- *Promote driver readiness* and keep the driver at a reasonable level in the loop.
- *Support the driver to return in the control-loop fast and easily*. For example, force-feedback and interruption of secondary tasks might be considered to actively direct attention away from the secondary task back to the driving task.
- *Support awareness of the system's operational envelope;* helping drivers understand the boundary limits within which the automation is able to operate.
- *Avoid counter-reactions* from automation after mode-changes

It has to be mentioned that the list does not reflect the role an interface has in raising acceptance. However we do affirm that acceptance is likely to be linked to the particular interaction-design. After all, if supervising the system requires more efforts than manual control, acceptance is likely to be absent. Acceptance will also be influenced by the interplay between these required efforts and the benefits a driver gains from being able to perform secondary tasks more easily during automation. These are all aspects that can be influenced with the particular interaction-design. Hence, we recommend to include acceptance as one of the aspects for assessment of future interfaces concepts.

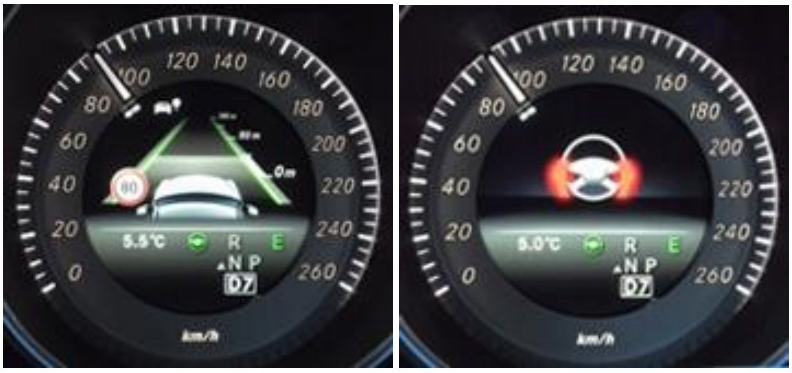
3. REVIEW EXISTING SYSTEMS AND IDEAS

As first systems for semi-automated are now being introduced to the market, these systems will be held against the design considerations formulated in the previous section. The intention of the review is to gain insight in what recommendations find adoption and what aspects seem overlooked. The systems we choose to review are the Mercedes-Benz system called 'Distronic plus with Steering Assist' and BMW's 'Traffic Jam Assist', as these system were one of the first being introduced on the market. Due to practical limitations, this review has not the intention to explore the possibilities for effective interface mechanism to its full extent. However, we wanted to achieve some exploration by including an interface proposal retrieved from an European project, called ‘interactIVe’. Furthermore, we reviewed the BMW system with an additional (not commercially available) feature: an illuminated ring on the steering wheel, as has been revealed by Schaller et al. [17].

3.1 Mercedes-Benz Interface for Distronic Plus with Steering Assist

Mercedes-Benz’s ‘Distronic Plus’ is an adaptive cruise control system with stop-start functionality, meaning that it maintains speed (cruising) and adapts distance when a target vehicle is detected, This functionality is also offered when the target comes to a complete stand-still and drives off again. The ‘Steering Assist’ encompasses lane centring and is designed as ‘add-on’. As a result, Distronic Plus needs to be activated first, before Steering Assist could be activated as well. The interface visualisation needs to accommodate both states. This is provided by depicting in bird’s eye-view the front of the own vehicle and a target vehicle. Therewith, the interface is able to display pre-set headway distances and actual follow-distance. In contrast to this sophisticated visualisation, the Steering Assist function is by default indicated only with a small steering wheel. See the green wheel below the ego-vehicle in Figure 1a. The colour of this steering wheel can change from grey to green depending on its activation state (available or activated). The interface provides some information about the environment the vehicle is in: It shows if lane markings are recognised with a green glow at the depicted road lines. It also shows the current speed limit based on GPS data. This might help to gain some situation awareness and to help understanding the system boundaries.

Characteristic for the Mercedes-Benz system is that it is designed with the obligation to keep your hands on-the-wheel. If a driver takes his hands off the wheel approximately longer than 15 seconds, the interface gives a warning tone in combination with a visible warning as shown in Figure 1b. If after 5s no hands have been placed on the wheel, lateral control is shut off. The visible warning to urge hands on the wheel shows red glowing hands on a steering wheel, while replacing the before mentioned bird’s eye-view. In the opinion of the authors, the absence of the cruise control visualisation (i.e. vehicle in bird’s eye-view, cf. fig. 1a) in combination with the prominent steering wheel picture could lead to confusion as drivers might think that ACC is not available anymore and that they would need to take over control completely.

