Cyclists' experiences in urban longitudinal traffic scenarios and their requirements for designing interactions with highly automated vehicles

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1 MOTIVATION & STUDY OBJECTIVE

As cycling becomes more popular and automated driving is on the rise, it can be assumed that in the city of the future highly automated vehicles (HAVs) and cyclists will share the same roads. Yet only little is known about how cyclists announce their maneuvers to motorized vehicles or how they communicate and interact with them. Knowledge on these aspects is currently missing to guide the design of cyclist-HAV interactions. Situations where a cyclist rides upfront a vehicle, will be especially challenging for HAVs, such as when a cyclist (A) avoids an obstacle on the road section ahead, (B) merges onto the road from an ending cycling path, or (C) leaves the road turning into a driveway (see Figure 1) [1]. Based on the cyclist's intention, the HAV will have to pass or keep following with only limited options to communicate to the cyclist ahead. Design solutions derived from the well-studied field of pedestrian-HAV interactions cannot simply be transferred to the here considered cyclist-HAV interactions, since in past research successful design concepts for pedestrians were not beneficial for cyclists [2]. Hence, it is vital to investigate the behavior and experiences of cyclists in more detail and to explore possible design solutions for HAV interaction behavior in these situations.

With this study we aim to get more insights into the subjective experience of cyclists travelling in longitudinal traffic, especially during cyclist-vehicle interactions, as well as to derive cyclists' requirements to design safe and desirable cyclist-HAV interactions.

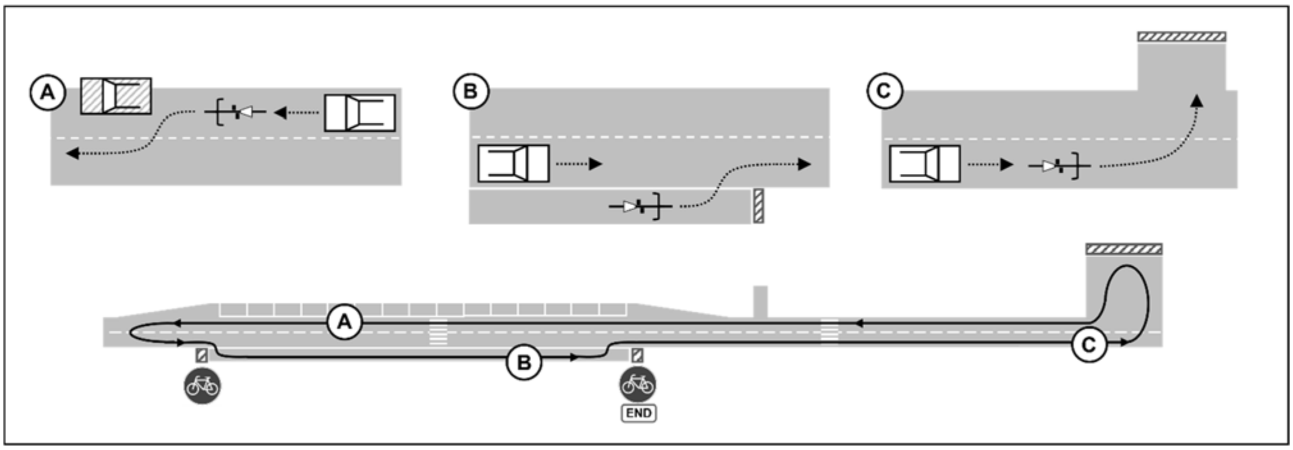

Figure 1: Bird's eye view of the investigated situations (A), (B), and (C) and of the circuit that the participants rode along in the test-track study.

2 METHODS

We conducted a semi-controlled test-track study to safely observe the cyclists' behavior in a controlled environment and to enable them to report their subjective experiences during and after experiencing the situations. To ensure that we could still observe natural cyclist behavior the participants were deceived about the real study purpose. Instead, we told them that we were aiming to explore different cycling patterns with a pedelec with the objective to potentially improve its drive unit. The study design was reviewed and approved by the Ethics Committee of the Technical University of Munich (ethical approval code 426/20 S-SR).

36 company employees (18 female) aged 19-62 (M = 38.4, SD = 12.8) took part in our test track study. Prior to the study, the participants filled in a questionnaire regarding their demographics, their personality, and their daily mobility behavior with a focus on driving and cycling.

Upon arrival, the participants were provided a pedelec that was equipped with data loggers, cameras and a microphone mounted to the handlebar to record their observable behavior as well as their verbal statements. The participants were instructed to ride along the approximately 450 m long circuit depicted in Figure 1 at a speed of 20 km/h. Along the circuit they experienced the three longitudinal traffic scenarios mentioned in section 1.

