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Enhancing Explainability of Automated Vehicles with Culturally-Aware HMIs

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ABSTRACT

In the future, automated vehicles can allow much longer journeys to be undertaken without a driver. This could involve travel across countries with different road systems, traffic rules, and regulations. Disparate cultures also have different expectations of how vehicles should behave. These need to be taken into account when designing HMIs to convey vehicle behaviour and intent. In this work, we presented four scenarios where culturally-sensitive HMIs could benefit both drivers and other road users in a cross-cultural setting. This video will hopefully provoke further discussion and research interest in cross-culture human-vehicle interaction.

KEYWORDS

eHMIs; autonomous vehicles; cross-cultural;

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1 INTRODUCTION

One of the perils of travelling away from your home country is having to navigate the different road and traffic laws at your destination. Driving regulations and laws can differ substantially even between neighbouring countries, and until now it has been the responsibility of the driver to maintain knowledge of and drive appropriately to the country they are in. However, as automotive user interfaces increase in complexity and function, and the adoption of automated vehicles (AVs) increases, human-machine interfaces (HMIs) [2] are being used to communicate between the vehicle and the driver. This is with the goals to improve explainability of the vehicle's behaviour, increase trust and acceptance and improve safety when interacting with AVs.

Whilst much research has been conducted into this, there has not been different cultures have different expectations from HMIs and interact with them differently. It has been shown how hazard perception ability differs across cultures, holding different perspectives on what constitutes a road hazard [16] and different visual search patterns on the road [6]. Understanding of local road signs has also been shown to be affected by culture [11]. Ranasinghe et al. highlight the importance of conducting cross-cultural research into interaction with HMIs, since this can differ significantly between cultures. A one-size-fits-all solution is likely to lead to confusion whilst travelling across multiple driving cultures.

The video presented here is an attempt to design and prototype culturally-aware HMIs that can communicate information about the vehicle both internally to the driver and externally to other road users. Four scenarios are presented in Figure 2 which illustrate potential applications of this concept, which are discussed here in greater detail.

2 SCENARIOS

2.1 Scenario 1: Pedestrian Interaction

In this scenario, the pedestrian behaviours between the Netherlands and South Korea were contrasted. Pedestrian behaviour has been shown to vary by country and culture [14, 15, 18]. In the Netherlands for example, it is common for pedestrians to step out into the road at crossings as in other European countries [18]. However, in South Korea, pedestrians will wait at crossings until it is clear to walk [12], similar to other Asian countries such as Japan [15].

This can cause a conflict when an AV is designed to allow a pedestrian to cross first as a priority. Much work has been conducted into how AV-pedestrian interactions should be characterised [3, 9]. The external appearance of a vehicle affects pedestrians decisions to cross [4]. Yet these only consider the local customs in the country where the research is conducted. Studies looking at cross cultural differences show that Chinese participants reacted differently to an external-HMI (eHMI) than their German and US counterparts [17]. The eHMI presented here allows communication between the vehicle and pedestrians, taking into account different cultural interactions with the road. This can help prevent misunderstandings and increase trust in automation

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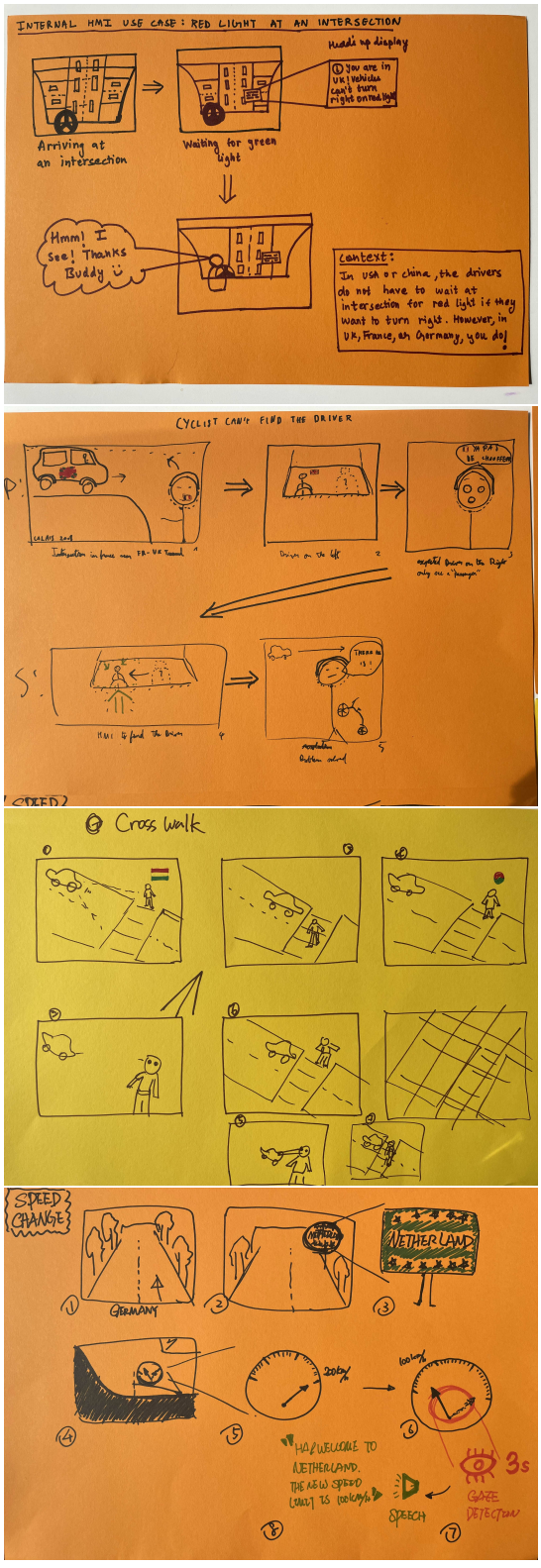

