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User Interfaces for Cyclists in Future Automated Traffic

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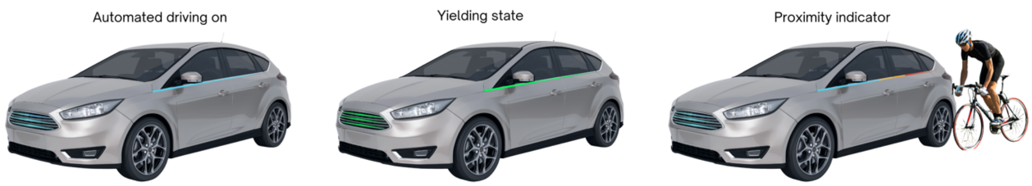

Figure 1: Omnidirectional eHMI concept

ABSTRACT

In future traffic, intelligent user interfaces may aid cyclists in interpreting the behaviour of automated vehicles. Cyclists can be equipped with obstacle-detecting sensors, and an interface could display relevant information or use audible alerts to warn or inform cyclists of other road users' intent and potential hazards. Researching intelligent user interfaces for cyclists is vital for understanding how users can efficiently and safely interact with automated vehicles. This work-in-progress paper presents two studies for developing and testing user interfaces for cyclists in future automated traffic. In the first study, we reanalysed interview data from 30 cyclists, resulting in two interface concepts: the app CycleSafe and an omnidirectional on-vehicle interface capable of communicating cyclist recognition. In the second study, we outline an envisioned experiment to test these two concepts in a naturalistic environment with cyclists and a vehicle emulating automation. We hypothesise that cyclists prefer receiving warning signals over no warnings, prefer early over late warnings, and that auditory signals and visual on-vehicle interfaces will perform better than visual on-bike interfaces.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **Empirical studies in HCI**;

KEYWORDS

Human-machine interface, cyclist, AV, smart bicycles

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1 INTRODUCTION

Integrating automated vehicles (AVs) into the transport system raises concerns about the potential impact on vulnerable road users such as cyclists. As cycling is an increasingly popular mode of transport [12], it is crucial to understand how AVs and cyclists interact to ensure the cyclists' safety and continued inclusion in the transport system.

Human-machine interfaces (HMIs) allow users to interact with a device, program, or machine. The electrification of bicycles and the introduction of intelligent HMIs can potentially revolutionise the cycling industry and enhance the overall cycling experience, including cyclists' interaction with AVs. Regarding safety, bicycles can be equipped with self-balancing technology [17, 18] and sensors detecting obstacles or conflicts [7]. An intelligent HMI for cyclists could include a display showing cyclists relevant information or warning signals of potential collisions or other hazards [10, 11, 14, 15]. With the advent of intelligent interfaces and connected transport systems, researching HMIs for cyclists is essential for understanding how users can efficiently and safely interact with these technologies.

This paper outlines a work in progress of two studies exploring the potential of using cyclist-oriented HMIs to improve the safety of cyclists in future traffic with AVs. The overall objectives of the studies are to develop HMI concepts and investigate when and how warnings should be presented to cyclists. In the first study, we analysed interviews with 30 cyclists to explore the type of information cyclists want from AVs and the design strategies applicable to cyclist-oriented HMIs. The second study outlines a naturalistic experiment investigating the effects of visual and auditory warning signals for cyclists interacting with a vehicle in ambiguous situations.

2 FIRST STUDY: USER INTERFACE DEVELOPMENT

2.1 Methods

In this study, we applied an exploratory approach by analysing qualitative data from 30 cyclists from Norway and the Netherlands [3] collected in a previous interview study [1]. The semi-structured interviews were conducted online. The sample consisted of 19 males and 11 females with an average age of 43 years (*SD* = 16). Most participants (73%) cycled daily, and one-third identified themselves as early adopters of technology.

We performed an inductive thematic analysis by Braun and Clarke [4] on data from the following questions:

- What kind of information would you need from an AV?
- Imagine a device that helps you interact with AVs: How should this device be designed? How should the device communicate with cyclists?
- If you could receive information about AVs through a device on your bike: What kind of traffic information would be useful? What kind of information about cyclists would be useful for the AV?

Combining the results from the thematic analysis with previous literature, we created mock-up designs of two HMIs. See supplementary data for the complete analysis and a selection of quotes.

2.2 Results

The interface concepts were developed to accommodate cyclists' needs and characteristics extracted from the thematic analysis. The analysis uncovered that cyclists' primary need in traffic with AVs is to be seen. Cyclists also prefer explicit communication of detection from the AV. However, the most frequently mentioned features of a cyclist-oriented HMI were a system detecting other road users – including vehicles and other cyclists – and conveying information about their trajectories and intentions to the cyclist while also providing an option for real-time recommendations about navigation, speed, and traffic information. The communication modality of choice varied among the interviewees, but a visual interface was the most recurring modality in the analysis. The first interface concept, CycleSafe, aspires to meet these criteria. CycleSafe is a mobile application that utilises bicycle, vehicle, and infrastructure sensors combined with mapping technology to detect the presence and location of other road users and display this information on the screen. It also includes an alert system for critical or urgent situations, such as an imminent conflict with a vehicle, e.g., an approaching vehicle, a vehicle in the cyclist's blind spot, or a vehicle attempting to overtake the cyclist, as well as features like speed tracking and turn-by-turn navigation.

