Prosocial Interaction between Vulnerable Road Users and Automated Vehicles

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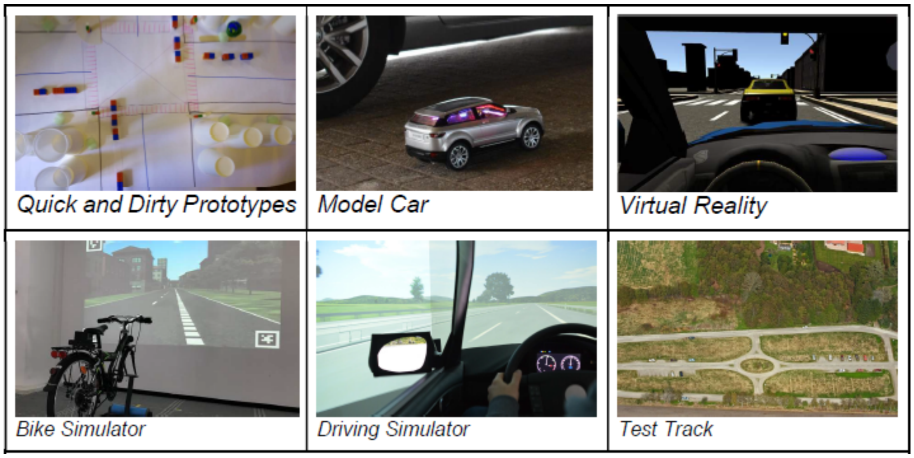

Fig. 1. Environments for design and evaluation.

Through the emergence of Automated Vehicles, it has been more and more intriguing to find out whether and how human road users will communicate with them. The current project focuses on how human road users behave towards Automated Vehicles, which communication cues are perceived as prosocial and if these cues are needed in order to provide a better communication between Automated Vehicles and human road users in rule-based and non-rule-based traffic situations.

Additional Key Words and Phrases: Automated Vehicles; Vulnerable Road Users; Pedestrians; eHMI; Communication; Interaction.

1 INTRODUCTION

The traffic is a highly regulated environment, however there is still high demand for informal negotiations between the users of the roads. For example, on a road that does not have a pedestrian crossing, pedestrians who wish to cross the road need to evaluate the behavior of the approaching vehicle or the driver in order to decide whether it is safe to cross.

1.1 Prosocial Behavior in Traffic

Although existing literature does focus on the communication between Automated Vehicles (AVs) and Vulnerable Road Users (VRUs), enabling prosocial behavior between them might to be further discovered. Harris et al. [11] define prosocial behavior in traffic context as *"a pattern of safe driving behaviours that potentially protect the well-being of passengers, other drivers, and pedestrians, and that promotes effective cooperation with others in the driving environment."* (p. 4).

Individuals were found to behave negatively towards AVs in the study of Liu et al. [13]. This raises the doubt if VRUs will "bully" the AVs in the future and how this could be prevented by promoting a prosocial communication between VRUs and AVs.

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Pedestrian behavior is a topic that has been paid attention by researchers. On the Pedestrian Behavior Questionnaire by Deb et al. [5], one of the sub items which was adopted by Granié et al. [9] evaluates the positive behavior of pedestrians by asking the participants if they yield the right of way to vehicles even if pedestrians have the priority. Because this item is directly related to the positive behavior of pedestrians towards vehicles, it might serve as a behavioral measure of prosocial behavior between VRUs and AVs in the future studies.

1.2 Implicit and Explicit Communication in Traffic

The conventional way of interaction between VRUs and drivers relies on implicit and explicit communication cues. Implicit cues can be summarized as the observable behavior of the vehicles, such as deceleration, acceleration or engine sounds. Explicit communication in traffic can be observed as eye contact, gestures and postures of the drivers and other type of signals [6, 7, 16, 17, 19].

In the near future, AVs will be seen on the roads more frequently. While implicit communication could still be performed between AVs and VRUs, it seems that explicit communication will be replaced with external Human Machine Interfaces (eHMIs) (see 1.4).

