BEYOND REALITY: USING AR FOR VRU-AV COMMUNICATION AND INTERACTION

RESEARCH UPDATE AND FUTURE DIRECTION: 04/X/2022

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ESR 9
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Communication between AVs and VRUs

EXPLICIT

hand gestures,
vocal
communication,
and eye contact

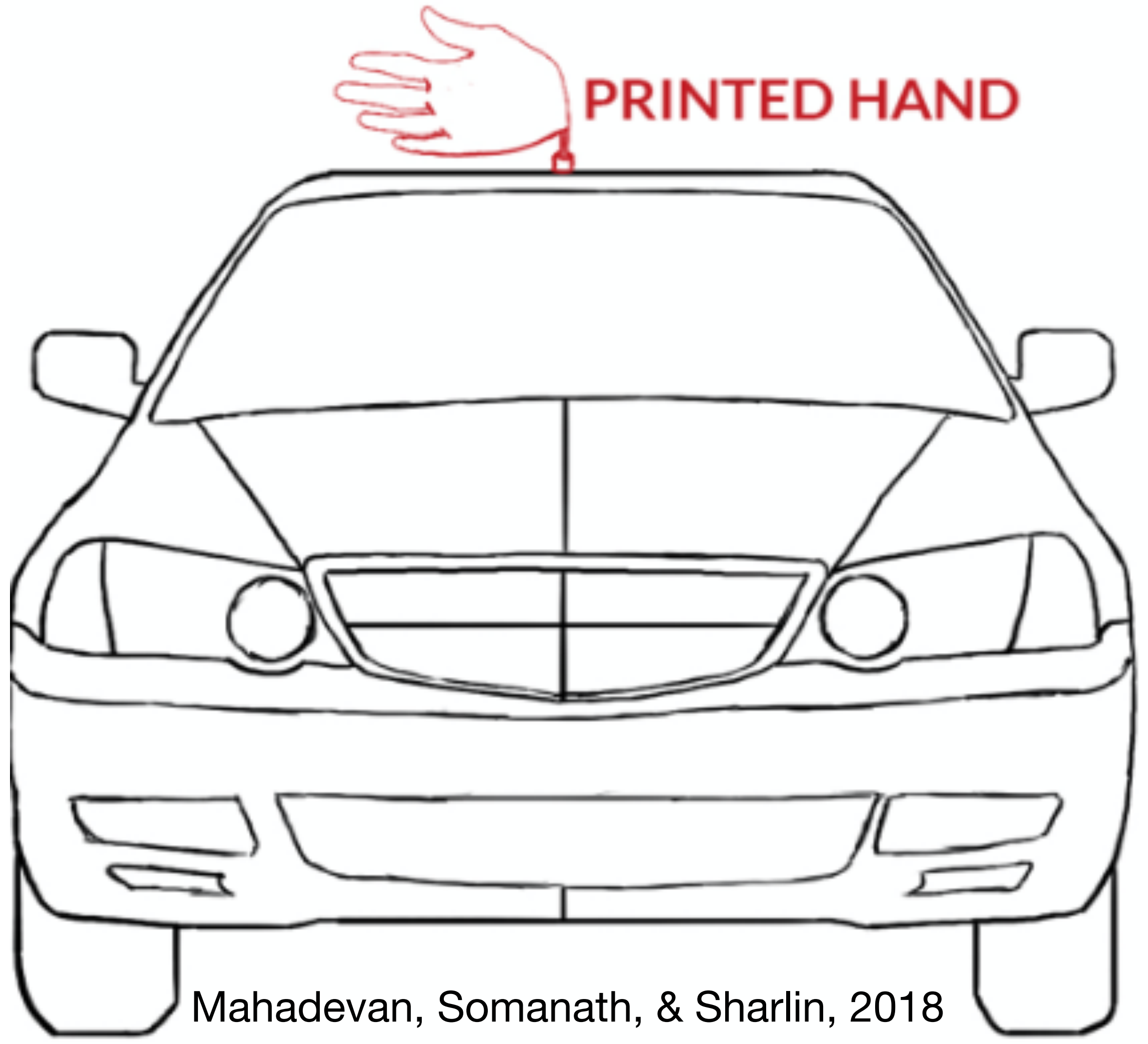
Loss of driver cues may decrease pedestrian confidence and trust.

