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Passenger-vehicle Interaction in Fully Autonomous Vehicles: current and future trends

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ABSTRACT

While current research in human-vehicle interaction tends to focus mainly on the safety driver in Level 3 autonomy, the advent of Level 4 (and even 5) fully autonomous vehicles will shift this focus from driver to passenger. During the transition phase from partial to full autonomy, passengers are likely to be apprehensive about their safety in a self-driving car. Provisions must therefore be made to minimize passenger anxiety at all times. This work explores current trends in human-vehicle interaction with a directed focus on the passenger, while posing questions that serve to tackle the problem of passenger comfort in fully autonomous vehicles.

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CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**.

KEYWORDS

autonomous vehicles, passengers, interaction

INTRODUCTION

Human-vehicle interaction research currently focuses heavily on the interaction of the safety driver with the vehicle. Current goals range primarily from enabling safe and effective takeover requests [14] (in which autonomy is disengaged and manual control is enabled) to keeping the driver in-the-loop with respect to future driving decisions [6], [7], [12], [15]. However, with the advent of Level 4 vehicles the notion of a safety driver when autonomy is engaged is removed as these vehicles are guaranteed to function completely autonomously in their operational design domain (note that these vehicles will still be driven manually outside this domain). In level 5 vehicles, there will be no need for manual driving at all.

One can, therefore, see how the focus will eventually shift from promoting safe takeovers and driver comfort, to addressing the needs of the actual passengers in the vehicle. It is, thus, critical that more research effort is directed towards passenger-vehicle interaction, especially during the period of transition from Level 3 to Level 4 (and 5) vehicles as, ultimately, the success of automated driving largely depends on how willing individuals are to actually use them.

With this in mind, we first address our position by reviewing the current work done in the area of human-vehicle interaction for Level 3 automated drivings systems and below, and then proceed to discuss the issues that would arise when Level 4 and 5 vehicles become the norm.

THE STATUS QUO - FOCUSING ON DRIVER HANDOVER

Proposed systems in current literature usually rely on multi-modal cues to communicate automotive intent to the driver. Van der Heiden et al. [14], investigated the use of audio pre-alerts to prime distracted drivers for handover requests, while Walch et al. [15], proposed a cooperative audio-visual interface for monitoring or approval of driving decisions instead of fully handing over control to the driver. Haptic feedback has been used extensively to communicate navigational cues. Vibrotactile eyeglasses and car seats [7], [12] as well as pneumatic shoulder pads and floorboards [6] have been used to provide a physical stimulus to the driver to convey directional as well as spatial information. Navigational cues have also been investigated by means of shape-changing and vibrotactile steering wheels [2], as well as skin-stretch steering wheels [8]. In some cases, haptic cues were found to be more effective than audio or visual cues alone.

Such research, however, applies mainly to Level 3 vehicles that have a strict requirement for a safety driver. In Level 4 and 5 vehicles, on the other hand, there is no such requirement as the vehicle itself would have a robust emergency policy in place. The question then arises: how can the shift in system design be made such that the focus now lies on passengers as opposed to drivers?

THE SHIFT IN TRENDS - FROM DRIVER TAKEOVER TO PASSENGER COMFORT

Transitioning from Level 3 to Level 4-5 autonomy will likely have a profound impact on passenger perceptions. For one, level 5 vehicles might have no steering wheel or pedals; level 5 vehicles thus might have very different interiors than existing vehicles. By extension, the presence of a driver to take over control "just in case" can be completely removed in Level 5 vehicles as well as in Level 4 vehicles that drive within their operational design domain. Consequently, in passenger-only situations, the said passengers might be confronted with anxiety regarding their safety in a vehicle that apparently has no option for an emergency takeover.

