Towards User Transparency of a Vehicle's Driving Behavior Equipped with a Highly Automated Driving System during Minimal Risk Maneuvers: An Ecological Human-Machine Interface Design Approach

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Extended ABSTRACT

1. Theory

Individual transportation will traverse towards vehicles with automated driving systems (ADS) in the near future that will independently execute the driving task and presumably provide safe and inclusive transportation. Current concepts, developments, and even regulations often include a supporting remote assistant in the ADS (SAE L4; Aramrattana et al., 2024; Society of Automotive Engineers, 2021). These, remote assistants can support the ADS, e.g., by providing waypoints to the ADS helping to resolve situations that exceed the ADS' own capabilities. By current German legislation, before an assistant intervenes, the ADS performs a minimal risk maneuver (MRM), meaning the vehicle comes to a safe stop. Since the ADS does neither inherently provide information to its users about its driving behavior nor its MRM resolution process, passengers might be exposed to an inconceivable driving situation (Skraaning et al., 2020; Vorm & Combs, 2022). This could lead to recurring similar situations potentially causing severe insecurities in passengers, especially when no information is given about the MRM and its resolution process. Recent research investigated ways to improve an ADS vehicle passenger's understanding and predictability of the ADS and its MRM by providing information that increases the system's transparency (Brandt et al., 2024). However, what still remains an open question in research is how an efficient way could be designed to provide this crucial and currently often needed information to passengers, not only to improve their experience, but also for satisfying experienced ones as well.

One design solution to communicate information in this case in an efficient and user-centered way, can provide the theory of ecological interface design (EID). According to EID, ecological presentation happens when information is depicted in a concise way that is still understandable. This can be achieved by presenting information through abstractions according to their underlying functionality (Rasmussen, 1999). When information is depicted unfiltered or unchanged, e.g., when for each sensor in a complex technical system the sensed values would be shown in detail, users would be overwhelmed. In contrast, fusing these types of information together instead and presenting them in an abstracted, but easy to understand way can provide the same information content in a more concise and thus more accessible way for users (Burns et al., 2008). So, this improved accessibility of the information about the ADS should improve understanding and predicting of the ADS' behavior (Beggiato & Krems, 2013; Carroll &

Olson, 1987). Also, better accessibility should improve user experience as the information is presented in a way that needs no evaluation by the user and prevents them from information overload (Bawden & Robinson, 2020). Following this argumentation, the research question investigated in the presented study is: Does a vehicle with ADS' communication of an MRM by an in-vehicle Human-Machine-Interface (iHMI) to its passengers using abstractions, based on an ecological interface design approach, lead to a better understanding, predictability, and user experience compared to an explicit communication only using semantic language?

2. Methods

To investigate this effect of ecological designed iHMIs on the understanding and predictability of passengers of an ADS, an experimental simulator study was conducted. In a within factors design an iHMI providing transparent information about an ADS was shown to participants in virtual reality (VR). The participants experienced a ride through a virtual environment created in the game engine Unreal Engine 5 as passengers of an ADS that performed MRMs in different situations (Epic Games, Inc., 2022). To provide information to the participants during the MRMs, an iHMI was designed based on EID. The iHMI utilized systematically varied abstractions providing the passenger with information about the ADS and the MRM resolution process involving the remote assistant. The activity of the ADS was depicted with paths that provided additional information about the system via their coloring. Teal signaled active automation, yellow a detected problem within the path, and grey alternative paths that needed evaluation of the assistant. The iHMI also provided abstract information on the involvement of the remote assistant and the vehicle's surrounding. A basic variant of the interface (base line) presented the same information as plain texts. In addition, a third variant was created that provided the information both via the aforementioned abstractions and the texts at the same time.

Each variant was evaluated over several scenarios, where the ADS of the vehicle performed an MRM and contacted a remote assistant for support. The scenarios varied between blocked roads, e.g. because of parked vehicles or construction sites, and rescue operations blocking the road. Additionally, dummy scenarios that did not pose the need for a remote assistant were shown to passengers, so that it was not always clear when an MRM would be performed by the vehicle. Depending on the variant, information was given about the situation and the MRM resolution process involving the assistant, via text, abstractions or both. To evaluate the different variants and their impact in each scenario, after each scenario, questionnaires regarding understanding, predictability and user experience were given to the participants.

3. Results and Conclusion

Study results provided insights into possibilities of ecological iHMI design for vehicles with ADS to account for the new situation for passengers of ADS, especially when performing an MRM. They present an answer to the question how ADS can communicate with their passengers to improve their understanding, predicting and user experience to provide a safe and inclusive design for vehicles with ADS.

4. References

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