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Experimental Results

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AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

Document information //

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Executive Summary

The objective of the work conducted in sub-project 3 (SP3) of the AdaptIVe project was to *"investigate how drivers' intentions and actions should be taken into account in the design of partly, highly and fully automated vehicles"* (AdaptIVe DoW, 2013). This Deliverable provides the results of a series of studies conducted as part of Work package 35 (Evaluation), which have been achieved using an iterative approach, working in collaboration with WP34: Human Factors Recommendations.

University of Leeds, DLR, Ford, WIVW, AB Volvo and Volvo Cars were partners conducting work in this SP, completing 18 empirical investigations, two focus group studies and one large international survey. The empirical studies were conducted using high fidelity driving simulators (5) and on-road vehicles (2), with over 500 participants (including 90 professional truck drivers), to study human interaction with automation. The on-line survey recruited over 2700 users to seek their views about the frequency of use and perceived usefulness of several parking related driver assistance and automation systems.

In addition to designing appropriate scenarios to investigate the interaction of humans with automated systems in urban and highway scenarios, SP3 partners have been working with designated colleagues responsible for the final demonstration, throughout this WP, to ensure results from WP35 are taken into account for the project's final demonstrations in June 2016. This has involved both bilateral collaborations between teamed partners, as well as shared workshops between all SP3 and VSP partners.

This Deliverable not only provides a comprehensive overview of the factors that need consideration when studying human interaction with automated vehicles, but also highlights a summary of the remaining challenges and research gaps, yet to be resolved in this area.

The work in WP35 began with an investigation of the research required to understand human interaction with automated systems, which also included a joint workshop between SP3 and VSP partners. The 4A structure (see Kelsch, 2015 and Appendix B) was used to determine high level research gaps in the area, and a research questions table was constructed, and regularly updated, to provide an overview of each partners' research programme, identifying both overlaps and gaps in the studies conducted by all partners.

A full overall summary of the main headlines, research gaps and challenges for each partner is provided in Chapter 10: Overall Summary of Findings. However, the following points summarise the **main conclusions** from each partner in this WP.

- Work from studies using driving simulators suggests that drivers were happy to engage with other (non-driving related or secondary) tasks quite quickly and were keen to do so in favour of driving. Therefore, at least in driving simulators, drivers' wish to cede the main task of driving and focus on other tasks, was quite high.

- New methodologies have been developed to study the driver 'Out of the Loop' (OotL) concept, using manipulations of the driving simulator dashboard information and scenery. Results suggest that although drivers do indeed direct their visual attention away from the driving scene during automation (as illustrated by eye tracking measures); they are able to redirect this attention back to driving, when required, within around 3 seconds. This conclusion is true for short durations of inducing the OotL concept (up to 10 minutes). However, resumption of control is not synonymous with satisfactory driving performance, and results show an overall safer management of critical situations during manual driving.
- High levels of visual attention away from the road centre during automation was more likely to result in crashes in critical situations after resumption of control.
- Drivers were able to appreciate the limitations of an automated system after one or two repetitions of the same scenario.
- An "uncertainty" alert for transition from automation (presented in favour of the routinely used 'Take over Request') showed good driver situation awareness after one or two repeats of the same scenario.
- Eye tracking data suggest that scenarios encouraging driver gaze towards the road centre are likely to bring drivers back into the loop more efficiently, facilitating better situation awareness/hazard perception during the transfer of control. Although further work is required to validate this proposal, these findings suggest that any information presented to drivers during automation should be placed near the centre of the road, akin to a Head Up Display.
- During lane changing manoeuvres, drivers prefer a highly automated system which can control the lane-change, to a partially automated system, which requires them to retake control in order to make a lane-change.
- In a lane changing study, resuming manual control from automation led to poorer vehicle control during overtaking, at least in terms of higher lateral accelerations. This poor control improved with experience of the system. Drivers also maintained shorter headways when resuming control from automation, compared to manual driving.
- An ambient light display was highly salient and has the potential to support drivers in understanding which automation level is currently activated, and which automation level is available for activation. Thus, leading to significant faster transition times (either from no automation to high automation, vice versa) compared to a more traditional HMI.

