International Co-operation on Theories and
Concepts in Traffic Safety

Smart Human-Machine Interaction for Cyclists Safety

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Introduction

Cyclists, who are vulnerable as other road users, may benefit from a smart system that provides collision warnings and assists in obstacle avoidance, displaying prospects for improving safety. Warnings using haptic or vibrotactile feedback were found to be intuitive, allowing cyclists to keep their attention on the road while receiving the hazard information (Brummelen et al., 2016). Human capability to recognize a tactile stimulus through body regions such as the face and fingers is advanced in perception, due to the higher density of the receptors in these areas (Wennerholm & Rosengren, 2008). Besides vibrotactile, auditory feedback also satisfies the criteria of effective warning; however, it may interfere with riders' desire to listen to music and communicate with other cyclists (Erdei et al., 2021). This study aims to evaluate the efficacy of a Smart Human-Machine Interaction (HMI) system that provides a combination of vibrotactile and visual warnings to cyclists experiencing three critical scenarios: a vehicle overtaking from behind, a vehicle entering a cyclist's path while making a turn, and a pothole ahead in the cyclist's lane.

Method

This study was conducted in a virtual-reality bicycle simulator, which presented participants with the simulated critical scenarios via a heads-up display (HUD) accompanied by a bicycle trainer rig allowing them to pedal and manoeuvre within the simulation. The proposed HMI incorporated vibrotactile feedback delivered through handlebar grips, along with visual cues via a display unit and an LED bar mounted on the handlebar. All warnings were provided in two stages, depending on the distance between the potential hazard and the cyclists. Longer distances are represented by amber-coloured visual warnings on the LED bar, assisted by an amber-coloured icon on the display unit. Shorter distances are represented by red-coloured visual warnings on the LED bar, assisted by red-coloured icon on the display unit (Figure 1). Overall, red-coloured visual warnings were aided by three pulses of vibrotactile cues. However, in the pothole scenario, a single pulse vibrotactile feedback was used along with amber-coloured warnings, and three pulses were used for red-coloured warnings. All twenty-four participants experienced the three critical scenarios while cycling, both with and without HMI activation. Data were gathered on participants' pedalling, speeding, and braking behaviours. At the end of the experiment, participant answered two subjective questionnaires: the System Usability Scale (SUS) and a User Experience Questionnaire (UEQ), providing their comprehensive experience with the proposed HMI solution.

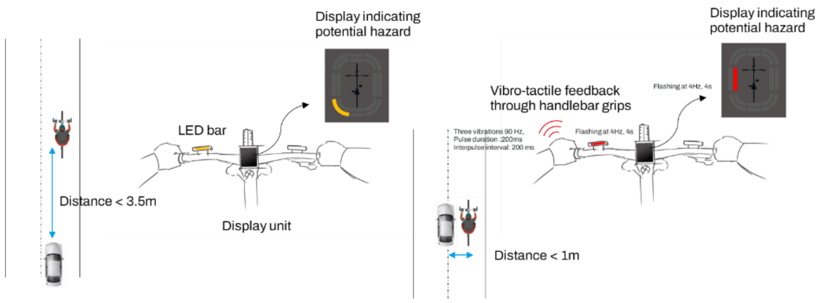

Figure 1 Proposed Smart HMI solution assisting cyclist for the scenario: vehicle overtaking from behind.

Results

The data analysis showcased that participants' pedalling, speeding, and braking were influenced by the HMI. For the vehicle overtaking scenario, no major difference was observed between the HMI activation and its absence regarding pedalling, speeding, and braking. However, for the scenario involving a vehicle entering the cyclists' path, about 50% of the participants initiated pedalling within 2 seconds of receiving the amber-coloured visual warnings. This percentage decreased to 30% during red-coloured visual warning. However, no major difference was observed in the speeding and braking behaviours. In the pothole scenario, about 40% of the participants began pedalling within 2 seconds after receiving amber-coloured visual warnings, which further decreased to 30% for red-coloured visual warnings. Additionally, a speed reduction of 2-3 km/h was observed within 2 seconds of receiving both amber and red-coloured visual warnings. About 30% of the participants braked in response to both amber and red-coloured warnings. Regarding subjective measures, the HMI obtained an SUS score of 78 inferring that the design is good. Moreover, the response from the UEQ indicated a positive experience with the HMI. Nearly, 70% of participants agreed with the question "*Does the assistance system (HMI) increase traffic safety*?". In addition, the user comments received after the experiment provide the necessity for improvements in the intensity of vibrotactile cues and the location of the display unit.

Conclusions

This study showcased that the concept of a Smart HMI system alerting cyclists about the critical scenarios is advantageous. Objective measures revealed that pedalling, speed, and braking behaviour were affected by the HMI for the scenarios "vehicle entering the cyclist path" and "pothole ahead in cyclist lane." Subjective measures indicated that the HMI design was perceived to be good.

References

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