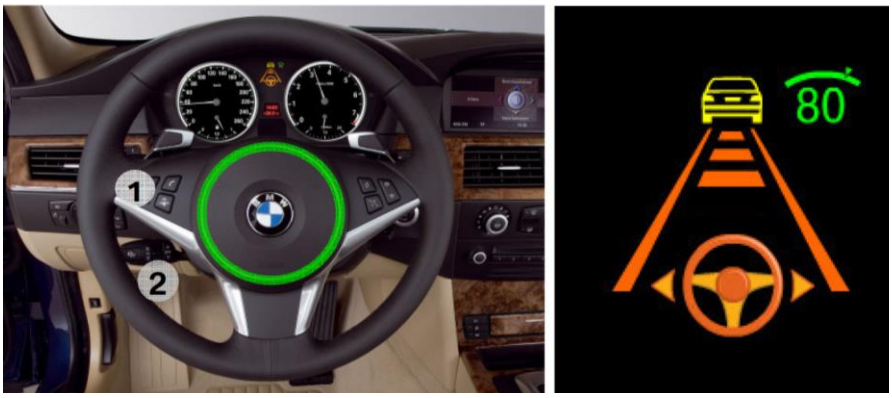


(a) *(b)*

Figure 1: Mercedes-Benz Distronic Plus with Steering Assist (Pictures: author’s archive)

3.2. BMW Traffic Jam Assist

Similar to the Mercedes-Benz system, BMW’s Traffic Jam Assist consists of actively controlling lane position in addition to longitudinal control, i.e. ACC. The system is available up to 40 km/h and as long as the driver keeps at least one hand on the steering wheel. The system is therewith clearly intended to alleviate the driver while passing through congestion. The visual interface shows a schematically road section with target vehicle, comparable with the Mercedes-Benz interface. The visualisation shows pre-set time headway as well as actual (relative) driving distance. At moments driver intervention might be required, the interface shows additional explanatory warnings at the centre display. However, dividing information over the instrument cluster and centre display could hinder to focus attention, especially when attention is needed outside the vehicle. The steering aid functionality is depicted with a steering wheel and two arrows to indicated that the system actively controls lane position. The previous interface (from section 3.1 and visualised in Figure 1) showed a picture with hands at both sides of the wheel to explain the opposite (i.e. requiring hands on the steering wheel). In the opinion of the authors, showing a steering wheel symbol could cause confusion whether the system is ‘using’ the steering wheel to control the vehicle or that the user should be controlling.



(a) *(b)*

Figure 2: BMW's interface for Traffic Jam Assist. An additional feature shown in (a) consists of an illuminated ring on the steering wheel to provide feedback on system status. Picture (b) shows the standard interface. (Picture: adopted from Schaller [17])

During earlier design iterations Schaller et al. [17] have presented an interesting alteration of this interface. They introduced an illuminated ring in the centre of the steering wheel (see Figure 2a) intended to avoid mode-confusion. When this ring is lit up green, the system is active. An advantage is that the light-ring is visible in the peripheral viewing area and helps explaining the steering aid function in itself. Schaller et al. do not iterate on further adaptation of this concept, like using different colours and lit-up behaviour. As this concept could indicate the status of steering assist (e.g. with different colours) as well as provide direct instructions with regard to the required driver's role (e.g. blinking intensively with red colour for urging the driver to take over) and contains a very direct relationship to the device itself that needs to be controlled (i.e. steering wheel), the concept seems interesting for further considerations. However, the interface mechanism does not give explanation *why* a take-over is necessary. Additional information would be necessary to provide awareness of the operational envelope. A study with this interface mechanism shows high acceptance of steering aid as an additive to ACC. However, no conclusion could be drawn to what extent this positive reaction is related to the specific HMI [17].