Cyclists have higher speeds than pedestrians and interact with vehicles longitudinally and in crossing and merging situations [2]. Accommodating cyclists' behavioural characteristics and desire for explicit communication, we developed the second concept: An omnidirectional external HMI (eHMI) placed on the vehicle (see Figure 1). The interviewed cyclists suggested that on-vehicle interfaces should be designed as an objective indicator of AV behaviour, as display, light, or LED lightbar, with different colours indicating the detection of the cyclist or the automated vehicle's intention. Taking cyclists' movement patterns into consideration, our proposed eHMI concept uses an LED light strip visible from all around the vehicle, to indicate whether the car is in automated driving mode. The light strip also changes colours from yellow to orange and red to indicate the proximity of the cyclist to the vehicle. As cyan is easily visible, perceptible to colour-deficient individuals, and not yet used in traffic signs [5, 16], the light strip is cyan when automated driving is active.

2.3 Discussion

This study aimed to improve cyclist-AV interaction by identifying cyclists' information needs and developing HMI concepts. Two concepts were developed: CycleSafe, an app-based smartphone concept, and an eHMI concept using an omnidirectional design and lights changing colours to indicate the cyclists' proximity to the vehicle. The analysis showed that cyclists prefer visual HMIs, although previous research indicates that audio is an efficient modality [9, 13] and that haptics is a slightly more preferred modality [6]. In sum, it is essential to continue further research on the effects of different HMI communication modalities on cyclists.

3 SECOND STUDY: REAL-LIFE TESTING

In this study, we outline an envisioned experiment for empirical testing of the two HMI concepts: a warning system feature of CycleSafe and the omnidirectional eHMI. Focusing on the effect of HMIs' communication modalities, this proposed experiment investigates whether cyclists benefit from receiving a warning signal and compare the efficiency of auditory and visual warning modalities. We derived the following research questions:

- Do cyclists benefit from and accept a warning about an approaching vehicle compared to no warning?
- Should the warning be presented in a visual or auditory modality or on the vehicle itself?
- Should the warning be presented early, i.e., anticipatory: before implicit communication manifests, or late?
- How does vehicle automation affect the efficiency of HMIs?

3.1 Methods

The experimental task is envisioned at a staged intersection without occlusion, where the cyclist crosses the intersection with a vehicle approaching from the right side in a 90-degree perpendicular direction. The cyclist will be instructed to cross the intersection if the car comes to a complete stop or stop if the vehicle implies taking the right-of-way. The driver will be instructed to initiate yielding or non-yielding by slowing down and stopping approximately 7 meters before the intersection or slowing down and crawling approximately 5 meters further to indicate the vehicle is not yielding. To the participant, the situation may appear ambiguous. The driver will not make head turns or eye contact with the cyclist, resembling the behaviour of a distracted driver or passenger of an AV with SAE level 3 or 4. The cyclist will receive an early or late warning through an on-bike smartphone with CycleSafe (see Figure 2)

Figure 2: The auditory, visual, and visual-auditory warning system features of CycleSafe

or the on-vehicle eHMI. In line with previous research, the auditory signal will be 75 dB [8, 9]. For the visual signal, we will use a warning triangle symbol flashing on the screen twice for a duration of 400 ms, followed by a 400 ms break and 2400 ms visibility, similar to Erdei et al. [9]. The eHMI will be illuminated in cyan colour, indicating automation is on. The eHMI will light up green for the yielding trials, referencing that of a traffic light (see Figure 1). Early warnings will be issued before the cyclist can differentiate the yielding and non-yielding trials. As CycleSafe and the eHMI are still at the concept stage, the warnings will be triggered by GPS at pre-determined location points decided through pilot testing. The cyclist will interact with the vehicle in 20 trials and perform each combination twice, adding up to 40 trials per participant. All conditions will be randomised in blocks, starting with the baseline condition, e.g., the cyclist will receive a late and early warning to a vehicle yielding and not yielding in a randomised order for one randomised HMI modality at a time.

Data will be collected with an instrumented bicycle, measuring cyclist speed, position, and swerving behaviour. The vehicle will be fitted with corresponding equipment measuring speed and position. We will use Tobii Pro Glasses 3 to measure cyclist eye-gazing behaviour. Post-trials, we will collect self-reported experiences with a short interview and questionnaire. The method of analysis of data is yet to be determined. We suggest a sample of 30 to 50 cyclists, likely recruited through social media advertisements and on-site flyers.

3.2 Results and discussion

The envisioned study is still being planned, and there are no results to date. We hypothesise that cyclists prefer receiving warning signals over no warnings. In the user interface development study, most cyclists preferred to receive explicit communication from the AV. Cyclists will likely prefer receiving warning signals early rather than late due to early warnings' anticipatory nature in an ambiguous situation at an intersection with an AV. Lastly, we assume that auditory signals and the eHMI will perform better than the visual on-bike HMI. As the cyclists will have to place their visual attention away from traffic and to a warning displayed on the handlebars, the visual on-bike warnings will likely interfere more with the cyclists' visual attention than audio and the eHMI.

4 CONCLUSION

This work-in-progress paper presented two studies aiming to develop and test user interfaces to improve the interaction of cyclists and AVs in future traffic. The first study indicated that cyclists need to be seen by AVs and prefer explicit communication of detection. Based on the interview data, we developed two HMI concepts, the app CycleSafe and an omnidirectional eHMI capable of communicating detection to cyclists. For the second study, we outlined an envisioned experiment to test the efficiency of the HMI's warning signals in a naturalistic study with cyclist-vehicle interaction. We hypothesise that cyclists prefer receiving warning signals over no warnings, prefer early over late warnings, and that auditory signals and the visual eHMI will perform better than the visual on-bike HMI.

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