Human-Machine Interface Communication Strategies of a Highly Automated Vehicle with its On-Board User to Reduce User's Uncertainty in Complex Traffic Situations with Multiple Other Road Users as Interaction Partners

Michael Oehl, & Marc Wilbrink

German Aerospace Center (DLR), Institute of Transportation Systems, Braunschweig, Germany

michael.oehl@dlr.de, marc.wilbrink@dlr.de

Background: Automated driving functionalities in vehicles are increasing year by year. To enable this, intensive research regarding highly automated vehicles (HAV; SAE 4) has been performed by research and manufacturers in recent years. Due to the shift of driving control, the role of drivers changes to rather on-board users without any driving related tasks. However, the interaction between the HAV and its on-board user stays vital in terms of creating a common understanding of the current situation and establishing a shared representation of the upcoming maneuver to ensure e.g. user acceptance, trust, and a safe interaction between on-board user and the automation. A major challenge for HAVs is still the detection and behavioral prediction of relevant objects and an interacting other road user (ORU). This forms the basis for driving maneuvers of the HAV and thus ensures successful interactions with ORUs. However, this information can also be used to shape the interaction of the HAV and its users in the vehicle itself via internal human-machine interfaces (iHMI) on-board of the HAV. Therefore, suitable communication strategies are needed. Novel iHMI strategies need to focus on creating a common understanding of the current driving situation and a foreseeable future behavior of the HAV for the on-board user to avoid automation surprises. Insufficient system transparency could result in inadequate knowledge regarding situation and HAV intention on the on-board user side which might lead to lower trust and acceptance or to unnecessary or even dangerous interventions with regard to the driving task by overruling the automation. In previous research, a LED light-band in the vehicle interior has been proposed as a suitable iHMI to communicate this information to the users. However, the studies and communication concepts were mostly limited to a one-on-one interaction of one HAV with one ORU. The scalability of the proposed concepts to an interaction in more complex scenarios with multiple ORUs is still an open question.

Aim: In the presented study, this open question will be addressed in a first step. Different communication concepts for a LED light-band as an on-board iHMI in the interior of the HAV were investigated to ensure the user's understanding of the current situation, establish system transparency as well as to ensure trust and acceptance among users for more complex driving scenarios of a HAV interacting with several ORUs. Main aim was to reduce the user's subjective uncertainty about the HAV's behavior in the presented traffic situation.

Method: In a video-based experimental online study (N=154) participants experienced and rated journeys in a HAV as an on-board user. On a shared space, the HAV had to consider three

ORUs (two closer and a third, more distant interacting ORU). It was investigated in a mixed design if an iHMI was needed (within; no iHMI vs. static iHMI showing only the automation status vs. iHMI showing the automation status with additional information about precepted interacting ORUs) and whether all present interacting ORUs on the shared space had to be shown on the iHMI in order to reduce the subjective uncertainty of the user or if it was sufficient to only present the two closer ORUs (between). A shared space as traffic scenario was chosen as previous research has suggested that especially here additional information and explicit communication via HMIs might be helpful due to the lack of interaction rules which are in other traffic scenarios imposed by signs or infrastructure.

Results: Results of this experimental study showed that a perception-based communication concept on the iHMI resulted in lower uncertainty user ratings compared to a static or no iHMI. No difference was found for whether all or only the two ORUs in the vicinity of the HAV were displayed on the iHMI.

Conclusions: One of the most often asked questions in HAV research and development when it comes to iHMI design is if and how a HAV user should be provided with information about interacting ORUs. The presented study offers answers in a first step. Results showed the iHMI perception-based communication strategies via the LED light-band to be beneficial to reduce user's uncertainty. Additionally, it was sufficient to communicate only the nearest ORU. Further evaluations in simulator studies and beyond must be performed for deeper insights.