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Cyclist support systems for future automated traffic: A review

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1 INTRODUCTION

Interpreting the subtleness and complexity of vulnerable road user (VRU) behaviour is still a significant challenge for automated vehicles (AVs). Solutions for facilitating safe and acceptable interactions in future automated traffic include equipping AVs and VRUs with human-machine interfaces (HMIs), such as awareness and notification systems, and connecting road users to a network of AVs and infrastructure. The research on these solutions, however, primarily focuses on pedestrians. There is no overview of the type of systems or solutions supporting cyclists in future automated traffic.

The objective of the present study is to synthesise current literature and provide an overview of the state-of-the-art support systems available to cyclists. The aim is to identify, classify, and count the types of communicative technologies, systems, and devices capable of supporting the safety of cyclists in automated traffic. The overall goal is to understand AV-cyclist interaction better, pinpoint knowledge gaps in current literature, and develop strategies for optimising safe and pleasant cycling in future traffic environments with AVs.

2 METHODS

We collected data through literature searches and then taxonomically coded and analysed the identified concepts. To collect relevant academic articles, we performed literature searches in the databases Scopus and Google Scholar. In addition, we used Google to identify informal concepts from the industry. The criterium for selecting the study sample was set to transport-related concepts capable of transferring messages or information among road users through technology, where articles not involving cyclists or bicycles were excluded. In total, we identified 62 publications that fit the inclusion criteria: 38 journal or conference papers, 18 commercial or industry products, four patents, one book section, and one poster. Several of the publications contained descriptions of more than one system, adding up to the identification of 92 concepts in total.

The study sample was analysed systematically using a taxonomical coding system: sorting, categorising, and counting the concepts across 13 dimensions based on terminology, the number of interfaces and placement, modality and strategy of communication, the systems' functionality, and the method of evaluation of the concepts. The results from the coding system were analysed through descriptive frequencies and pivot tables.

3 RESULTS

The descriptive analysis of the coding and categorisation of the 92 communicative concepts showed that one out of three concepts was categorised as having more than one placement, see Figure 1. The most common placement of the system or interface was cyclist wearables (39 % of all concepts), closely followed by on-bike devices (38% of all concepts), and vehicle systems (33% of all concepts). About one in four concepts had placements on infrastructure or projections on infrastructure.