External Human-Machine Interfaces

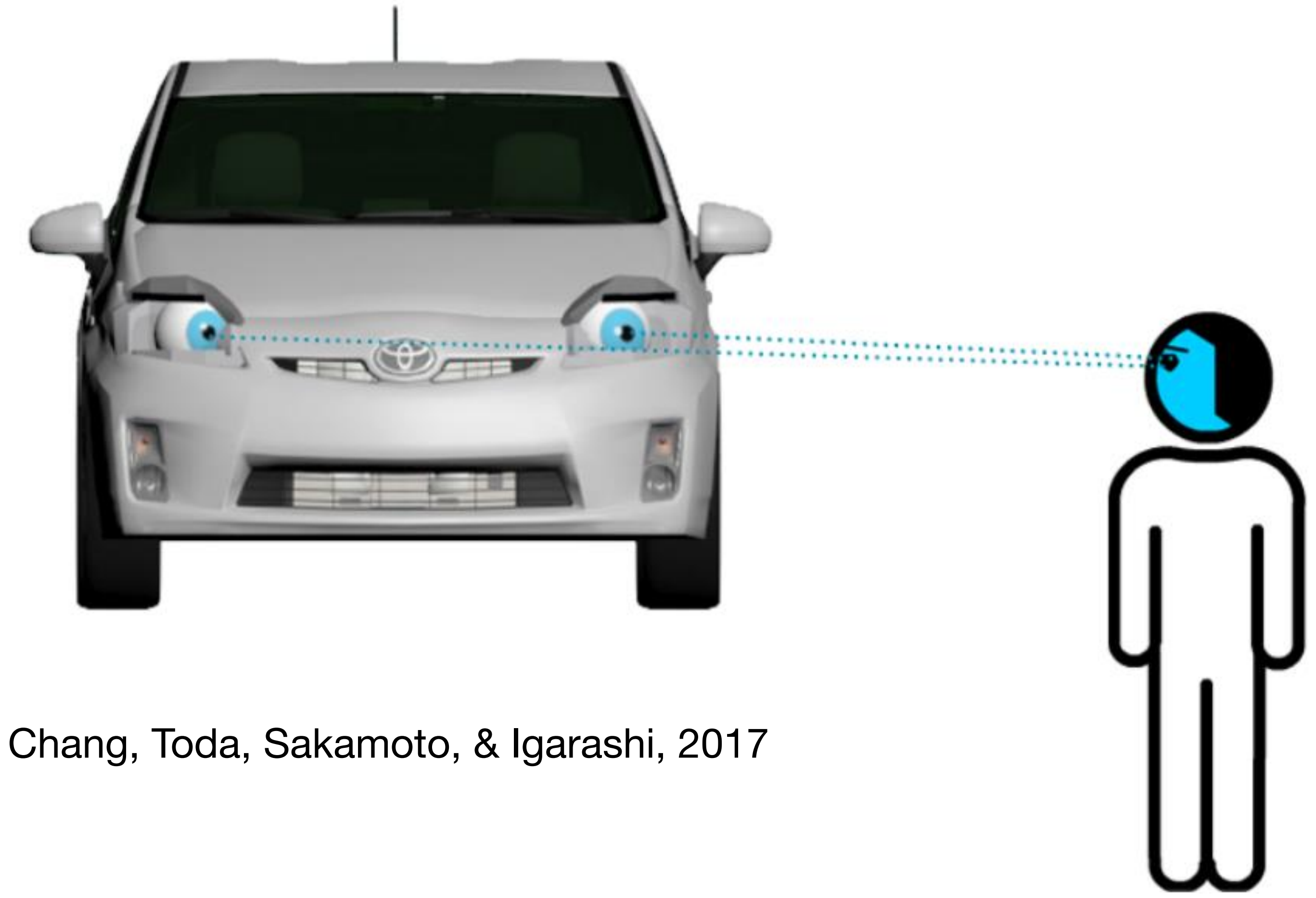
eHMIs

Daimler, 2017

Dietrich, Willrodt, Wagner, & Bengler, 2018

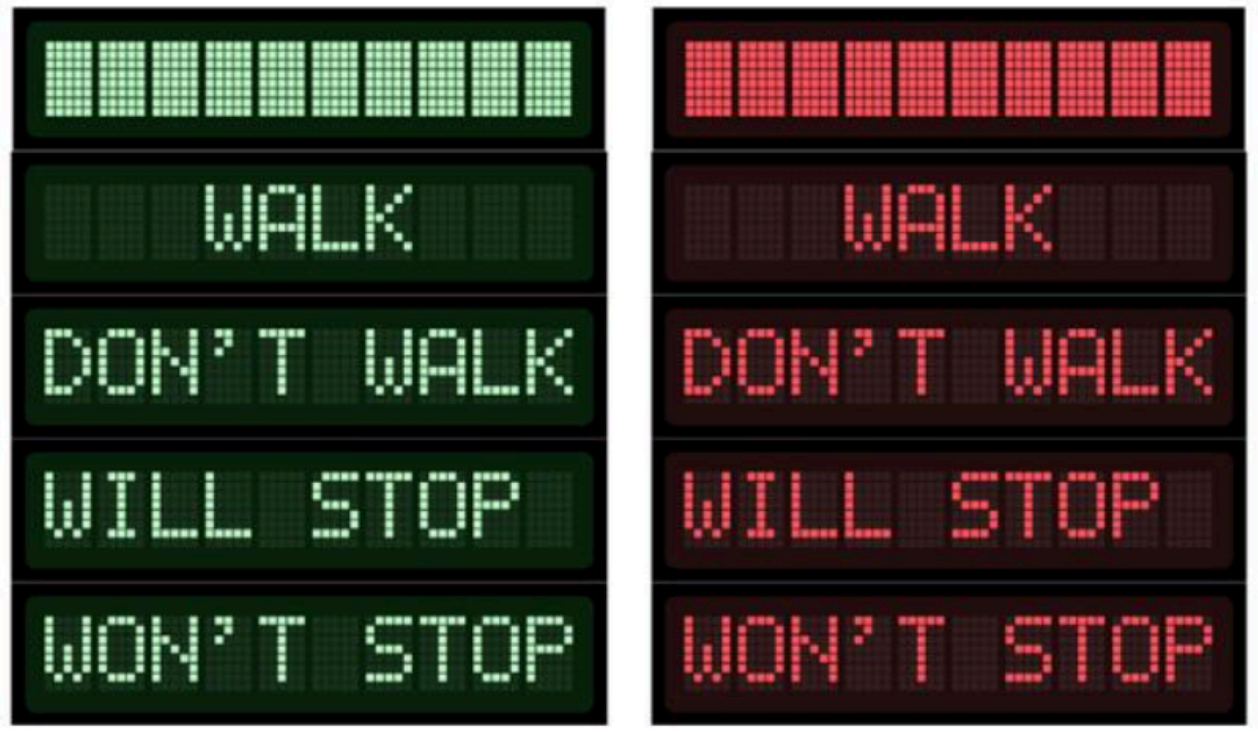


Mahadevan, Somanath, & Sharlin, 2018



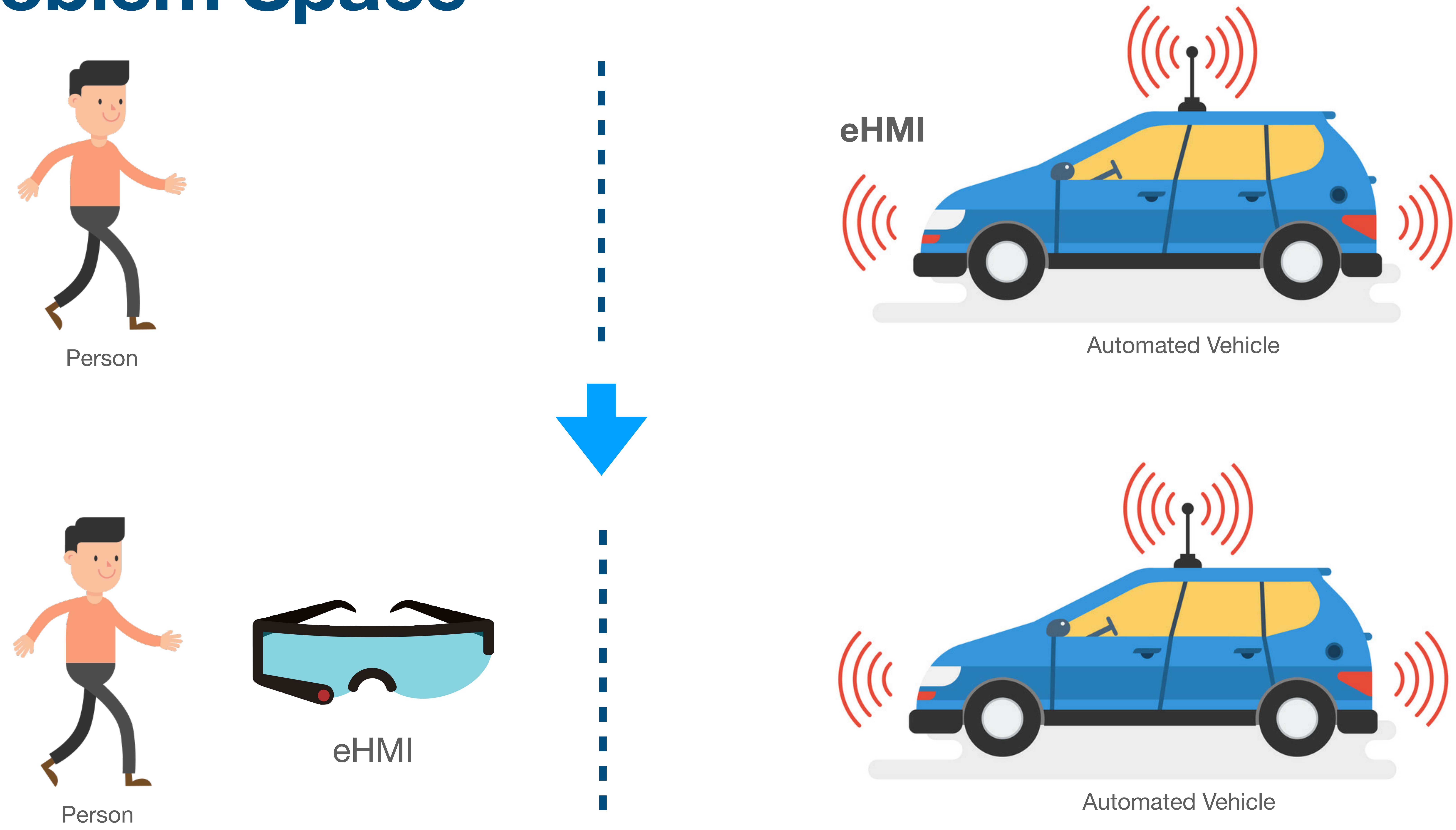
Chang, Toda, Sakamoto, & Igarashi, 2017

Semcon, 2016



Bazilinskyy, Dodou, & de Winter, 2019

Problem Space



Main Themes and Objectives

1. Assess whether humans trust indirect communication from an Automated Vehicle.

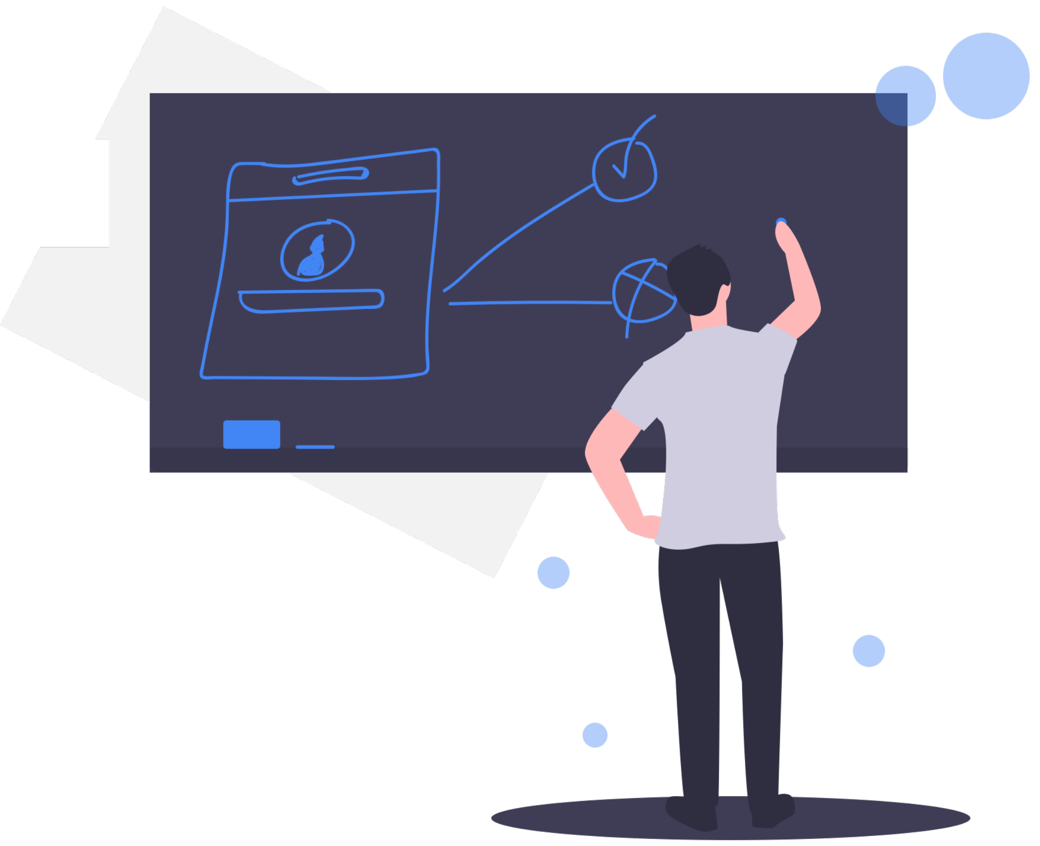
2. Assess whether augmented reality is a suitable technology for the development of interfaces which facilitate AV-VRU communication.

3. Identify user-preferred design elements for AR interfaces which facilitate AV-VRU communication.

4. Develop virtual/augmented reality simulation methods to investigate the interaction between AVs and VRUs.

Approach

Design and implement theoretically informed prototypes, and assess their validity and effectiveness empirically.



Brainstorming Design Exercise

Implement and test in VR and AR

Evaluate with users

Work so far

Vulnerable Road Users and The Coming Wave of Automated Vehicles: Expert Perspectives

Towards future pedestrian-vehicle interactions: Introducing theoretically-supported AR prototypes

Augmented reality interfaces for pedestrian-vehicle interactions: An online study

Interview Study

Vulnerable Road Users and The Coming Wave of Automated Vehicles: Expert Perspectives

Expert position paper.

