Understanding the interaction between cyclists and automated vehicles: Results from a cycling simulator study

Ali Mohammadi, Giulio B. Piccinini, Marco Dozza

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
Chalmersplatsen 4, 41296, Gothenburg, Sweden
email: ali.mohammadi@chalmers.se
email: giulio.piccinini@chalmers.se
email: marco.dozza@chalmers.se

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1 INTRODUCTION

Cycling as an active mode of transport is increasing across all Europe [1]. Multiple benefits are coming from cycling both for the single user and the society as a whole. With increasing cycling, we expect more conflicts to happen between cyclists and vehicles, as it is also shown by the increasing cyclists' share of fatalities, contrary to the passenger cars' share [2]. Understanding cyclists' behavioral patterns can help automated vehicles (AVs) to predict cyclist's behavior, and then behave safely and comfortably when they encounter them. As a result, developing reliable predictive models of cyclist behavior will help AVs to interact safely with cyclists.

Cyclists' conflicts with vehicles most often happen in crossing situations when the two road users share the path [3]. Frequent conflicts happen at unsignalized intersections where priority rules determine which road user should pass the intersection first. Even though the priority of passing at unsignalized intersections is with the cyclists, in 42% cases, drivers do not yield for the cyclists in Sweden [4]. Very few studies tried to analyze quantitatively the interaction process of cyclists with vehicles at crossing scenarios. Silvano et al. developed a logit model to predict which agent would yield at the intersection when a conflict occurs [5]. In another study, Boda et al. proposed a computational model to predict driver behavior when interacting with a cyclist at unsignalized intersection. This model mainly predicts when drivers initiate braking and for how long they brake [6]. However, what is lacking in previous studies is that they either focused on the driver's side or they did not include detailed information from the cyclists.

Cycling simulators provide a safe and controlled environment to conduct tests with participants under different configurations. They are powerful tools to imitate real environments with the chance to repeat the scenarios. Further, a cycling simulator may be employed to measure participant's interaction with vehicles at intersections in a safe way, because collisions cannot result in damages or injuries. This study investigated cyclists' response process when they interact with a crossing vehicle at an unsignalized intersection. We propose quantitative models to predict cyclist behavior at intersections and a qualitative explanation of the interaction.

2 METHODOLOGY

The cycling simulator at VTI (the Swedish national road and transport research institute) facilities was used to imitate a real intersection in Gothenburg, Sweden. The simulated intersection is an unsignalized intersection with three legs, and conflicts between straight moving cyclists and vehicles that are coming from the right side were investigated (GPS coordinates: 57°42'31.1"N, 11°56'22.9"E). In Figure 1, the layout of the intersection and the moving direction of interacting agents are depicted. After some pilot tests, the independent variables for the experiment narrowed to three different times to arrival at the intersection (TTA) and two visibility distances (FOV distance). Three intersections without oncoming vehicle were included in between the trials to break the participant's expectation. At the end of the trials, a surprise event was included: specifically, in this trial the interacting vehicle was a truck instead of a car.

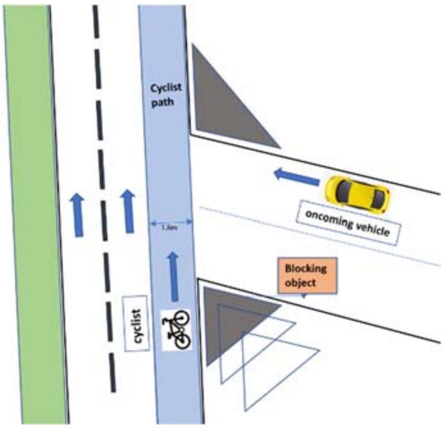

Figure 1: Layout of the intersection considered for the simulator.

Figure 2: Bike simulator and VR setup for the experiment.

