A WOZ Study of Feedforward Information on an Ambient Display in Autonomous Cars

Hauke Sandhaus
Bauhaus-Universität Weimar
Fac. of Media, Human-Computer-Interaction
99423 Weimar, Germany
hauke.sandhaus@uni-weimar.de

Eva Hornecker
Bauhaus-Universität Weimar
Fac. of Media, Human-Computer-Interaction
99423 Weimar, Germany
eva.hornecker@uni-weimar.de

ABSTRACT
We describe development and user testing of an ambient display for fully autonomous vehicles. Instead of providing feedback about driving actions once executed, it communicates driving decisions in advance, via light signals in passengers' peripheral vision. This was tested in an WoZ-based on-the-road-driving emulation of a autonomous vehicle. Findings from a preliminary study with 14 participants suggest that such a display might be particularly useful to communicate upcoming inertia changes for passengers.

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI); Interface design prototyping;** HCI design and evaluation methods;

Author Keywords
Autonomous Vehicle Interfaces; Methodology; On-Road simulation; Ambient Display;

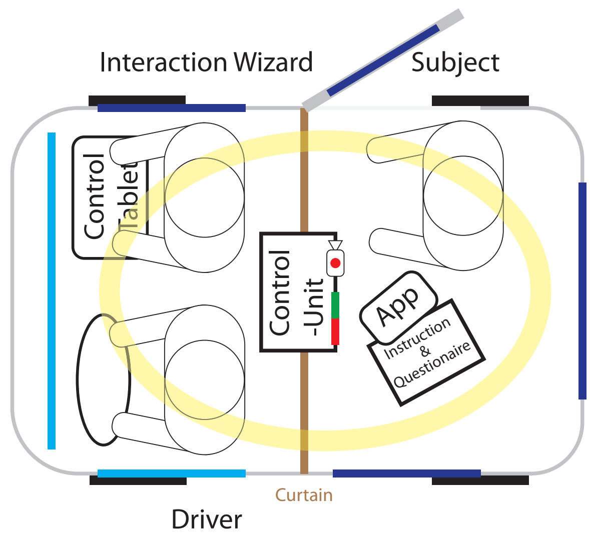

Figure 1. The study setup

INTRODUCTION
HCI research on passengers in fully autonomous vehicles is sparse, and reasons are multifold: access to real autonomous vehicles is limited as few companies have working prototypes. Current research focuses on semi-autonomous cars, as these will be sooner available and have urgent HCI issues to be solved (such as hand-over scenarios or collaborative driving [15, 13]). Finally, fully autonomous vehicles appear to have few user interactions beside selecting the pick-up and drop-off location. Some work [16, 1] addressed accessibility to self-driving vehicles with the RRADS driving platform: our study presented here used a modified version which seats passengers in the back seat to simulate fully autonomous driving. Being a passenger in a car or bus is arguably not as enjoyable as traveling on a modern train. One reason might be the acceleration-deceleration behavior [2], and self-driving vehicles might worsen this because of frequent inertia changes due to falsely detected obstacles[11]. Furthermore, many passengers exhibit back-seat driver behavior[3], and we do not know how they will behave faced with total loss of control.

The cabin of an autonomous cab should be practical and comfortable. Passengers might adjust their seats for comfort (lying down, seated backward, facing each other or turned away). They might prefer to use their own devices over the cars' infotainment system. Therefore, unnecessary graphical interfaces should be avoided [8]. Instead of putting screens everywhere, our proposed ambient display turns the cabin itself into a surface for feedback, utilizing colored light to convey information. Ambient displays have been used in vehicles to keep drivers' eyes on the road [9, 12, 10]. 'Feedforward' is usually used in context with affordances of interfaces, here it is used as 'advance feedback before executing an action' [7, 4, 14].

OUR PROTOTYPE
Our ambient display augments the driving decisions of the vehicle with light animations before they are carried out. It visualizes both planned events such as taking turns, speeding up and slowing down, as well as unplanned events such as swerving because of unexpected obstacles. The events are animated smoothly and mapped to the shape of the light display: urgent events use stronger light, colors and rapid animations whereas less important events are animated subtle. Where