The test ride consisted of two blocks. The 1st block focused on the observable cyclist behavior during the maneuvers and in spontaneous interactions with a confederate vehicle (BMW 520d Touring, equipped with data loggers and cameras) approaching from behind once per situation as the cyclist rode along the circuit ten times.

Before the 2nd block started, the participants were informed that the confederate vehicle was part of the study. They were instructed to ride along the circuit two more times. They were informed that in both rounds they would again encounter the vehicle in one of the three situations. The specific situation was declared to the participants before. Each situation was covered by 12 participants. During one of the encounters with the vehicle, they were told to let the vehicle pass first and during the other encounter they should pass before the vehicle. This ensured that the cyclists experienced both the situation when they maneuver in front of a vehicle and when the vehicle passes first. During both rounds, the cyclists were instructed to give concurrent verbal protocols about their thoughts during the ride.

After the test ride, the participants were fully debriefed and interviewed about the three situations that they had just experienced during the study. The interview was semi-structured and consisted of two very general questions, regarding (1) comments on the experienced interactions with the vehicle from the viewpoint of developing HAVs and (2) requirements regarding the communication and interaction behavior of HAVs in the experienced situations. The interviewer would ask more detailed questions about the topics that the participants mentioned during the interview.

To explore the subjective cyclist experience in the examined situations, the presented results will be based on the verbal protocols and cyclist behavior of the 2nd block and on the final interviews.

3 ANALYSIS & RESULTS

All verbal protocols and interviews were transcribed verbatim. Then a qualitative content analysis [3] was performed. Qualitative content analysis provides a systematic approach to analyzing textual data using deductive (theory-based) categories or inductive categories that are revealed from the participants' statements.

For the verbal protocols we categorized all verbal statements by the participants regarding the relevant main concepts in the given situations and compared them to the observed cyclist behavior.

To categorize the interview data, we used a mixed approach of deductive and inductive categories. The subcategories for the main categories 'experience' (interview question no. 1) and 'requirements' (interview question no. 2) were created inductively with the aim of systematically organizing the verbal statements from the participants and to discover their underlying needs regarding the design of HAV interactions. The main categories 'message type', and 'HMI type' were derived deductively from the literature to systematically collect information requests and actual human machine interface (HMI) design solutions formulated by the participants. All statements from the participants regarding the message type were categorized into 'HAV automation status', 'environmental perception', 'planned next HAV behavior', and 'HAV cooperation/request' according to [4], who derived the message types from a literature review on nowadays human-human traffic interactions. All statements regarding potential HMI solutions were categorized according to the HMI types for external communication, as proposed by [5] i.e., 'dynamic HMI' and 'external HMI' and their proposed subtypes. Two independent raters paraphrased and categorized a subsample of the data to determine the category system combining deductive and inductive categories. Using the resulting category system another subsample of interviews was categorized by the two raters. The results were then compared to assess the intercoder agreement.

As one main finding, the cyclists reported that the auditory channel was very important when riding in urban traffic in general and particularly in the experienced situations. Several participants announced the presence of the following vehicle before they performed any observable behavior e.g., a shoulder glance, or stated that they require an approaching vehicle to clearly announce its presence. Consequently, adding a message type 'vehicle presence' to the already recommended message types by [4] is important for cyclists interacting with an HAV approaching from behind. The cyclists reported the vehicle's engine noise to be an important channel to announce that a vehicle was present and to also predict its next maneuver or willingness to cooperate. Designing the driving behavior and the related sound produced by the vehicle seems vital, especially when considering that HAVs may also be electrified and therefore only produce little natural noise. Some cyclists discussed additional external HMIs regarding their usefulness and desirableness as well as more general required characteristics of the HAV. Additionally, important inductive categories derived from the participants' statements were not limited to the design of HAV communication and interaction behavior e.g., 'infrastructure' and 'connectivity'.

4 CONCLUSIONS

The study provides insights into how cyclists subjectively experience riding in longitudinal traffic and interacting with a vehicle approaching from behind. The presented findings offer a more holistic view on the design of HAV interaction behaviour with vulnerable road users, complementing the findings from research on pedestrian-HAV interaction. Because of its explorative approach the study further promotes the formulation of research questions and hypotheses to be focused on in future studies. This all contributes to achieving save and desirable future interactions between cyclists and HAVs, considering the cyclists' needs from the very beginning of the design process.

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