3.3. Dual-mode Interface from InteractIVe

The main goal of the interactIVe project is the design, development and evaluation of integrated advanced driver assistance systems (ADAS) while focussing on safer and more efficient driving through application of semi-automation. To achieve this goal prototypes have been developed along with an Information, Warning and Intervention (IWI) Strategy. The graphical interface that accompanies this strategy is used for this review, see Figure 3. The graphical interface is intended to be displayed in an instrument cluster behind the steering wheel. A strong point of the interface is that it distinguishes between three levels of driver's assistance: (a) "alert", meaning that the system provides alerts (warnings) to the driver, (b) "active", meaning that the system is able to actively intervene if required, and (c) "assist", meaning that the system actively controls the complete driving task. With these generic levels the design tries to avoid confusion from mixing up the meaning of many separate technical descriptions like FCW, LCA, ACC, ASL, etc. However, the chosen labels of the three levels remain rather 'abstract', leaving again room for misunderstanding. The difference between 'active' and 'assist' is for example difficult to understand. Moreover, the graphical solutions on how to present these levels (i.e. provide mode-awareness) leave room for doubts about their effectiveness. Differences are provided through contrasts in background colour and the presence or absence of an 'halo' (i.e. hairline) around the ego-vehicle, cf. Figures 3a, 3b and 3c. To the opinion of the authors, these differences will be too subtle to notice and too abstract to understand. Nonetheless, something interesting is that the display provides clear instructions to the driver in case of emergencies like the direction to avoid an accident, see Figure 3d. However, it does not provide a clear relation to where the attention is really needed, i.e. outside the vehicle.

(a) (b) (c) (d)

Figure 3: Interface examples from interactIVe: Figure 3b and 3c show respectively a white and blue hairline around the ego-vehicle to distinguish between the level 'Active' of driver-assistance and the level 'Assisted'. (Pictures: author's archive)

3.4. Conclusions from Reviewing existing Interface Examples

As there was only one system available with results from a test drive, the review mainly focussed on the graphical parts of the interface. No attention was given to other interface modalities (audible, haptic, etc.). Table 1 summarises the review's results by describing the relevant characteristics of each system for the most important design considerations. The main function of the graphical interfaces is to reflect system state. Each of the three interfaces show this information quite effectively. However, the subtle graphical differences for the interactIVe interface seem to be least discriminately. Moreover, we observed that the interfaces are in a varying degree successful in educating the driver to understand system state. The Mercedes-Benz interface succeeds best in depicting elements that are relevant for system state, like showing the system's recognition of road lines and target vehicle. However, the interactIVe interface is remiss in explaining why a specific level of driver assistance is or is not available. Furthermore, the interfaces do not provide help in anticipating mode-changes. In this respect it is notable that none of the interfaces is able to provide 'feed-forward', the messages asking for attention or take-over appear all of sudden, asking for immediate attention without prior warning. Especially since giving explanatory information is always difficult in critical situations, we would recommend developers to give more attention to educating the drivers in understanding system state and the system boundaries that influence system-state. This is because better understanding of the relationship between system boundaries and available state would improve drivers' ability to anticipate mode-changes based on changes in the environment. In our opinion the bird-eye's view from all three examples, depicting an ego and target vehicle along with road lines, provides a good basis for offering such information. Furthermore, the interfaces do hardly give clear cues on the required driver's role, but we consider the light ring from the BMW system a promising concept.

Example **Consideration**	**Distronic plus with steering assist**	**Traffic Jam Assist**	**interactIVe**
Avoiding mode confusion &providing mode-info	Visualisation of system state is interrupted by instructions	Basic but consistent and continuously available mode-information	Differentiation in modes is difficult to comprehend
Providing instructions on driver's role	Clear instructions for hands-on-wheel obligation but might be mistaken for take-over request	Instructions provided on centre display, but without direct linkage with real world situation outside vehicle	Clear instructions, but without direct linkage with real world situation outside vehicle
Promote driver readiness	Through hands-on-the-wheel obligation	Through obligation to have at least one hand on the wheel	- no mechanism known -
Support the driver to return in the control-loop fast and easily	Indirectly supported through hands-on-the-wheel obligation	Concept of light ring in steering wheel seems promising	- no mechanism known -
Support awareness of the system's operational envelope	Yes, with respect to line recognition and target detection	Reviewed interface does not provide explanatory information	Rather limited through abstract visualisations of system state

Table 1: Summary of observations from three reviewed interface examples to support driver-system interaction for semi-automated driving.