Invited **16 researchers** to give their **perspectives** of **automated vehicles** (AVs) and the **interaction with vulnerable road users** (VRUs) in the **future urban environment.**

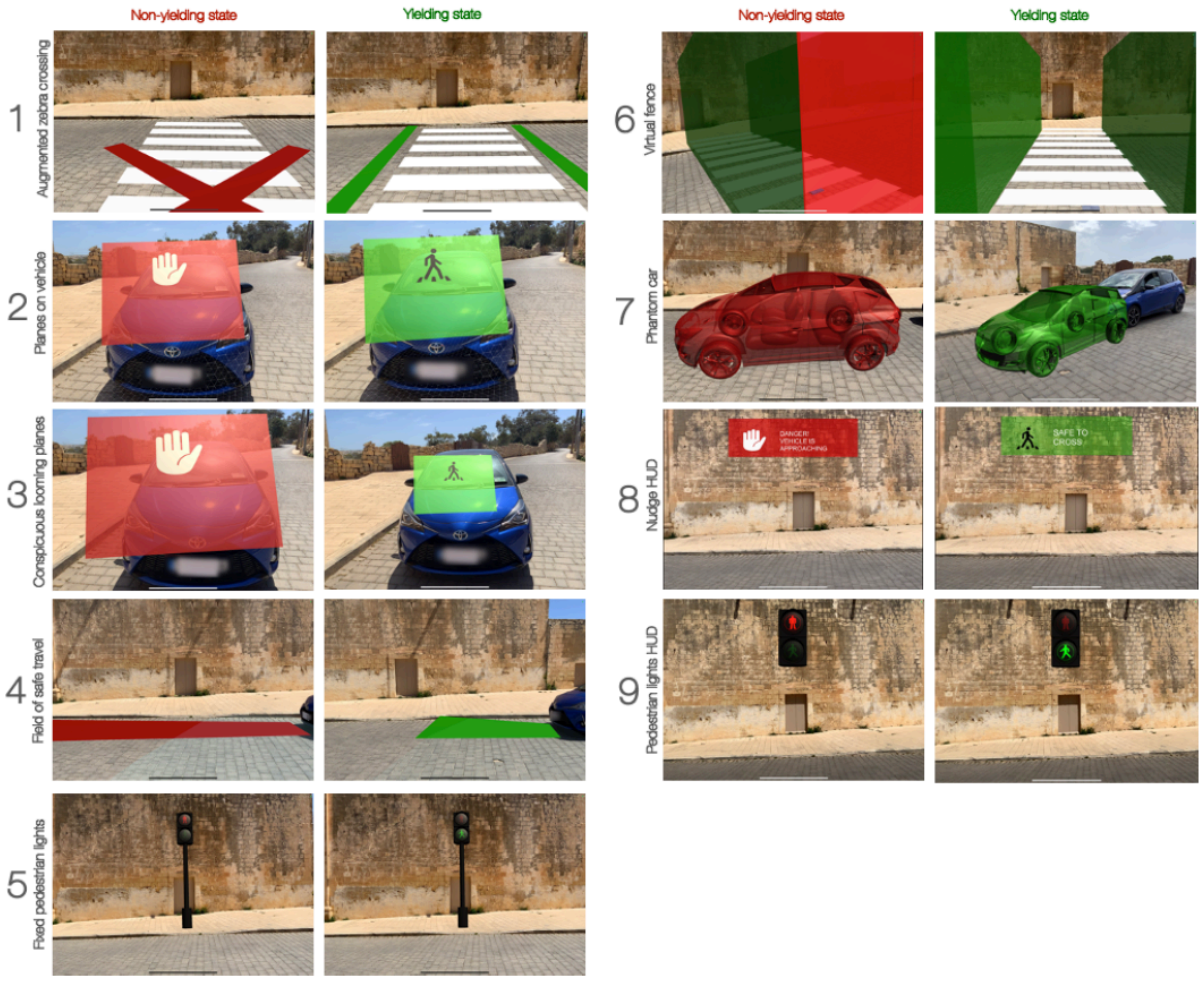
Aspects such as **smart infrastructure**, external human-machine interfaces (**eHMIs**) and the **potential of augmented reality** were addressed during the interviews.


Transportation Research Interdisciplinary Perspectives 9 (2021) 100293
Contents lists available at ScienceDirect
Transportation Research Interdisciplinary Perspectives
journal homepage: www.elsevier.com/locate/trip
Vulnerable road users and the coming wave of automated vehicles: Expert perspectives

(Tabone et al., 2021)

Design Study

Towards Future pedestrian-vehicle interactions: Introducing theoretically-supported AR prototypes



Towards future pedestrian-vehicle interactions: Introducing theoretically-supported AR prototypes

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ABSTRACT

1 INTRODUCTION

CCS CONCEPTS

KEYWORDS

Figure 3: Concept 2. Left: non-yielding state with the red plane and hand icon augmented on the vehicle. Right: yielding state with the green plane and crossing figure icon augmented on the vehicle.