1.3 Communication Process between AVs and VRUs

The communication process composes of different elements (see Figure 2). Firstly, the **sender** should be identified. In the current project the sender is defined as AVs. **Message** is **encoded** by the sender in forms of words or non-verbal methods such as symbols or gestures [15]. In this step, cue types such as symbols and exposure timing of these cues are considered in the present project. After encoding, message takes its form. In this phase, the content of the message becomes important for a successful communication. In the current project, message content types such as automation status, AV intent, AV awareness of pedestrians and advice by AVs are considered as possible options [4, 6, 17]. Encoded message is sent via a **channel** in regular communication processes. The prospective channel in the current project will be eHMIs that will be positioned on the surface of AVs. The most popular positions to place eHMIs in the current literature has been the windshields, bumpers, headlights, hoods and side body panels [1, 8, 14, 16, 17]. The **receiver** in the communication process example is defined as Vulnerable Road Users. If VRUs **decode** the message correctly, a healthy communication will be accomplished between AVs and VRUs. In this step it is a worthy concern that VRUs from various cultures, VRUs that have disabilities or VRUs from different ages could decode the message. It is worth mentioning that the **noise** can affect some of the steps in this schema. The message or the channel can be omitted by different noise sources such as traffic noise or other traffic elements that can block the channel, or different weather or daytime conditions. Consecutively, VRUs may fail to decode the message. VRUs may also be equipped with distracting products such as smart phones or earphones. Their attention level could also serve as a noise in this concern. In order to complete the communication loop, VRUs may give **feedback** to AVs and receive feedback from AVs.

1.4 eHMIs

While some studies suggest that explicit communication does not play a crucial role in traffic situations [7, 19], other studies support the use of eHMIs as they build a more positive experience on VRUs. For example; Ackermans et al. [2] recommend the use of eHMIs since they make pedestrians feel seen and more comfortable. Pedestrians feel safer when an eHMI is attached to the AV [10]. Some studies accept the usefullness of eHMIs from the previous literature and conduct their studies accordingly [14].

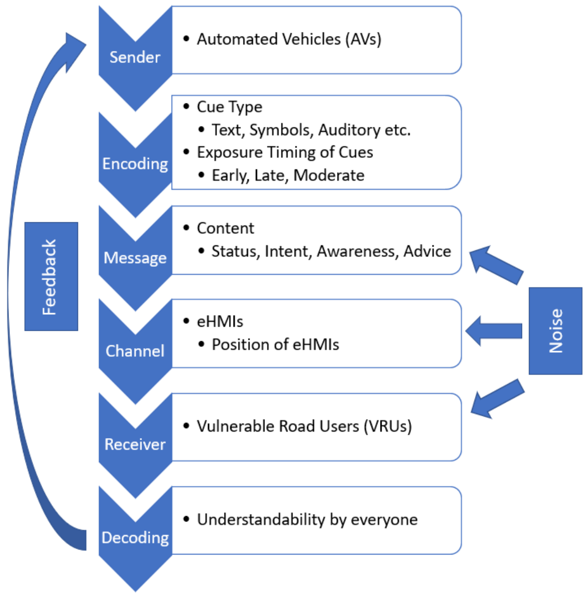

Fig. 2. Communication process between Automated Vehicles and Vulnerable Road Users in the current project.

Holländer et al. [12] found on their studies that participants consider eHMIs in their crossing decisions even if eHMIs were faulty. This finding also raises the question of overtrust of VRUs in AVs. Ackermans et al. [2] also suggested that eHMIs create an overwhelming trust, yet they also bring up some skepticism. This issue needs to be further addressed in future studies.

The current eHMI designs range from smart roads [18] to LED strips [1, 10], displays [1, 17] and anthromorphism [3]. Existing literature emphasizes the growing interest for interaction between AVs and VRUs. However, it also indicates a lack of consensus on a standardized design or message of eHMIs. What could be generally taken by previous related work is that the ideal eHMI should be universal and familiar [14], but also novel; hence an already assigned meaning would not interfere with the message content of the eHMI.