4. CONCLUDING REMARKS

With market introduction of systems for semi-automated driving new demands for appropriate driver-vehicle interaction arise. Therefore this study formulated considerations for the design of appropriate interaction between driver and automation, along with a review of three existing interfaces. The review focussed particularly on solutions for providing system information and used heuristic evaluations. While providing a graphical road situation in bird's eye view, all three examples effectively showed the interplay between the own and target vehicle and the road lines and related these elements to system functioning. Therefore we expect that providing information on such system-relevant elements graphically and within a simplified road-representation, helps to gain system awareness. Nonetheless, the review does not provide answers about time-aspects of providing mode-information: it remains disputable whether continuous system feedback is necessary or information at the moment of mode-changes suffice. Set beside the achievements in providing system information, the examples showed to be in a varying degree successful in offering instructions to the driver with respect to his or her role. One inspiring example is the light ring on the steering wheel to instruct drivers with their lateral-control task. Based on human factors' recommendations for fast and direct transfer of sensory-input, we expect that combinations of operational controls (i.e. wheel, pedals) with solutions to steer driver's alertness outside the vehicle to the location where attention is needed, provide promising interface directions. Overall, we observe that there is at this moment no univocal understanding of what kind of interface mechanism works best. No consensus has been reached yet on appropriate ways to communicate mode-changes and to effectively instruct drivers when a role-change (i.e. retrieving control) is required. Because confusion might easily occur when needing to interpret mode-information in time-critical situations and when revealing the associated driver's role, we strongly recommend more focus on drivers' instructions in the development of future interfaces. Finally, we observed a limited focus on the cooperation between system and driver in combination with acceptance of the system. Although the systems are clearly considered to support in circumstances where the driver does not have a pleasurable driving experience (jammed traffic, stop&go traffic), acceptance of semi-automation is not necessarily a fact. For acceptance we presume that drivers' efforts for the supervisory task should not exceed manual operation and the benefits during supervisory control should outperform the required efforts. Further research on the interplay between required efforts and gained benefits is therefore recommended.

REFERENCES

[1] Endsley, M. R., & Kiris, E. O. (1995). The out-of-the-loop performance problem and level of control in automation. Human Factors: The Journal of the Human Factors and Ergonomics Society, 37(2), 381-394.

[2] Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 30(3), 286-297.

[3] Saffarian, M., De Winter, J., & Happee, R. (2012). Automated driving: human-factors issues and design solutions. Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

[4] Martens, M., Beukel A.P. van den (2013).The road to automated driving: dual mode and human factors considerations. In: Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, 2262-2267

[5] Jarašūniene, A., & Jakubauskas, G. (2007). Improvement of road safety using passive and active intelligent vehicle safety systems. Transport, 22(4), 284-289.

[6] Van Arem, B., van Driel, C. J., & Visser, R. (2006). The impact of cooperative adaptive cruise control on traffic-flow characteristics. Intelligent Transportation Systems, IEEE Transactions on, 7(4), 429-436.

[7] Young, M. S., Stanton, N. A., & Harris, D. (2007). Driving automation: learning from aviation about design philosophies. International Journal of Vehicle Design, 45(3), 323-338

[8] Martens, M. H. (2007). The failure to act upon important information: where do things go wrong. Doctoral thesis. Vrije Universiteit, Amsterdam, The Netherlands.

[9] Kazi, T. A., Stanton, N. A., Young, M. S., & Harrison, D. (2005). Assessing drivers' level of trust in Adaptive Cruise Control and their conceptual models of the system: implications for system design. Driver behaviour and training, 2, 133.

[10] Rudin-Brown, C. M., & Parker, H. A. (2004). Behavioural adaptation to adaptive cruise control (ACC): implications for preventive strategies. Transportation Research Part F: Traffic Psychology and Behaviour, 7(2), 59-76.

[11] Nielsen, J. (1992). Finding usability problems through heuristic evaluation. Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems.

[12] Schmidt, R. A., & Young, D. E. (2010). Cars gone wild: the major contributor to unintended acceleration in automobiles is pedal error. Frontiers in psychology, 1.

[13] Pfromm, M., Cieler, S., Bruder, R. (2013). Driver Assistance via Optical Information with Spatial Reference. In: Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, 2006-2011.

[14] Mulder, M., Abbink, D. A., & Boer, E. R. (2012). Sharing Control With Haptics Seamless Driver Support From Manual to Automatic Control. Human Factors: The Journal of the Human Factors and Ergonomics Society, 54(5), 786-798.

[15] Norman, D. A. (1990). The 'problem' with automation: inappropriate feedback and interaction, not 'over-automation'. Philosophical Transactions of the Royal Society of London. B, Biological Sciences, 327(1241), 585-593

[16] Schutte, P. (1999). Complemation: An alternative to automation. Journal of Information Technology Impact, 1(3), 113-118.

[17] Schaller, T., Schiehlen, J., Gradenegger, B. (2008). Congestion Assistance - Supporting the driver in lateral and longitudinal guidance. System development and customer acceptance. Aktive Sicherheit durch Fahrerassistenz, vol. 3, no. 10