Validation of a VR cycling simulation in terms of perceived criticality and experience of presence

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1 INTRODUCTION

Cycling offers many benefits, such as reducing traffic congestion, lower emissions and health benefits [1]. To further promote cycling, the cyclists' perceived safety needs to be addressed [2]. In this context, automated vehicles offer high potential for designing safe and comfortable interactions with cyclists in the future [3]. A key parameter in these interactions constitutes the proximity of vehicles passing cyclists to avoid causing discomfort [4]. To evaluate specific scenarios with varying proximity, cycling simulators provide a safe and standardized environment for traffic safety research. Therefore, there are numerous efforts to implement cycling simulators for use in research [5]. However, it is important to verify the simulator validity to ensure the generalizability of results [6]. In this work, an implementation of a virtual reality (VR) cycling simulation is presented and it is aimed to investigate the simulator validity in terms of perceived criticality in traffic conflict scenarios as well as the participants' experience of presence within the VR cycling simulation.

2 METHOD

2.1 Experimental Design

The study is implemented as a 3 x 4 within-subjects design and consists of three conflict scenarios between a cyclist and vehicle, each with four different levels of potentially critical outcome: non-critical (baseline condition) as well as low, moderate and high potential of a critical outcome. As dependent variable, the perceived criticality within the conflict scenarios is assessed.

2.2 Material

2.2.1 Cycling Simulation

The open source project LoopAR [7] is used as basis for the VR cycling simulation. Originally, this virtual reality environment of a city was developed in the Unity 3D game engine and used for studies on automated driving from the passenger perspective (e.g., takeover requests) [7]. The simulation was modified to provide a naturalistic impression of a bike ride, including the cyclist's perspective when sitting on a bike as well as the moving bicycle wheel, the handlebar and the cyclist's hands in the foreground. In addition, three different perspectives of the cyclist were implemented, i.e. to the front, to the right and to the left. Using a static bicycle, this setup allows laboratory studies in front of three monitors. Alternatively, the VR cycling scenarios with only a frontal perspective and no static bicycle can be used as video files in online studies. The latter is applied in the present work.

2.2.2 Conflict Scenarios

In all conflict scenarios, the cyclist has priority. However, the vehicle crosses the cyclist's trajectory in front of him with varying proximity. The three conflict scenarios are depicted in Figure 1: In the first scenario (see Fig. 1, left), the cyclist approaches to an intersection while a vehicle from the left closely crosses the cyclist's trajectory. In the second scenario (see Fig. 1, middle), the cyclist passes vehicles standing on the parking lane while one of them suddenly leaves the parking lot. In the third scenario (see Fig. 1, right), the cyclist overtakes waiting cars using the bike lane while the first vehicle suddenly accelerates and turns right.
To systematically vary the proximity in the three scenarios, the initially attempted post encroachment time (IAPT) is used [8]. This prospective measure is based on the timespan between the leaving of the first and arrival of the second road user at a conflict point, if no speed adjustments are initiated by the road users. A lower IAPT is related to a higher potential for a critical outcome of the scenario while the vehicle crosses the cyclist's trajectory with lower proximity. In this study, scenarios with low potential for a critical outcome are designed with an IAPT of 3 seconds, a moderate potential for a critical outcome with an IAPT of 2 seconds and a high potential for a critical outcome with an IAPT of 1 second.

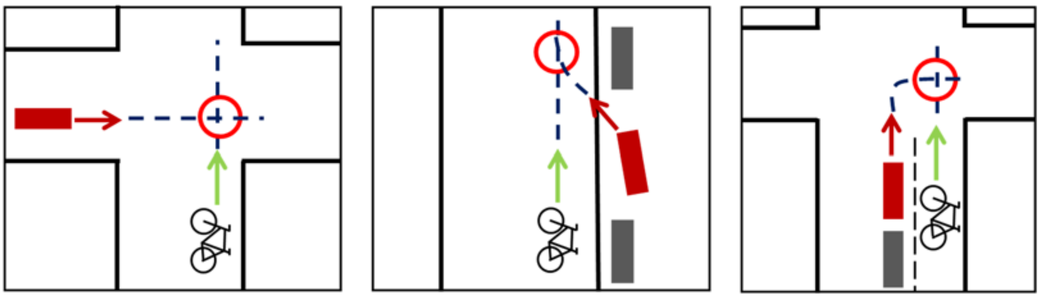

Figure 1: Three conflict scenarios between cyclist (green) and vehicle (red).

2.2.3 Questionnaires

Sociodemographic variables are asked including the cycling experience and frequency of bike use. Additionally, sensation seeking [9] as well as affinity for technology interaction [10] are rated. For measuring the perceived criticality within the conflict scenarios, the Scale for criticality assessment of driving and traffic situations [11] is used. The scale ranges from 0 (~ not critical at all) to 10 (~ most critical). Further, the participants' experience of presence in the cycling simulation is measured. For this, the Igroup Presence Questionnaire [12] is used, containing 14 questions regarding spatial presence, involvement and experienced realism. The scale ranges from -3 to +3 with different verbal anchors.

2.3 Procedure

The online study is conducted using jsPsych [13] and starts with a sociodemographic questionnaire. Then, the videos with the conflict scenarios are presented in random order. Each video has a length of approximately 30 seconds, beginning with an urban bike ride and ending with a black screen shortly after the onset of the conflict scenario. Thus, it is not clear to the participants how the scenario ends, i.e., whether the vehicle still yield to the cyclist or not. This should focus on the potential criticality and avoid changes of mind after showing the successful resolution of the scenario [14]. After each video, the perceived criticality is assessed. At the end of the study session, the experience of presence within the VR cycling simulation is rated.

3 RESULTS & DISCUSSION

The study results are pending and will be presented at the conference. The analysis will include whether the perceived criticality varies according to the different IAPT levels within the three conflict scenarios. Furthermore, individual differences, such as regarding cycling experience and sensation seeking, will be considered. In addition, the VR cycling simulation will be evaluated based on the ratings for the experience of presence. The results will provide first indications on the simulator validity, especially regarding the perceived criticality in traffic conflict scenarios. This is important for future studies investigating the interaction between automated vehicles and cyclists to design safe and comfortable driving maneuvers. Further, advantages and disadvantages of the presented implementation of a VR cycling simulation will be discussed.

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