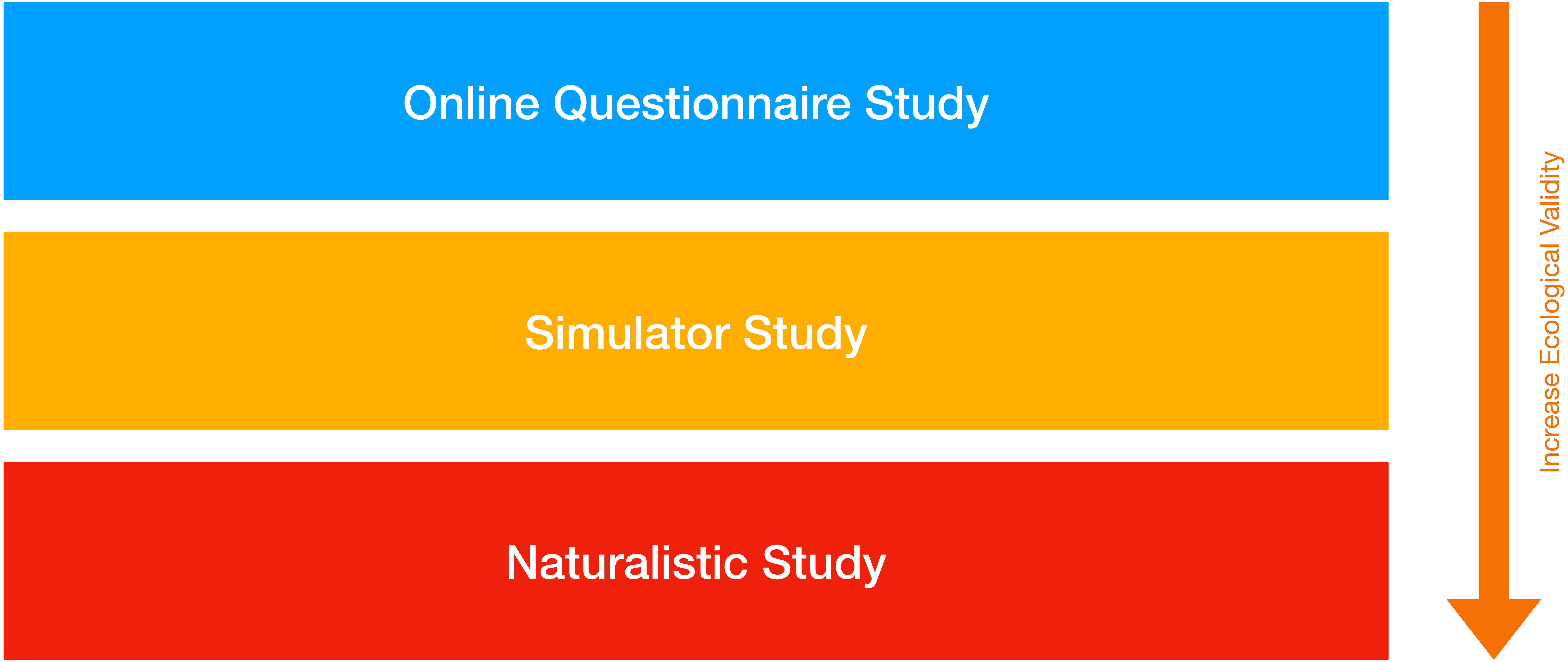
Figure 4: Concept 4. Left: non-yielding state with the red field of safe travel extending over the crossing area. Right: yielding state with the green field of travel shortened and truncating before the crossing area.

Figure 5: Concept 5. Left: non-yielding state with red pedestrian icon. Right: yielding state with green pedestrian icon.

3.5 Concept 5: Fixed pedestrian traffic lights

(Tabone et al., 2021b)

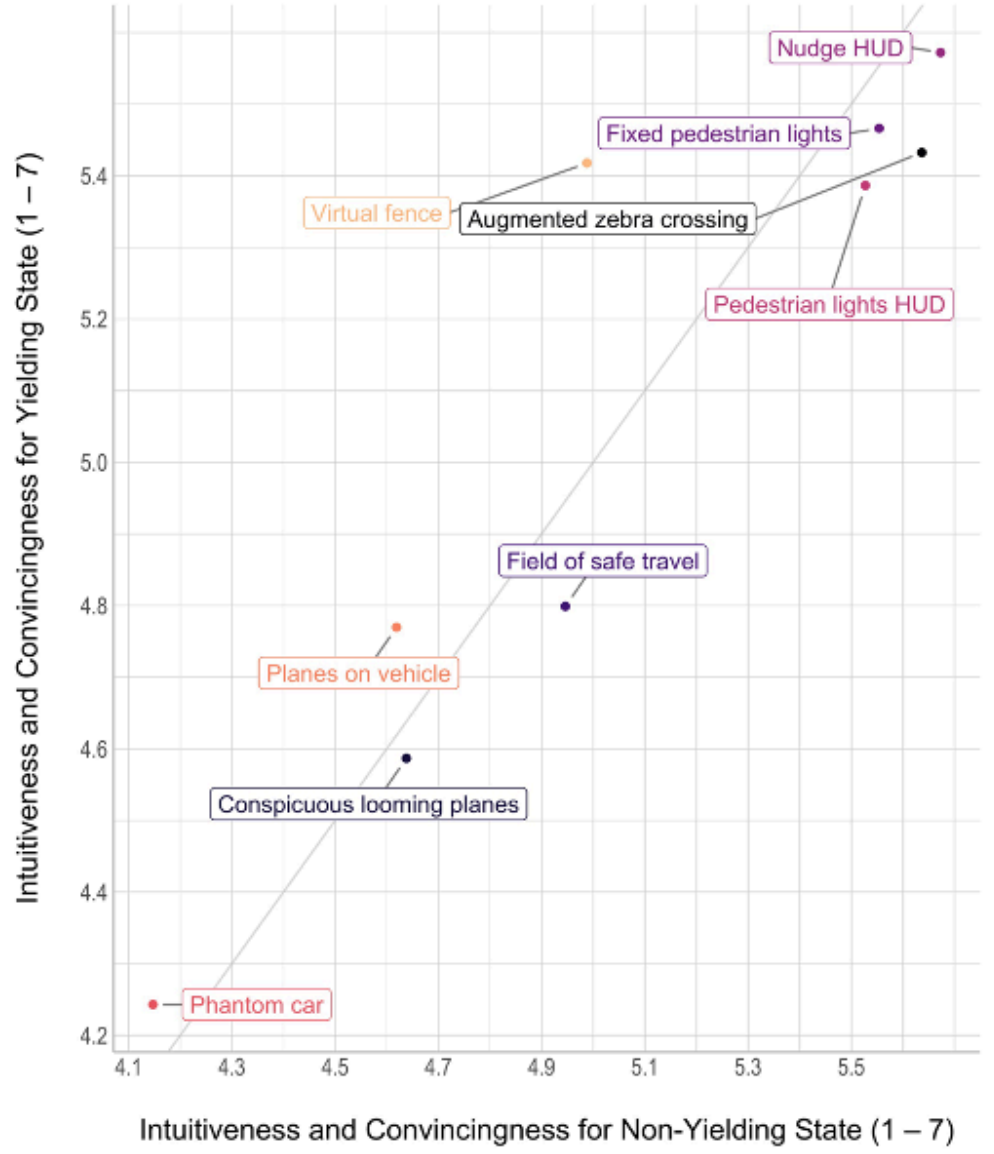
Evaluation of Augmented Reality Interfaces