UIST '18 Adjunct October 14–17, 2018, Berlin, Germany

ACM ISBN 978-1-4503-5949-8/18/10

DOI: https://doi.org/10.1145/3266037.3266111

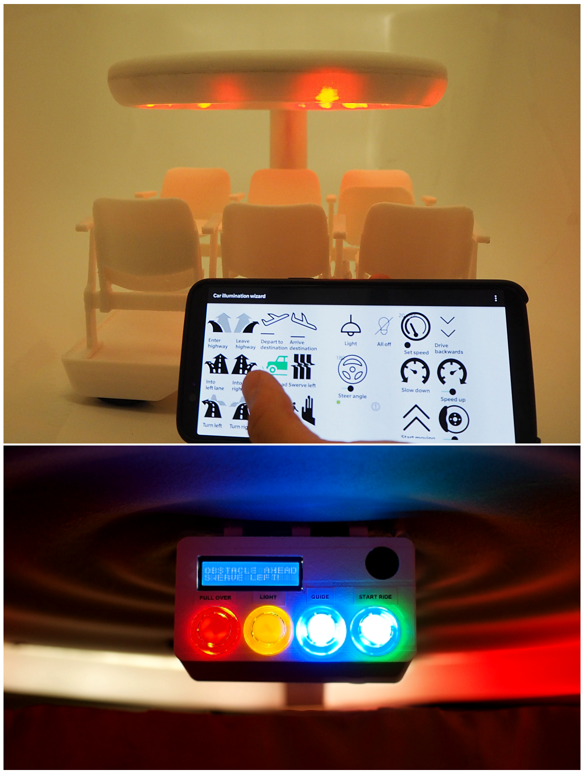

Figure 2. (top) Prototyping platform with wizard interface on a smartphone and (bottom) control unit inside the car prototype with lit-up buttons

possible self explanatory colors and animations were used (e.g. yellow for turn signals, red for braking and green pulsating light for traffic signals).

The light display should double as a reading light. Therefore it has to be placed on the ceiling and be within reach of all seats. An oval shape is ideal for this. To diffuse the light white pipe insulation proved to diffuse the LED smoothly. The LED strip for the prototype is an RGBW strip with 60 LEDs per meter. For the final prototype, which requires more elaborate software to integrate the multiple components, a Raspberry Pi was utilized. It manipulates two 2-meter chains in parallel [5] and is housed in the control unit. This control unit (Figure 2 bottom) also provides a simple interface to the passengers with a segment display, buttons for start, emergency stop, and switching the reading light and light signals. The Interaction Wizard (Figure 1) triggers the events from an Android Tablet. The segment display shows text that explains the light signals. The light display and control unit were integrated into the ceiling of a Nissan Cube test vehicle.

Prototyping Platform

During development, it proved challenging to imagine how light signals will be perceived in the final car environment. It also was uncomfortable to develop software when inside the vehicle. Finally, the light display is not just meant for one particular vehicle but also for other vehicles of different size and seating arrangements. Therefore, a prototyping platform was developed that can be directly manipulated from a computer.

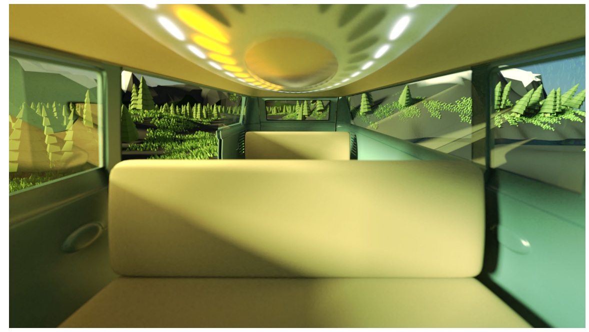

Figure 3. Ambient display in envisioned self-driving cab

Currently, this prototyping platform is used in a workshop with people with reduced mobility (elderly and disabled).

OUR STUDY DESIGN

In a counterbalanced, 2x2 experimental design setup, 12 individual participants first rode either route A or route B, with the feedforward information either turned on or off. Next, they rode in the inverse constellation. Test rides each had a total length of 45 minutes.

Participants were briefly introduced in the lobby of the Bosch Technical Center in Plymouth. After consent was collected, the researcher left and subjects were on their own. They called the cab with a web app as instructed. The cab arrived in front of the lobby and honked to inform of its arrival. Because of the angle at which the vehicle approached and a curtain that separates passengers in the back from the wizards in front, participants could not establish eye contact. Once buckled up they pressed the 'start ride' button. During each of the 15 minute rides the subjects were videotaped and could use their time freely. The participants filled out one pre-study questionnaire, two identical trust in automation questionnaires [6, 7] and a post-study questionnaire. In the feedforward-information-on condition the cars decisions were augmented through the interaction wizard.

CONCLUSION

Our findings from this preliminary, not fully controlled study are promising. Participants reported slightly higher trust and lower mistrust in the vehicle, as well as positive emotional valence (self-reported). The participants' attention was visibly drawn by the light to the screen and then outside to the street.

A limitation of our study was that test drives all varied slightly due to varying traffic and position of the sun differed between rides. Rides took place in winter with sunlight reflected by snow into the cabin. Furthermore, participants were students and acquainted with the researcher. In future work, the light display should use luminance dependent on current light intensity. The ambient display should be integrated into a multimodal feedforward and feedback system. A full study should use a diverse set of participants and use physiological measures for stress and car sickness.