Figure 1: Images showing the storyboard prototypes of each of the four scenarios (1-4, from top left in clockwise order)

2.2 Scenario 2: Social Interaction with LHT vs RHT

In this scenario, expectations and social interactions of drivers with vulnerable road users (VRUs) was considered. Whilst the majority of the world drives on the right hand of the road in right-hand traffic (RHT), a significant proportion of countries have a system of left-hand traffic (LHT). Vehicles that cross between countries with different handed traffic will have a different cockpit orientation based on the country of origin. For example drivers of vehicles crossing from the UK to France, or from Hong Kong to mainland China will be sat in a different seating position to other local drivers vehicles. This is important to consider as one of the ways in which VRUs engage with vehicles is by making eye contact with the driver to ensure they have been seen [10]. This could lead to confusion when a LHT vehicle is driving in a RHT country, as drivers will not be in the position that is expected by local VRUs. Even in an automated context, VRUs will still look to a driver to establish this connection [5] and use this information to mediate how they behave around them [13]. The concept proposed here is an eHMI that directs attention to properties of the vehicle in a novel cultural context that may not be obvious to those in the local area, such as the location of the driver in the cockpit of a LHT vehicle in a RHT country. This can facilitate mutual understanding and social interaction that is used by vulnerable road users

2.3 Scenario 3: Communicating local traffic rules and regulations

This scenario considered the converse of scenario 2; how to communicate changes in vehicle behaviour to the driver. An AV travelling through multiple different countries will need to comply to multiple different traffic laws and regulations, changing it's behavioural model depending on it's location. Since it is no longer the driver's responsibility for the driving task in a highly automated vehicles, there is a gap between the driver's awareness and the vehicle's behaviours and intent. It has been suggested that communicating the vehicle's state and intention is rated as important by passengers [8]. In this scenario, a vehicle from France is driving in the UK, where there are different laws regarding turning right on a red light. This is legal in France, but not in the UK. A driver of a French AV travelling in the UK might intrinsically expect the vehicle to behave as it would back home. The information relevant to drivers has been shown to be linked to trust [1]. An internal HMI to describing and explaining changes in the AVs behaviour would help improve this trust in the vehicles safe operation in a different traffic context, rather than a malfunction.

2.4 Scenario 4: Crossing into another country

The final scenario expands on the previous on of internal HMI aiming to explain behaviour of the vehicle. In this case, a change in speed limits between two countries, such as Germany and the Netherlands. As previously mentioned, information drivers require is linked to their trust in the AV [1]. An advanced HMI could detect if the vehicle users are confused about changes in its behaviour by measuring driver behaviour through gaze tracking or physiological arousal levels, common measures used to assess the state of the driver [7]. For example, after detecting user attention on the

speedometer changes, the system would trigger a voice assistant to explain the speed shift due to crossing two countries with different speed limits on highways.

3 FUTURE DIRECTION AND FURTHER WORKS

The work presented here is an initial prototype into how culturally-aware HMIs could be implemented to improve the explainability of AV behaviour. This video will inspire discussion about how cross-cultural driving might be accounted for when developing HMIs for both manual and automated vehicles, and how explainability is an important factor to consider for increase trust and acceptance of this technology. This video will hopefully serve as research stimulus for future work investigating human-vehicle interaction across cultures.

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REFERENCES

[1] Matthias Beggiato, Franziska Hartwich, Katja Schleinitz, Josef Krems, Ina Othersen, and Ina Petermann-Stock. 2015. What would drivers like to know during automated driving? Information needs at different levels of automation. In *Proceedings of the 7th Conference on Driver Assistance*. Technische Universitat Munchen (TUM) Munich.

[2] Debargha Dey, Azra Habibovic, Andreas Löcken, Philipp Wintersberger, Bastian Pfleging, Andreas Riener, Marieke Martens, and Jacques Terken. 2020. Taming the eHMI jungle: A classification taxonomy to guide, compare, and assess the design principles of automated vehicles' external human-machine interfaces. *Transportation Research Interdisciplinary Perspectives* 7 (2020), 100174.