Online User Evaluation Study

Augmented reality interfaces for pedestrian-vehicle interactions: An online study

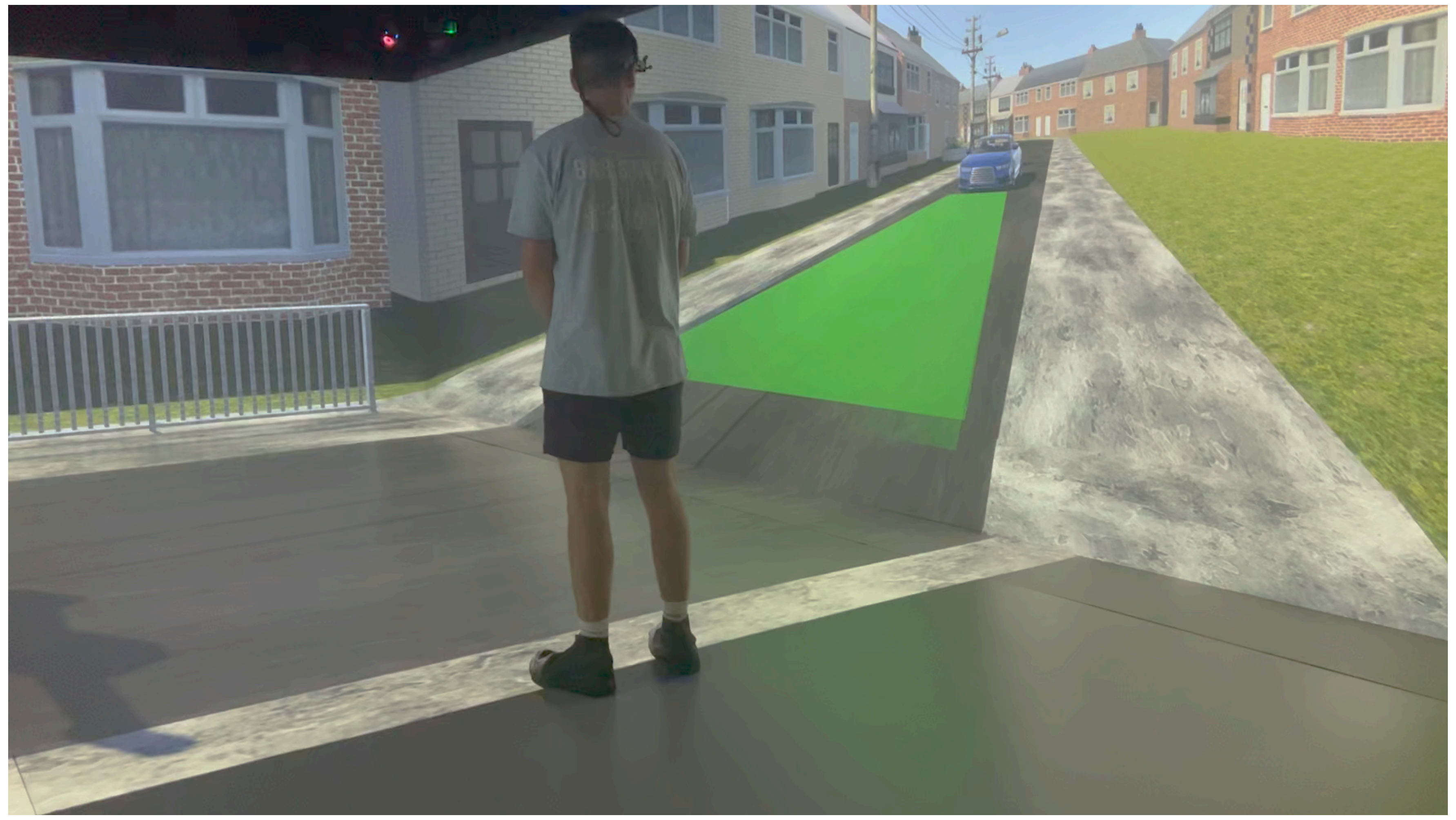
Interface	Composite Score M (SD)
8. Nudge HUD	**0.36** (0.85)
1. Augmented zebra crossing	0.32 (0.89)
5. Fixed pedestrian lights	0.28 (0.88)
9. Pedestrian lights HUD	0.24 (0.86)
6. Virtual fence	0.03 (1.00)
4. Field of safe travel	-0.13 (1.00)
2. Planes on vehicle	-0.22 (0.98)
3. Conspicuous looming planes	-0.36 (1.00)
7. Phantom car	-0.53 (1.05)



(Tabone et al., 2022)

Simulator User Evaluation Study

Augmented reality interfaces for pedestrian-vehicle interactions: An simulator study



