Real-World Interactions between Cyclists and Automated Vehicles – A Wizard-of-Oz Experiment

Anna Marie Harkin*, Tibor Petzoldt*, Jens Schade*

*Chair of Traffic and Transportation Psychology
University of Technology Dresden
Hettnerstr. 1-3, 01069, Dresden, Germany
email: anna_marie.kuehn@tu-dresden.de

Keywords: cyclists, automated vehicles, interactions, road safety.

1 INTRODUCTION

The introduction of automated vehicles (AVs) changes the way road users interact and communicate. In AVs, informal communication such as eye contact or gestures with other road users is omitted. Because interaction should still be objectively and subjectively safe, many studies are currently focusing on the communication processes between (automated) vehicles and predominantly vulnerable road users (VRUs), like pedestrians and cyclists [1]. These road users are highly at risk of being fatally injured in road traffic accidents, with the WHO reporting pedestrians and cyclists account for 32 % of all fatalities in Europe [2].

The interaction and communication between pedestrians and AVs have already been analyzed in observational and experimental studies. Cyclists are a less researched topic in this context, even little is known about current interaction processes with manually driven vehicles. However, the bicycle is a means of transport that is and should be promoted, especially in light of the desired change in transport. At the same time, compared to pedestrians, its use involves a potentially higher risk due to the higher speeds and less flexible directional adjustments. To ensure that the introduction of automated vehicles does not lead to less frequent use or - even worse - more accidents, it is necessary to investigate how cyclists interact and communicate with motorized road users and whether this can be transferred to the interaction with automated vehicles.

Do cyclists, for example, notice explicit communication from other road users, like facial expressions or gestures? Are their decisions based on such explicit communication or do they rather use movement signals, i.e. implicit communication, to assess whether they can continue cycling or not? On the other hand, do cyclists themselves communicate more explicitly or implicitly? So far, only a few studies have dealt with these questions, some of the insights are briefly presented next.

In a driving simulator study by Hou et al. [3], participants had to drive around an obstacle in their lane and move into the left lane to do so. They had to decide whether to do this in front of an approaching AV or wait until it had passed them. 16 of the 18 participants stated that they had decided to move into the left lane mainly based on the vehicle's position. Nuñez Velasco *et al.* [4] came to similar conclusions. Here, cyclists decided to cross in front of the vehicle primarily based on the distance between the bicycle and the car as well as the right-of-way rule. The automation status of the vehicle had no influence. This was also shown in a photo experiment by Hagenzieker *et al.* [5]. Here, subjects did not believe they were better recognized by automated vehicles. However, there were tendencies for participants to have more confidence in the human driver of manually driven vehicles than in AVs. But the differences were strongly influenced by the context. Subjects trusted the AV more than a human driver in situations where they had the right of way, while the opposite was true for situations where the vehicle had the right of way. What such studies have in common is that they do not look at realistic behavior, but conduct the experiments in a controlled laboratory with the use of videos or photos.

Field studies addressing this issue are even rarer and are mostly limited to observations. For example, in a field study with automated buses in Sweden the buses slowed down in complex situations, e.g. when they were overtaken by another vehicle. As a result, following cyclists suddenly steered away from the bus and sometimes rode into oncoming traffic [6]. Here, the participation of AVs in road traffic not only led to negative subjective safety assessments but also reduced objective safety. Such a behavioral adaptation was also shown in the CityMobil2 project. After some time, cyclists avoided getting too close to automated shuttle busses. If this could not be prevented, they accepted to travel very close to the AV instead of letting it pass a narrow section of the road first, for example [7]. However, current concepts of automated buses are not fully comparable to automated cars due to their very slow and defensive driving style as well as their unfamiliar outer appearance. Initial surveys of interactions with Uber´s semi-automated cars in Pittsburgh show that cyclists feel safer around them than around human drivers [8].

This shows why it is so important to study the interaction processes between VRUs, such as cyclists, and AVs in real traffic. The algorithms of the AVs must be able to anticipate the behavior of VRUs and thus ensure a subjectively and objectively safe interaction (cyclists should feel and be safe around them). This is the aim of the present study. How do cyclists behave when they encounter an apparent AV for the first time? How do they assess the situation and on what basis do they decide to cross? To answer these questions, a field study will take place in Munich in the summer of 2022, in which such interactions will be observed and the cyclists will be interviewed afterward. The study takes place within the TEMPUS project funded by the BMDV (German Federal Ministry for Digital and Transport).

2 METHOD

In the summer of 2022, we will conduct a field experiment in the city center of Munich, where we analyze interactions between cyclists and seemingly automated vehicles (Wizard-of-Oz experiment), as well as between cyclists and manually driven vehicles (between-subjects design). Structured observations and interviews are included in the analysis to generate both objective behavioral data of the cyclists and subjective experience data of the interaction. The observation site and the interactions we are interested in are shown in figure 1. The right-turning vehicle has a green light at the same time as the crossing cyclists. This site was chosen because of several considerations. First, it ensures that cyclists are confident about their right of way. At the same time, studies have shown that even at signalized crossings, VRUs are hesitant to cross until the vehicle clearly shows that it will stop, so the situation can still require communication [9]. In addition, this site allows us to position the vehicle directly at the red light, so the probability of an interaction with waiting cyclists is high.