The inclusion criteria comprised being 18-45 years old, riding a bike at least once a month, not wearing prescribed eyeglasses, having no physical disabilities, and being under 180 cm of height. Two questionnaires were also filled out during the experiment. The first questionnaire was about demographic information and participant's experience in the simulator. The second questionnaire is called the misery scale, and it was used for capturing the level of discomfort or dizziness that participants experienced during the experiment. It should be noted that a virtual reality headset was used in this experiment to visualize environment. In Figure 2, the experiment setup and the bike simulator can be seen. Sensor data were collected during the experiment and included kinematic information of the car and the cyclists, pedaling, steering angle, and head movement.

3 RESULTS

So far, 14 participants have been tested in the simulator; they had an average age of 29 years (SD = 8.4; range = 19-42). The participants included four women with an average age of 28.8 years and ten men with an average age of 29.1 years. Five participants completed all the trials, and the rest of the participants did not because they showed some signs of motion sickness, and the experiment stopped at that point. The data loss varied much across participants; in fact, the participants that completed only some trials passed the intersection from zero to 11 times (the total number of trials was 12).

Preliminary results show that each participant behaved similarly when the independent variables time to arrival to the intersection and field of view distance changed. Six out of 14 participants that succeeded in doing most of the trials were chosen for the analysis. In Figure 3, cyclists' speed profiles are depicted when the TTA changed, and the rest of the variables were kept constant. As is shown in the figure below, changing TTA values had no major effect on participants' behavior. No significant difference was found either when the FOV changed. Based on interviews, the participants expressed that lacking a driver inside the car to communicate was a major reason to behave safely in most trials (which resulted in cyclist yielding). This experiment is ongoing, and the results will be completed before the conference.

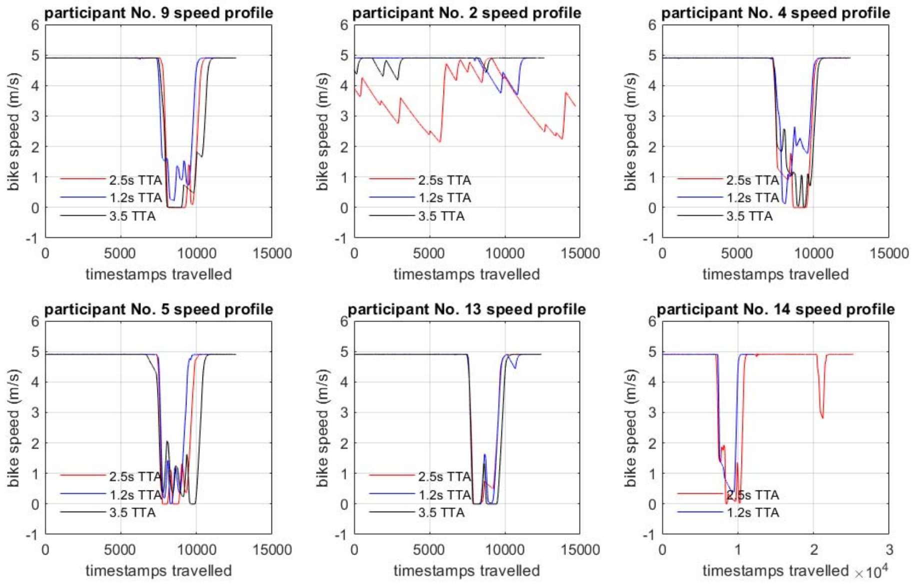

Figure 3: Cyclists' speed profile for different time to arrival (TTA) to the intersection values

4 DISCUSSION

According to the results and interviews, in most cases, participants chose to be safer by yielding to the vehicle because they could not communicate with the driver. Therefore, cyclists' behavior in this experiment implies the importance of implicit communication for interaction between cyclists and vehicles. This experiment is ongoing and will soon test more participants to increase the sample size. Full results will be presented at the conference and included in our paper. Our models will include 1) the cyclist's actions during the interaction (e.g., pedaling, braking, and head movement) and 2) subjective measurement results about the motion sickness and participant's experience during the test.

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