ACKNOWLEDGMENTS

Thanks to Philip Ventimiglia and Stefan Weissert from Robert Bosch for their supervision. Furthermore, all colleagues for participation and Martin Beeker for providing the test car. Finally, the first author thanks his parents and boyfriend for their support during the Master's thesis work. (CC): Vector icons from The Noun Project, 3D files from Blendswap: Jay-Artist, Hoboo, CinecaVisitLab

REFERENCES

1. Sonia Baltodano, Srinath Sibi, Nikolas Martelaro, Nikhil Gowda, and Wendy Ju. 2015. The RRADS Platform : A Real Road Autonomous Driving Simulator. *AutomotiveUI '15* 7 (2015), 281–288. DOI: http://dx.doi.org/10.1145/2799250.2799288
2. P. S. Bokare and A. K. Maurya. 2017. Acceleration-Deceleration Behaviour of Various Vehicle Types. *Transportation Research Procedia* 25 (2017), 4737–4753. DOI: http://dx.doi.org/10.1016/j.trpro.2017.05.486
3. David Carter. 2018. *Back Seat Driver Survey Results 2018*. Technical Report. 1–32 pages. https://www.accidentadvicehelpline.co.uk/blog/are-you-a-backseat-driver/
4. Tom Djajadiningrat, Kees Overbeeke, and Stephan Wensveen. 2002. But how, Donald, tell us how? *Proceedings of the conference on Designing interactive systems processes, practices, methods, and techniques - DIS '02* (2002), 285. DOI: http://dx.doi.org/10.1145/778712.778752
5. Jgarff. 2018. Userspace Raspberry Pi PWM library for WS281X LEDs. (2018). https://github.com/jgarff/rpi_ws281x
6. Jiun-yin Jian, Ann M Bisantz, Colin G Drury, Jiun-yin Jian, Ann M Bisantz, and Colin G Drury. 2010. Foundations for an Empirically Determined Scale of Trust in Automated Systems. *International Journal of Cognitive* January 2015 (2010), 37–41. DOI: http://dx.doi.org/10.1207/S15327566IJCE0401
7. Jeamin Koo, Jungsuk Kwac, Wendy Ju, Martin Steinert, Larry Leifer, and Clifford Nass. 2015. Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust, and performance. *International Journal on Interactive Design and Manufacturing* 9, 4 (2015), 269–275. DOI: http://dx.doi.org/10.1007/s12008-014-0227-2
8. Golden Krishna. 2015. *The best interface is no interface: the simple path to brilliant technology*. Pearson Education.
9. Florian Laquai, Fabian Chowanetz, and Gerhard Rigoll. 2011. A large-scale LED array to support anticipatory driving. *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics* (2011), 2087–2092. DOI: http://dx.doi.org/10.1109/ICSMC.2011.6083980
10. Andreas Loecken, Wilko Heuten, and Susanne Boll. 2015. Supporting Lane Change Decisions with Ambient Light. *AutoUI '15* (2015), 204–211. DOI: http://dx.doi.org/10.1145/2799250.2799259
11. Dawn C. Marshall, John D. Lee, and P. Albert Austria. 2007. Alerts for In-Vehicle Information Systems: Annoyance, Urgency, and Appropriateness. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 49, 1 (2007), 145–157. DOI: http://dx.doi.org/10.1518/001872007779598145
12. Alexander Meschtscherjakov, Christine Döttlinger, Christina Rödel, and Manfred Tscheligi. 2015. ChaseLight: ambient LED stripes to control driving speed. *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI '15* (2015), 212–219. DOI: http://dx.doi.org/10.1145/2799250.2799279
13. Ioannis Politis, Stephen Brewster, and Frank Pollick. Language-Based Multimodal Displays for the Handover of Control in Autonomous Cars. (????). DOI: http://dx.doi.org/10.1145/2799250.2799262
14. Jo Vermeulen, Kris Luyten, Elise van den Hoven, and Karin Coninx. 2013. Crossing the bridge over norman's gulf of execution. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13* (2013), 1931. DOI: http://dx.doi.org/10.1145/2470654.2466255
15. Marcel Walch, Kristin Mühl, Johannes Kraus, Tanja Stoll, Martin Baumann, and Michael Weber. 2017. From Car-Driver-Handovers to Cooperative Interfaces: Visions for DriverâĂŞVehicle Interaction in Automated Driving. (2017), 273–294. DOI: http://dx.doi.org/10.1007/978-3-319-49448-7
16. Peter Wang, Srinath Sibi, Brian Mok, and Wendy Ju. 2017. Marionette: Enabling On-Road Wizard-of-Oz Autonomous Driving Studies. *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17* (2017), 234–243. DOI: http://dx.doi.org/10.1145/2909824.3020256