[3] Debargha Dey, Azra Habibovic, Bastian Pfleging, Marieke Martens, and Jacques Terken. 2020. Color and animation preferences for a light band eHMI in interactions between automated vehicles and pedestrians. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[4] Debargha Dey, Marieke Martens, Berry Eggen, and Jacques Terken. 2019. Pedestrian road-crossing willingness as a function of vehicle automation, external appearance, and driving behaviour. *Transportation research part F: traffic psychology and behaviour* 65 (2019), 191–205.

[5] Debargha Dey, Francesco Walker, Marieke Martens, and Jacques Terken. 2019. Gaze patterns in pedestrian interaction with vehicles: Towards effective design of external human-machine interfaces for automated vehicles. In *Proceedings of the 11th international conference on automotive user interfaces and interactive vehicular applications*. 369–378.

[6] Leandro L Di Stasi, Carolina Diaz-Piedra, José M Morales, Anton Kurapov, Mariaelena Tagliabue, Anna Björtå, Alberto Megias, Jens Bernhardsson, Svitlana Paschenko, Samuel Romero, et al. 2020. A cross-cultural comparison of visual search strategies and response times in road hazard perception testing. *Accident Analysis & Prevention* 148 (2020), 105785.

[7] Tobias Hecht, Anna Feldhütter, Jonas Radlmayr, Yasuhiko Nakano, Yoshikuni Miki, Corbinian Henle, and Klaus Bengler. 2019. A review of driver state monitoring systems in the context of automated driving. In *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018) Volume VI: Transport Ergonomics and Human Factors (TEHF), Aerospace Human Factors and Ergonomics 20*. Springer, 398–408.

[8] Andreas Korthauer, Clemens Guenther, Andreas Hinrichs, Wen Ren, and Yiwen Yang. 2020. Watch Your Vehicle Driving at the City: Interior HMI with Augmented Reality for Automated Driving. In *22nd International Conference on Human-Computer Interaction with Mobile Devices and Services*. 1–5.

[9] Yee Mun Lee, Ruth Madigan, Jorge Garcia, Andrew Tomlinson, Albert Solernou, Richard Romano, Gustav Markkula, Natasha Merat, and Jim Uttley. 2019. Understanding the messages conveyed by automated vehicles. In *Proceedings of the 11th international conference on automotive user interfaces and interactive vehicular applications*. 134–143.

[10] V Onkhar, P Bazilinskyy, D Dodou, and JCF De Winter. 2022. The effect of drivers' eye contact on pedestrians' perceived safety. *Transportation research part F: traffic psychology and behaviour* 84 (2022), 194–210.

[11] Yang-Kun Ou and Yung-Ching Liu. 2012. Effects of sign design features and training on comprehension of traffic signs in Taiwanese and Vietnamese user groups. *International Journal of Industrial Ergonomics* 42, 1 (2012), 1–7.

[12] Champika Ranasinghe, Kai Holländer, Rebecca Currano, David Sirkin, Dylan Moore, Stefan Schneegass, and Wendy Ju. 2020. Autonomous vehicle-pedestrian interaction across cultures: towards designing better external Human Machine Interfaces (eHMIs). In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–8.

[13] Aïsha Sahaï, Elodie Labeye, Loïc Caroux, and Céline Lemercier. 2022. Crossing the street in front of an autonomous vehicle: An investigation of eye contact between drivengers and vulnerable road users. *Frontiers in psychology* 13 (2022).

[14] Gaye Solmazer, Derya Azık, Gizem Fındık, Yeşim Üzümcüoğlu, Özlem Ersan, Bilgesu Kaçan, Türker Özkan, Timo Lajunen, Bahar Öz, Anton Pashkevich, et al. 2020. Cross-cultural differences in pedestrian behaviors in relation to values: A comparison of five countries. *Accident Analysis & Prevention* 138 (2020), 105459.

[15] Cédric Sueur, Barbara Class, Charlène Hamm, Xavier Meyer, and Marie Pelé. 2013. Different risk thresholds in pedestrian road crossing behaviour: A comparison of French and Japanese approaches. *Accident Analysis & Prevention* 58 (2013), 59–63.

[16] Petya Ventsislavova, David Crundall, Thom Baguley, Candida Castro, Andrés Gugliotta, Pedro Garcia-Fernandez, Wei Zhang, Yutao Ba, and Qiucheng Li. 2019. A comparison of hazard perception and hazard prediction tests across China, Spain and the UK. *Accident Analysis & Prevention* 122 (2019), 268–286.

[17] Florian Weber, Ronee Chadowitz, Kathrin Schmidt, Julia Messerschmidt, and Tanja Fuest. 2019. Crossing the Street Across the Globe: A Study on the Effects of eHMI on Pedestrians in the US, Germany and China. In *HCI in Mobility, Transport, and Automotive Systems: First International Conference, MobiTAS 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26-31, 2019, Proceedings 21*. Springer, 515–530.

[18] George Yannis, Dimitrios Nikolaou, Alexandra Laiou, Yvonne Achermann Stürmer, Ilona Buttler, and Dagmara Jankowska-Karpa. 2020. Vulnerable road users: Cross-cultural perspectives on performance and attitudes. *IATSS research* 44, 3 (2020), 220–229.