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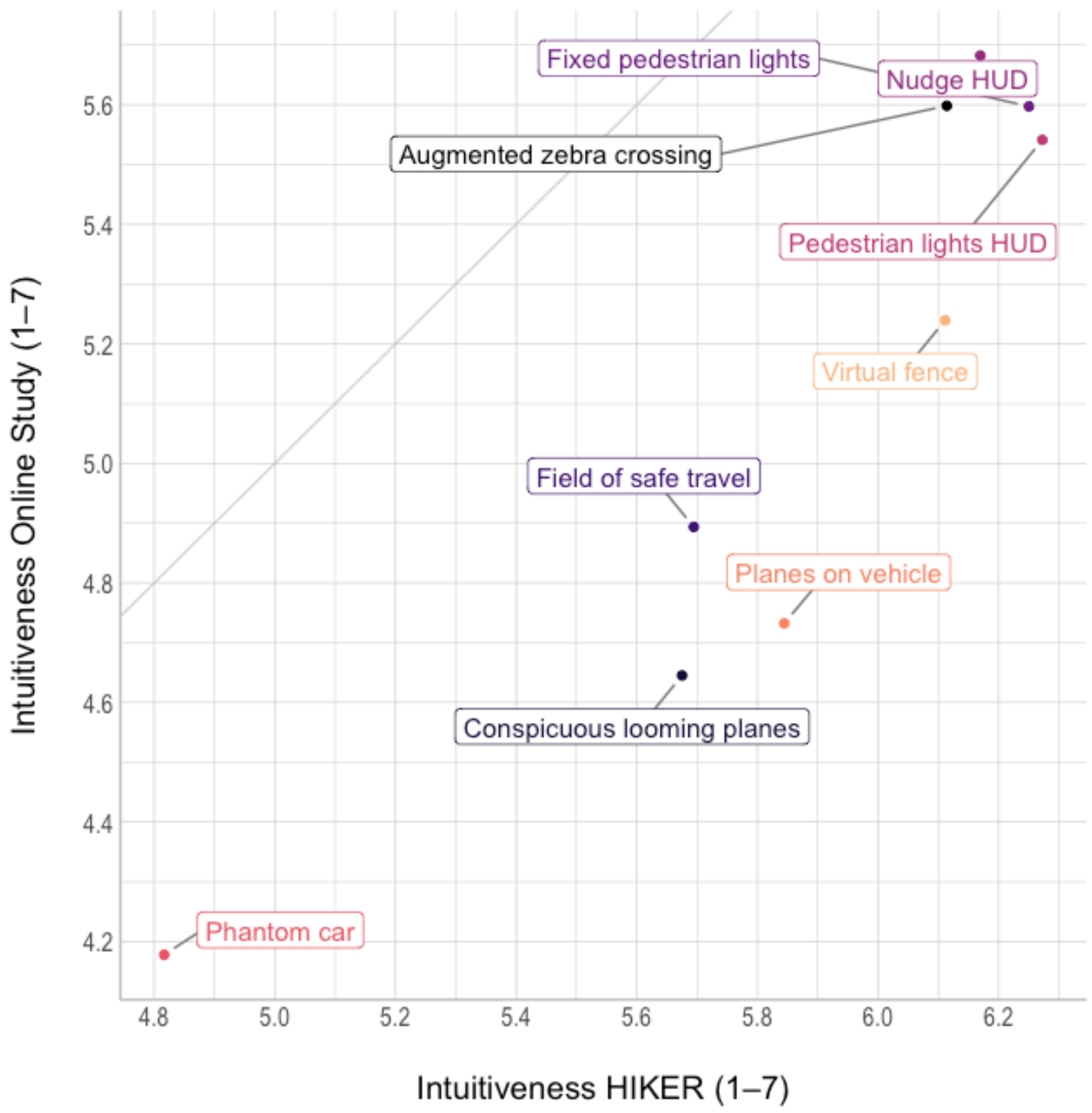
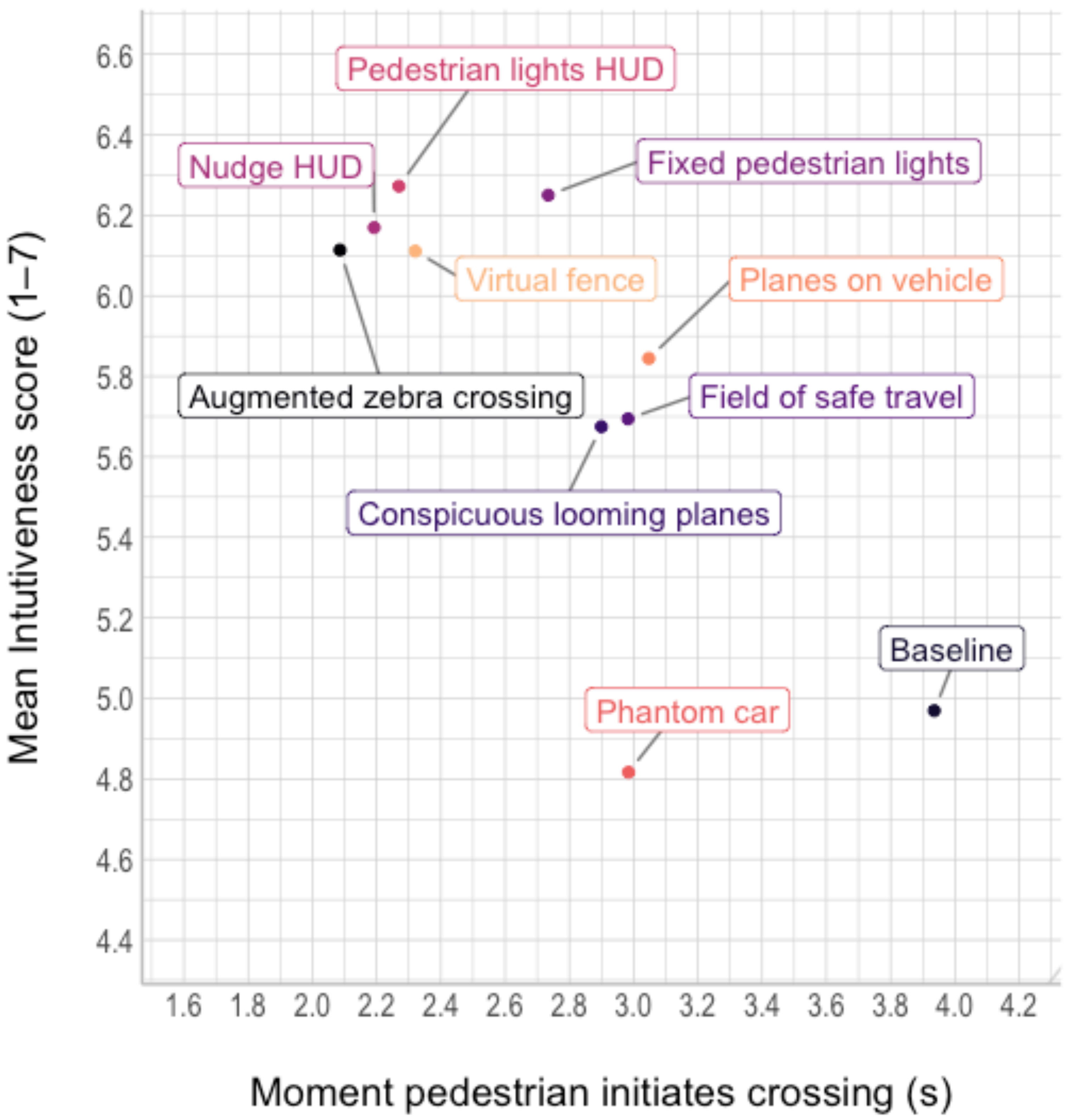


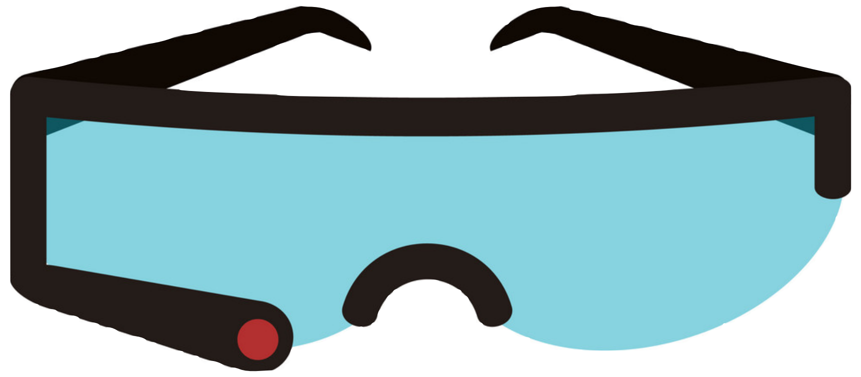


Moving forward

Select the most promising AR interfaces, re-implement them in AR, and assess their validity and effectiveness empirically.