1.5 Research Contributions

The current project will be important in terms of understanding the basis of prosocial communication in traffic and it will help developing a prosocial communication between the AVs and VRUs. While designing the experiments, the focus will not be only on the prosocial behavior of AVs towards VRUs, but also prosocial behavior towards AVs. For instance, in a busy pedestrian crossing scenario in Germany, an AV might be waiting for the pedestrians for a considerable amount of time. We will investigate how to promote prosocial behavior towards AVs, so that AVs would not overwait. Furthermore, we will investigate pedestrians' over-reliance of AVs and how this could be adressed while designing eHMIs. eHMIs will be designed in the light of safety and prosocial communication.

2 RESEARCH QUESTIONS

- Do VRUs behave towards AVs in a prosocial way? How can we promote prosocial behavior of VRUs towards AVs? (see related work projects 3.1 and 3.2)

- How eHMIs need to be designed in order to promote prosocial behavior of AVs? (see related work projects 3.2, 3.3 and 3.4)
- Would eHMIs be effective in providing prosocial communication in rule-based traffic situations such as pedestrian crossings and non-rule based situations such as carparks? (see related work projects 3.2, 3.3 and 3.4)

3 WORK PROJECTS

3.1 WP 1 Moral Behavior Towards Autonomous Vehicles

In this work project we aim to understand the social norms and cues that humans use in traffic situations. The project will consist of two parts. Firstly, an online survey with multiple traffic scenarios will be implemented. Secondly, on a VR study the behavior of participants towards AVs and conventional vehicles will be assessed within scenarios such as carparks, streets without clear rules and pedestrian crossings without traffic lights. AVs and conventional vehicles will be used in order to evaluate how often VRUs yield the right of way as a sign of prosocial behavior. In order to assess the robustness of the findings, the results of the two parts will be compared. From these studies, we expect to find that participants show a less prosocial approach towards AVs than conventional vehicles.

3.2 WP 2 Supporting Rule-based Traffic Interactions

As part of the second work project, online design workshops will be organized. Participants will be asked to comment on the topic of prosocial behavior of VRUs and AVs in traffic, pedestrians' overtrust on AVs, benefits and problems of eHMIs. An interactive section will be reserved for eHMI design details such as cue types, cue timings, message contents and eHMI positioning. While considering these details, the prosocial communication notion will be reminded. Quick and dirty prototypes will be implemented in this step.

The results of the workshops will allow a comparison between the findings of the first WP and they will serve as the basis for consecutive model car experiments. eHMI designs will be tested primarily on model car experiments.

3.3 WP 3 Assessing the Need and Feasibility of Implementing Prosocial Behavior

This work project focuses on how an AVs should behave in rule based traffic interactions according to the participants. The model car from the second work project will be developed with further workshops focusing on prosocial behavior. In order to do this, the scenarios where we expect prosocial behavior to occur will be used (Pedestrian crossings and intersections). These scenarios will be implemented with VR or bike simulators. With the help of WP 3, it is aimed to understand the social expectations of VRUs from AVs. The need for eHMIs and their understandability will be further assessed.

3.4 WP 4 Supporting Non-rule Based Traffic Interactions

In the last work project, eHMI designs from WP 2 and WP 3 will be developed for non-rule based traffic situations, such as parking areas or roads without clear traffic rules. As in the previous WPs, the project will start with workshops and model cars. Further implementations in VR and/or simulations will test the updated eHMIs. Lastly, in order to get more realistic behavioral outcomes, as previously done by Rothenbücher et al. [20], a Wizard-of-Oz study will be conducted on a test track.

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4 APPENDIX

4.1 Video Presentation Link

https://cloudstorage.elearning.uni-oldenburg.de/s/JKM6n8RYHoz747Z