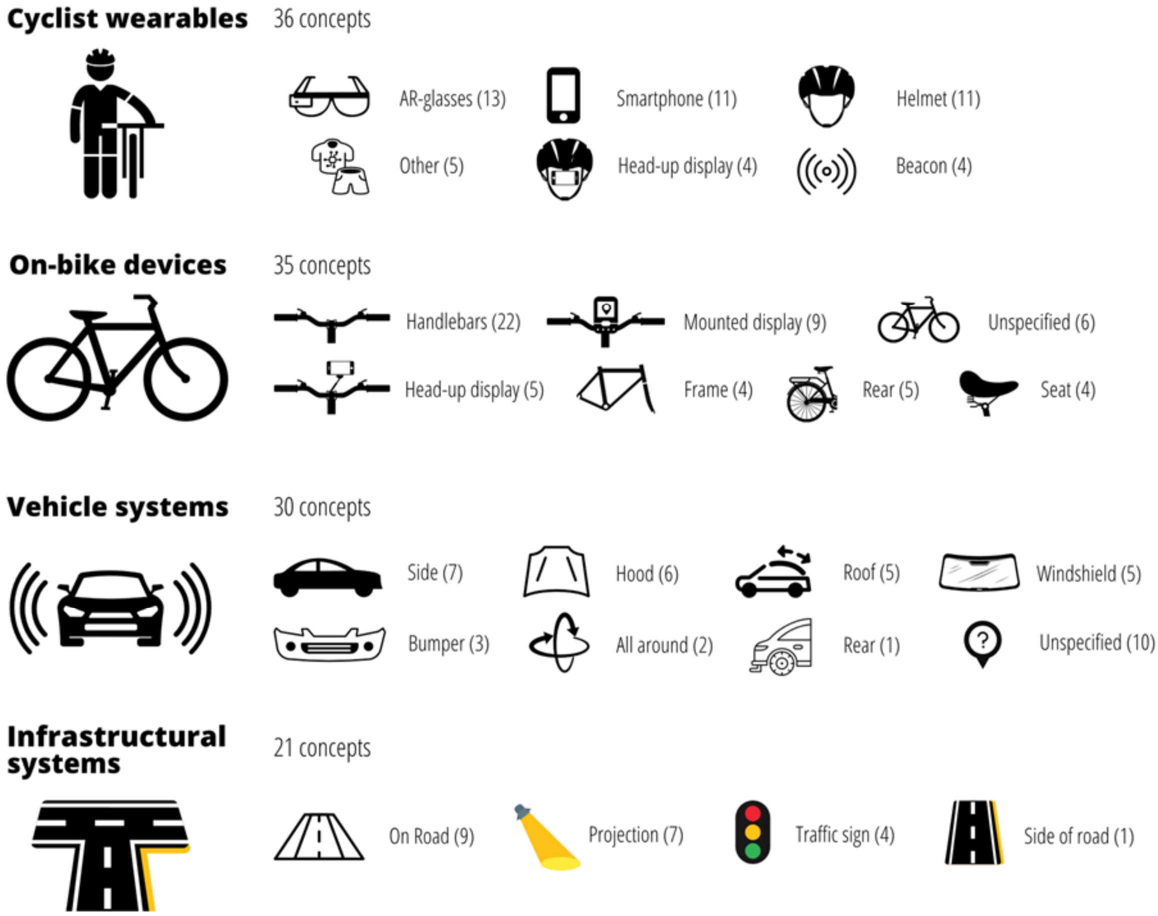

Figure 1: HMI placement of the 92 concepts.

The most common communication modality was visual; four out of five concepts communicated their message visually. Abstract/light was the most frequent modality (54% of visual concepts). For visual interfaces, red (19%), green (18%), and yellow (13%) were the most recurrent colours.

Approximately one out of three concepts used auditory and motion-based communication modalities. The most common way of auditory communication was a signal or buzzer (17 concepts, 68% of auditory concepts), typically as an alert or warning to the cyclist. In about two out of three motion-based concepts, the modality of communication was haptic feedback, like vibrating handlebars. Nine concepts use gestures, typically to control augmented reality (AR) glasses. 38 out of 92 (41%) concepts involved a connectivity feature or technology with the potential of connecting multiple agents to transmit messages.

The concepts were categorised with functionality spanning three groups of systems: information systems, warning systems, and support systems. Two-thirds of the concepts functioned as information systems, informing the user about a particular arrangement or sequence of events. However, the most common functionality across concepts was a warning system communicating an alert of an imminent or potential conflict or collision. Only 11 of the concepts were coded as a support system, conveying messages with a behavioural component of the cyclist or bicycle, such as information about a cyclist's current or potential future behaviour.

4 DISCUSSION

Cyclists differ from pedestrians in terms of eye-gazing behaviour, speed, and movement patterns; while pedestrians usually interact with vehicles at crossings, cyclists regularly share the road and travel parallel with vehicles, experiencing crossing, merging, and overtaking situations. Almost all of the concepts categorised as vehicle systems (97%, 29 out of 30 concepts) had the functionality of an information system. Most of these concepts were external on-vehicle HMIs (eHMIs) targeting pedestrians and cyclists, and only seven concepts were omnidirectional (i.e., with placements on the roof or all around the vehicle). The differences between VRUs must be considered in the design and evaluation process of eHMIs. It is essential that the interfaces are visible from all around the vehicle to accommodate the differences in movement patterns and that the message can be observed at the higher speeds of cyclists.

When anticipating their needs in future automated traffic, interviewed cyclists' main concerns were visibility and confirmation of detection by the automated vehicle [1]. The concepts identified in our study have the potential to cover these needs. For instance, CommDisk, a 360° rooftop-mounted eHMI providing omnidirectional two-way communication [2], and The Tracker, a band of light surrounding the vehicle illuminating a small segment in the spatial proximity of the detected VRU [3], both show potential to accommodate the topography and needs of cyclists.

Moreover, several concepts categorised as cyclist wearables and on-bike devices were warning systems detecting a nearby entity, using targeted communication to alert the cyclist of a potential conflict. Most of the vehicle system concepts aimed to inform the cyclist of the vehicle's current or future behaviour by broadcasting messages. Combining these concepts by utilising the bandwidth mode of communication by connecting the cyclist or bicycle to a network of AVs and infrastructure might enhance visibility and provide sufficient acknowledgement to the cyclists. Such vehicle-to-everything concepts exist; however, the complexity of implementation and use is a major future challenge.

5 CONCLUSION

The findings from this study provide a synthesis of the present literature on AV-cyclist interaction and an overview of the state-of-the-art cyclist support systems. In the final paper, we aim to further align this overview with knowledge about cyclists and their behaviour from a human factors perspective, assess whether the solutions meet cyclists' needs, and explore their potential impact on cyclists in the future.

Concluding on a recommended system based on the identified concepts is challenging as most concepts have not been tested nor evaluated with automated vehicles, and the results are ambiguous regarding the need and necessity of the systems in future traffic. However, the overview we provide is helpful for future research, testing, and development of concepts for supporting cyclists in future automated traffic.

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