Evaluate with users

Implement and test in VR



Test in AR

Validation study

Implement the AR interfaces on actual AR HMDs (eg. Varjo XR3).

Test on Wizard of Oz vehicles, virtual vehicles, or actual AVs.

Investigate whether there are any correlations between the simulator study and the real-world study.

Challenges and Open Issues

1. Best approach for real-world validation (measures)

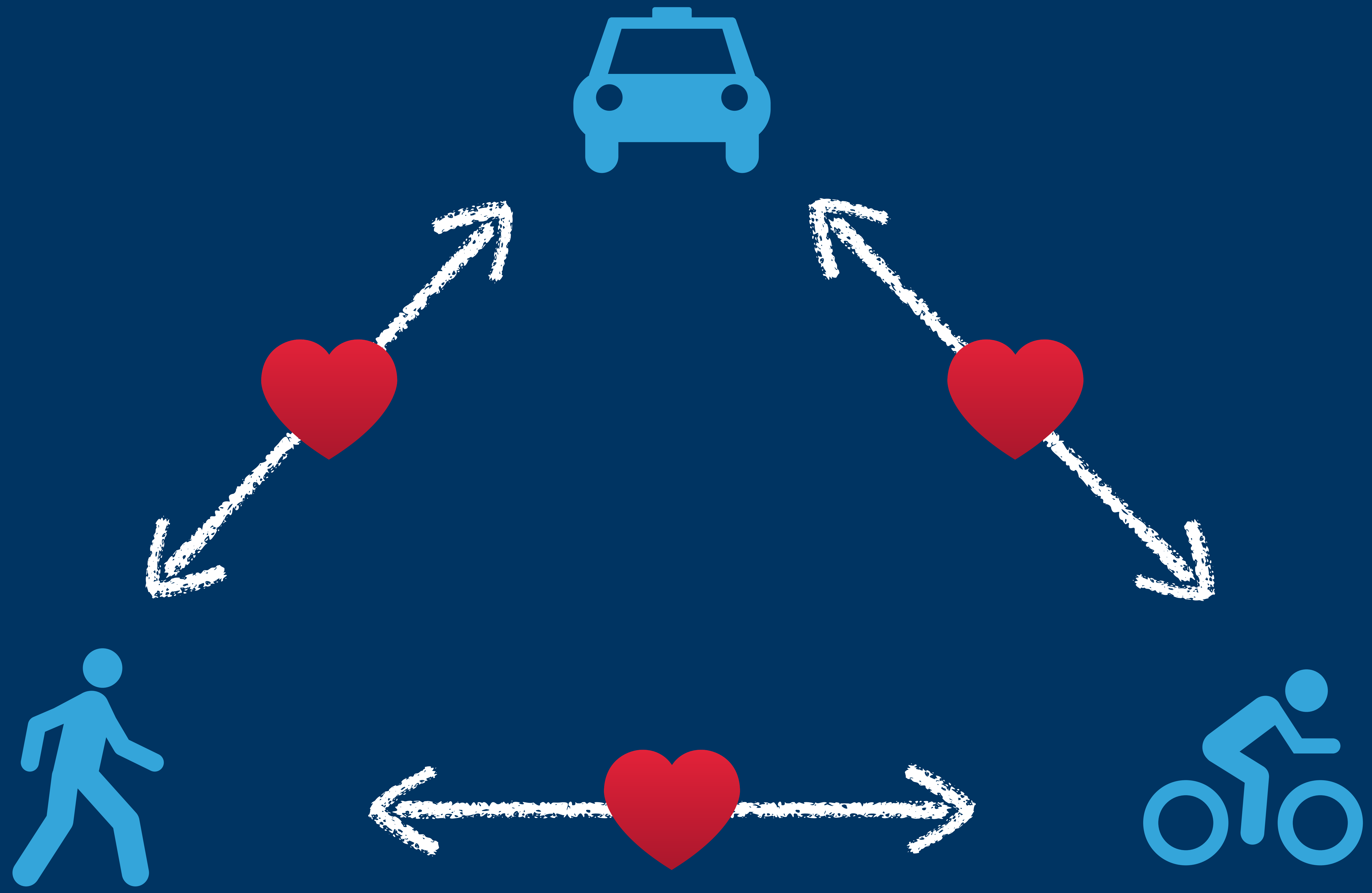
2. Arguments towards the adoption of this technology

References

Tabone, W., De Winter, J. C. F., Ackermann, C., Bärgman, J., Baumann, M., Deb, S., Emmenegger, C., Habibovic, A., Hagenzieker, M., Hancock, P. A., Happee, R., Krems, J., Lee, J. D., Martens, M., Merat, N., Norman, D. A., Sheridan, T. B., & Stanton, N. A. (2021). Vulnerable road users and the coming wave of automated vehicles: *Expert perspectives. Transportation Research Interdisciplinary Perspectives, 9*, 100293. https://doi.org/10.1016/j.trip.2020.100293

Tabone, W., Lee, Y.M., Merat, N., Happee, R., & De Winter J.C.F. (2021b). Towards future pedestrian-vehicle interactions: Introducing theoretically-supported AR prototypes. *Proceedings of the 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 209–218). Leeds, United Kingdom. https://doi.org/10.1145/3409118.3475149

Tabone, W., Happee, R., García, J., Lee, Y. M., Merat, N., Lupetti, L., & De Winter J. C. F. (2022). Augmented reality interfaces for pedestrian-vehicle interactions: An online study. Under review.



#SpreadTheVRU-AV-Love

THANK YOU

Questions?

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 860410