- The ambient light display supports the shift of attention that drivers need to fulfil when the system switches from different levels of automation, by a salient, colour-coded indication of the current level of automation.
- The presentation of tracked vehicles on the ambient light display helps drivers to understand which objects are detected by the automation and to predict future automation behaviour. This led to faster take over times in silent failure scenarios.
- The ambient light display supported drivers in predicting and understanding the future automation behaviour, during more complex, urban, environments, especially in situations where behaviour of the vehicle was in contradiction to the environmental scene (i.e., red traffic light – vehicle not decelerating).
- Participants illustrated a high acceptance of the ambient light display, and rated it more comfortable, more inviting and more pleasant than the other HMI designs used in these studies, for comparison.
- Contrary to expectations, the large on-line survey with over 2700 participants did not show any difference between responses from citizens of the 12 countries enlisted, regarding the evaluation of the usage frequency and perceived usefulness of several parking related driver assistance and automation systems (Ford).
- Results of an on road test with a remote parking aid demonstrator vehicle indicated a high usability and acceptance of the assessed parking automation system developed by Ford: the so-called remote parking aid system. The remote parking aid system also received a high controllability rating, which was not influenced by the presence of a secondary task.
- A smartphone App controlled parking automation system developed by IKA within the AdaptIVe project was well accepted. The HMI mode offering permanent interaction made it slightly easier to cancel the parking process than the one with non-permanent interaction. People having experience with one mode preferred this mode and not the other one. The system's controllability ratings were reduced after being exposed to a critical event. This event was not mastered by all participants, which can be attributed to various factors, such as overreliance, velocity of the test vehicle but also testing out the limits. Both HMI mode groups showed no difference with regard to the handling of the final critical event (Ford).
- Suitable concepts were developed to support drivers in using their free time effectively in highly automated driving, e.g. by showing them when and how long to drive in automation mode and when to return to the manual driving task.

- When drivers were out of the loop, new concepts were developed to bring them back only in cases if their intervention was necessary. It is hoped that these concepts will prepare drivers to take over manual control to increase both driving safety comfort.
- Such a goal is reached by providing “cues” that direct drivers’ attention back to the driving task. An effective example includes a situation announcement, given 30 s before a system limit is reached i.e. the end of a particular section of the route.
- The HMI that represented few and distinct levels of automation and displayed in a clear way was easier for drivers to understand and (re)act on, than HMI that includes many levels.
- Most drivers preferred the HMI that provided less information, which they thought was easier to comprehend.
- Contextual factors, such as traffic density can influence drivers’ reaction. For example, high traffic density resulted in shorter time to button press for engaging automation.
- Non-driving related secondary tasks and passive monitoring impaired drivers’ ability to take lateral and longitudinal control of the truck during a critical situation in automation.
- Studies suggest that today’s truck cabs are not designed for non-driving related secondary tasks and that cab design should (i) not obstruct take-over control manoeuvres when required, (ii) ensure that important information is in the driver’s field of view (iii) provide ergonomic and safe use of mobile devices.
- Drivers hold their hands on the steering wheel in many very different ways (ring and/or spokes, one/two hands, fingers only etc.), which needs to be taken into account when installing grip-sensors.
- Clear messages and symbols which are coherent with the drivers’ intentions, actions and observations of the surrounding traffic environment are important to enhance mode and task awareness as well as to gain acceptance of these kinds of systems.
- Learning how to disengage automation is not immediately intuitive, with 30 % of drivers failing to properly disengage the automation. However the learning curve is fast.
- Drivers deeply engaged in a secondary task while in automation mode are much more sensitive to multimodal alerts and timing, compared to drivers in manual driving. A separate alert/warning tuning (modalities, amplitudes) is thus likely required for automation mode.

The empircal studies also highlighted some **methodological challenges and research gaps**, which require further investigation in this area. In particular:

- It is clear that traditional vehicle metrics can no longer be used to understand drivers' behaviour during automation. Therefore, eye movements and physiological measurements are necessary to understand performance and driver engagement/readiness to resume control.
- On a similar note, it is clear that response time alone is not enough to provide information about how well drivers can handle a vehicle after re-taking control. Other metrics, including steering and braking patterns, lateral positioning, etc. need to be considered.
- Effect of long term expsoure to automation, and ensuing factors such as driver fatigue, boredom and distraction on drivers' ability to resume safe control from automation are not currently understood.
- Drivers' ability to handle complex take-over situations, for example, where the driver is expected to make more strategic level decisions such as route choice decisions, is not known.
- With respect to the ambient light, in particular, further knowledge is needed regarding its visibility and efficacy in different environments, its effect on driver distraction, and drivers' ability to learn, understand and accept its different forms.
- The fact that most of the studies reported in in this Deliverable rely on results from driving simulator studies must be taken on board with further work required to understand factors such as driver trust, risk perception, engagement in secondary tasks, resumption of control etc. in real world settings.
- Driver performance and behaviour after long-term presence in automation is also important, to understand the above factors, as well as investigating the effect of automation on skill aquisition and loss.
- Finally, understanding how different driver groups (such as the young and older population) interact with automated systems is the next important step to ensure these systems are accepted, used and trusted by all cross-sections of the population.