2.1 Observation

A tablet-based software tool was developed for the observation. The designed coding scheme includes three different phases of a crossing in front of a turning vehicle at a signalized intersection: before, during, and after the crossing. In each of these phases, certain characteristics of the cyclists' behavior will be annotated. Categorizations are waiting time, distraction, gaze behavior, movement characteristics (e.g., fast, slow, …), and explicit communication. Additionally, the gender and age group, as well as observable handicaps were noted.

2.2 Interview

After an interaction is observed, the cyclists will be interviewed. For this, a station will be set up where cyclists will be invited to answer questions about cyclist safety. Questions will range from sociodemographic information to more specific interaction questions, for example, whether they felt safe in the before-experienced situation. The focus of the questionnaire is the cyclist´s subjective impression of the interaction.

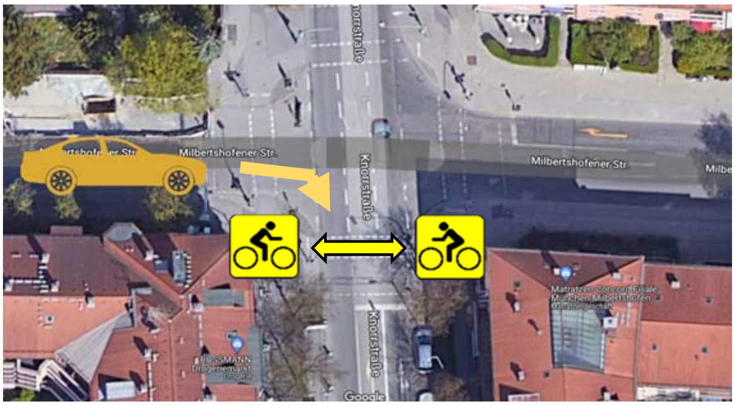

Figure 1: Observation site and interactions we are interested in.

3 IMPLICATIONS

With the help of the results, we hope to be able to assess the effects of AVs on the objective and subjective safety of cyclists. A comparison of interactions between cyclists and seemingly automated vehicles and cyclists and manually-driven vehicles will also allow us to anticipate behavioral changes before AVs enter the market.

4 REFERENCES

[1] W. Tabone *et al.,* "Vulnerable road users and the coming wave of automated vehicles: Expert perspectives," *Transportation Research Interdisciplinary Perspectives*, vol. 9, p. 100293, 2021, doi: 10.1016/j.trip.2020.100293.

[2] World Health Organization, *Global status report on road safety 2018*. Geneva, Switzerland: World Health Organization, 2018.

[3] M. Hou, K. Mahadevan, S. Somanath, E. Sharlin, and L. Oehlberg, "Autonomous Vehicle-Cyclist Interaction: Peril and Promise," in *Bernhaupt, Mueller et al. (Hg.) 2020 – Proceedings of the 2020 CHI*, pp. 1–12. doi: 10.1145/3313831.3376884.

[4] J. P. Nuñez Velasco, A. de Vries, H. Farah, B. van Arem, and M. P. Hagenzieker, "Cyclists' Crossing Intentions When Interacting with Automated Vehicles: A Virtual Reality Study," *Information*, vol. 12, no. 1, p. 7, 2021, doi: 10.3390/info12010007.

[5] M. P. Hagenzieker *et al.,* "Interactions between cyclists and automated vehicles: Results of a photo experiment *," *Journal of Transportation Safety & Security*, vol. 12, no. 1, pp. 94–115, 2020, doi: 10.1080/19439962.2019.1591556.

[6] H. R. Pelikan, "Why Autonomous Driving Is So Hard: The Social Dimension of Traffic," in *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, Boulder CO USA, 2021, pp. 81–85. doi: 10.1145/3434074.3447133.

[7] R. Madigan *et al.,* "Understanding interactions between Automated Road Transport Systems and other road users: A video analysis," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 66, pp. 196–213, 2019, doi: 10.1016/j.trf.2019.09.006.

[8] E. Boerer and A. Shewczyk, "AV Survey Results 2019: "Sharing the Road" with Autonomous Vehicles Survey Results 2019," 2019. [Online]. Available: https://bikepgh.org/our-work/advocacy/save/av-survey-results-2019/

[9] D. Dey, S. Ackermans, M. Martens, B. Pfleging, and J. Terken, "Interactions of Automated Vehicles with Road Users," in *Studies in Computational Intelligence, User Experience Design in the Era of Automated Driving*, A. Riener, M. Jeon, and I. Alvarez, Eds., Cham: Springer International Publishing, 2022, pp. 533–581. doi: 10.1007/978-3-030-77726-5_20.