The driving style of the vehicle itself may also be a significant cause for passenger anxiety. Categorized in terms of aggressiveness or defensiveness [1], the driving style refers to the overall driving behavior in terms of speed, acceleration, following distance, and traffic law obedience. Most work suggests that passengers would prefer a driving style based on their own: aggressive if the passenger drives aggressively, and more defensive otherwise. Basu et al. [1], however, showed that most passengers actually prefer to be driven according to their perceived driving style which is usually more defensive compared to their own. This discovery undermines work that relies on identifying the passenger's personal driving style through techniques such as imitation or inverse reinforcement learning [5]. The new task is, therefore, to accommodate the passenger's discomfort with the current driving style and alter it accordingly.

Situations might also arise in which the passenger is perfectly comfortable with the driving style itself but may need to stop or change the route. For example, the option to take a slower but more scenic route might be available - should the car continue on the quicker but less scenic path? Perhaps the car might detect a stationary object up ahead - could this be an accident and the passenger the first to arrive on the scene? What about passengers with motion sickness or disabilities [3]? A study [10] showed that passengers in rearward facing seats had a greater tendency towards experiencing motion sickness than passengers in regular font facing seats. Given that both front and rear facing seats is a common concept for future autonomous vehicles with increased cabin space (due to a lack of physical driving controls), such an issue is likely to limit passenger experience. It would thus be beneficial to address the issues presented by looking into different ways of promoting situational awareness and communicating future navigation decisions.

Systems that can circumvent these new challenges propose to keep the user in the loop, and though many are currently targeted at drivers, they are equally applicable for use by passengers. For instance,

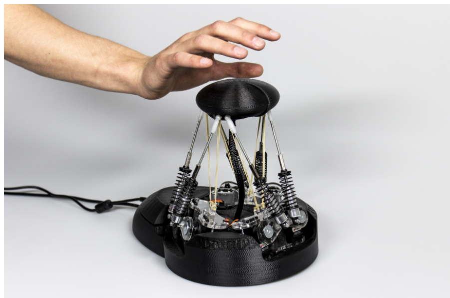

Figure 1: Stewart: a device that allows the user to engage in a "haptic discussion" with the driving automation. [13].

Figure 2: Scribble: a haptic interface that allows users to "draw" their way through traffic. [9].

Stewart [13] is a haptic device that conveys upcoming driving decisions through subtle actuator movements and allows the user to engage in a "haptic discussion" with the driving automation . "Scribble" [9] is another interface that allows the user to change driving decisions by "drawing" their way through traffic. With respect to maintaining situational awareness, Sivak and Schoettle [11] devised a light array system that provides visual stimuli in the passenger's field of view with the goal of preventing motion sickness. A solution for combating motion sickness was also proposed by Jaguar [4]; the car manufacturer devised a motion sickness detection platform through a suite of non-intrusive sensors that measure signals such as changes in temperature and passenger stimulus (for example, reading a book). The vehicle would automatically adjust its settings, such as by lowering the interior temperature, to respond to the detected sickness level.

WORKSHOP GOALS

With the aforementioned issues in mind, our goals for the workshop would be to further explore the challenges imposed by passenger-vehicle interaction by discussing some of the pertinent questions in this domain:

- What kind of interfaces would be beneficial to passenger-vehicle communication? How obtrusive may these interfaces be?
- How could the problem of multiple passengers with different needs be addressed (for example, in ride-sharing services)? How can passenger anonymity be dealt with in such scenarios?
- What would be the newer norms governing the interactions of passengers and pedestrians both with each other as well as with vehicles?

Furthermore, while this paper primarily focuses on the transitioning period from partial to full autonomy, we would also be interested in understanding how perspectives might shift when fully autonomous vehicles have become the norm. Would there be a change in the acceptable limits for speed profiles? Would fully autonomous vehicles be ubiquitous or would manually driven vehicles still be on the road? This workshop would be the ideal venue to discuss such issues among a community of researchers dedicated to a future with autonomous vehicles.

REFERENCES

[1] Chandrayee Basu, Qian Yang, David Hungerman, Mukesh Singhal, and Anca D. Dragan. 2017. Do You Want Your Autonomous Car To Drive Like You?. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction (HRI '17)*. ACM, New York, NY, USA, 417–425. https://doi.org/10.1145/2909824.3020250

[2] Shadan Sadeghian Borojeni, Torben Wallbaum, Wilko Heuten, and Susanne Boll. 2017. Comparing Shape-Changing and Vibro-Tactile Steering Wheels for Take-Over Requests in Highly Automated Driving. In *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '17)*. ACM, New York, NY, USA, 221–225. https://doi.org/10.1145/3122986.3123003

[3] disabilities 2017. Will Autonomous Vehicles Be Accessible to People with Disabilities? https://sharedusemobilitycenter.org/news/will-autonomous-vehicles-be-accessible-to-people-with-disabilities/.

[4] jaguar 2018. Future Jaguar and Land Rover Vehicles Will Help Reduce Motion Sickness. https://media.jaguarlandrover.com/news/2018/11/future-jaguar-and-land-rover-vehicles-will-help-reduce-motion-sickness.

[5] Markus Kuderer, Shilpa Gulati, and Wolfram Burgard. 2015. Learning driving styles for autonomous vehicles from demonstration. In *Robotics and Automation (ICRA), 2015 IEEE International Conference on*. IEEE, 2641–2646.

[6] Sonia Baltodano Nikolas Martelaro Rohan Maheshwari David Miller Wendy Ju Nikhil Gowda, Srinath Sibi. 2015. Nudge: Haptic Pre-Cueing to Communicate Automotive Intent. In *Automotive User Interfaces (AutomotiveUI), 2015 ACM*. ACM.

[7] Tomi Nukarinen, Jussi Rantala, Ahmed Farooq, and Roope Raisamo. 2015. Delivering directional haptic cues through eyeglasses and a seat. In *World Haptics Conference (WHC), 2015 IEEE*. IEEE, 345–350.

[8] Christopher J Ploch, Jung Hwa Bae, Caitlin C Ploch, Wendy Ju, and Mark R Cutkosky. 2017. Comparing haptic and audio navigation cues on the road for distracted drivers with a skin stretch steering wheel. In *World Haptics Conference (WHC), 2017 IEEE*. IEEE, 448–453.

[9] Felix Ros, Jacques Terken, Frank van Valkenhoef, Zane Amiralis, and Stefan Beckmann. 2018. Scribble Your Way Through Traffic. In *Adjunct Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '18)*. ACM, New York, NY, USA, 230–234. https://doi.org/10.1145/3239092.3267849

[10] Spencer Salter, Cyriel Diels, Paul Herriotts, Stratis Kanarachos, and Doug Thake. 2019. Motion sickness in automated vehicles with forward and rearward facing seating orientations. *Applied Ergonomics* 78 (2019), 54–61.

[11] Michael Sivak and Brandon Schoettle. 2017. Universal Motion Sickness Countermeasure System.

[12] Ariel Telpaz, Brian Rhindress, Ido Zelman, and Omer Tsimhoni. 2015. Haptic Seat for Automated Driving: Preparing the Driver to Take Control Effectively. In *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '15)*. ACM, New York, NY, USA, 23–30. https://doi.org/10.1145/2799250.2799267

[13] Jacques Terken, Pierre Levy, Chao Wang, Juffrizal Karjanto, Nidzamuddin Md Yusof, Felix Ros, and Sergej Zwaan. 2017. Gesture-based and haptic interfaces for connected and autonomous driving. In *Advances in Human Factors and System Interactions*. Springer, 107–115.

[14] Remo van der Heiden, Shamsi T Iqbal, and Christian P Janssen. 2017. Priming Drivers before Handover in Semi-Autonomous Cars. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 392–404.

[15] Marcel Walch, Tobias Sieber, Philipp Hock, Martin Baumann, and Michael Weber. 2016. Towards Cooperative Driving: Involving the Driver in an Autonomous Vehicle's Decision Making. In *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. ACM, 261–268.