IS GESTURE-BASED INTERACTION EQUALLY VIABLE IN MANUAL AND AUTONOMOUS DRIVING?

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ABSTRACT

Reducing driver distraction is important for road safety, as manual driving requires the driver to keep their eyes on the road. In the era of autonomous driving, drivers will still need to be able to rapidly take control of the vehicle, but constant observance will no longer be required. Therefore, it is desirable to both focus the driver's attention on the traffic situation and to provide stimulation to avoid driver fatigue. Previous studies have shown that, compared to touch-based interaction, the use of gestures to perform secondary tasks on an infotainment system results in higher ratings of user experience, acceptance, and trust as well as reduced workload. In an autonomous vehicle, the driver's hands do not need to stay on the wheel for the entire driving time, and decreasing visual distraction is less important than in manual driving. In the forthcoming study described in this paper, we plan to investigate whether the subjective advantages for gestures in secondary task interaction are present in both manual and autonomous driving.

KEYWORDS

Gestures, Driver Distraction, Secondary Tasks, User Experience

1. INTRODUCTION

In manual driving, distraction plays a crucial role in driving safety. In 2020, driver distraction was implicated in approximately 13% of all crashes in the US, 14% of injury crashes, and 8% of fatal crashes, leading to a total of over 3,000 deaths (National Center for Statistics and Analysis 2022). Driver distraction is defined by the shifting of the driver's attention from the primary driving task to a secondary task (see Lee *et al.* 2009, Regan *et al.* 2009b), for example using the in-vehicle infotainment system (IVIS), talking to a passenger, or using a mobile phone. Studies have shown that distracted drivers exhibit poorer driving performance (for an overview, see Regan *et al.* 2009a, Regan *et al.* 2013). In autonomous driving, the criticality of driver distraction may be reduced, as the driver is not required to observe the traffic situation constantly. Nonetheless, the driver may still be required to take control of the vehicle and should therefore still be aware of the current situation. However, driving an autonomous vehicle can also be uneventful for the driver: it does not require a high level of attention and may lead to driver fatigue. Therefore, it would be beneficial to provide positive stimulation using modern in-vehicle interaction technologies, such as gesture-based interaction (GBI), in order for the driver to maintain an appropriate level of situational awareness and to avoid fatigue. Studies on GBI in manual driving have found that gesture-based systems are associated with higher user experience ratings (e.g. Chiesa and Branciforti 2012, Loehmann *et al.* 2013, Häuslschmid *et al.* 2015, Fariman *et al.* 2016) and can increase the driver's awareness of the driving situation, leading in particular to increased reaction times in hazardous situations (e.g. Graichen *et al.* 2020).

In previous studies, we observed that GBI garnered higher ratings of acceptability, trust, and user experience compared to a conventional touchscreen when drivers performed secondary driving tasks using an IVIS (Graichen *et al.* 2019a). Because autonomous driving will likely enter the market in future, it would be interesting to investigate whether these advantages hold for autonomous driving as well. In the forthcoming study, we will address the following research questions:

RQ1: Is GBI rated similarly positively in terms of acceptance, trust, and user experience when used in autonomous driving compared to manual driving?

RQ2: How distracting, in terms of looks to the display, are gestures when used for autonomous driving?

RQ3: Does subjective workload receive similarly low ratings when using gestures for manual and autonomous driving?

2. METHODS

2.1 Design and Independent Variables

A one-way repeated measures design has been chosen, where two types of driving mode (manual vs. autonomous) make up the factor. To increase task variety for the secondary tasks, we will implement interaction stories with the IVIS to represent basic, frequently used functions and tasks that would require more complex operations when performed using a touchscreen. Table 1 presents the task details and gestures used. All participants will experience both driving modes. One driving scenario has been selected from the set of pre-delivered scenarios provided by the simulation software. This scenario allows drivers to perform three IVIS tasks during manual and automated driving, respectively. The driving mode will remain constant during each trip, and the sequence of tasks during the trip as well as the task type alternations will be balanced according to the standard Latin square. Within each scenario, the timing of the interaction tasks will be fixed to provide participants with sufficient time to perform them without time pressure.

2.2 Participants

An opportunity sample will be obtained and will consist primarily of students from the Technical University of Berlin in Germany. No restrictions will be established regarding driving experience or visual aids. This study will comply with the tenets of the Declaration of Helsinki such that informed consent will be obtained from each participant.

2.3 Facilities and Apparatus

A fixed-based driving simulator will be used for the study. Participants will sit in a driving simulation mock-up with automatic transmission. We will use Carla as a driving simulation environment (Dosovitskiy *et al.* 2017). To record driver interactions with the IVIS, a camera will be placed on a table close to the mock-up and angled towards the driver. To investigate participants' visual behavior towards the displays, a Pupil Labs eye tracker will be used (see https://pupil-labs.com/).

Figure 1. Experimental situation

The driving scenario is a city scenario that was selected from the tracks provided in Carla. A 15-inch screen will be mounted on the center console to display the IVIS (see Figure 1). The screen will be connected to a gesture recognition device (Leap Motion). Although the gesture detection rate of the Leap Motion is relatively high, we will use the Wizard of Oz method (WoO; Dahlbäck *et al.* 1993) for the interaction, meaning that all user inputs will be enacted by the examiner. This method will be employed to avoid sensor-related errors;

long screen response times; or participants performing the incorrect gesture, which may confound individual evaluations of the interaction system. Carla itself can perform automated driving in most driving situations (such as stabilization and some maneuvering tasks). However, in one situation, the vehicle is required to overtake a stopped vehicle. Here, the examiner is required to use the WoO technique and manually steer the vehicle using a joystick in order to provide a continuous experience of autonomous driving.

The IVIS screens are based on the original displays of a Seat Leon ST brand vehicle to ensure that they are realistic. They will be used to display the information needed to perform the secondary tasks. The display figures are embedded in a slide show format that the examiner will control. For both driving modes, three interaction tasks have been derived from typical IVIS tasks. Two of the tasks can be performed by operating a single control element in a conventional touch-based IVIS. The completion of the remaining task usually requires more complex operations and several interaction steps in a conventional touch-based interface.

To ensure that gestures are suitable for performing the respective tasks, a pre-study with 31 participants was conducted. Participants were presented with images of various gestures and were asked to choose the most appropriate gesture for each task. They could also report that no gesture would be suitable. In the present study, we selected three gestures that had been rated as highly appropriate for the chosen interaction tasks. Table 1 presents the IVIS task descriptions and their corresponding gestures. Each task interaction includes an audio snippet of acoustic feedback (e.g., a song snippet that is stopped for the "mute radio" task) to signal to participants that the task has been completed without requiring them to look at the interface.

2.4 Procedure

Upon arrival, participants will complete questionnaires pertaining to their demographics and technical affinity. They will then be introduced to the IVIS tasks and the general use of the gesture-based functionalities. Each participant will be given as much time as they need to learn and practice the interaction tasks and their respective gestures. Participants will be tested repeatedly on their interaction performance in order to reduce training effects during the experiment and lower the odds of participants performing the incorrect gesture during an interaction task. Gesture recognition functionality will be demonstrated using an online visualization of the Leap Motion on the screen which illustrates the device tracking of the participant's fingers and palm. Before the experiment starts, participants will be introduced to the eye-tracking device, which will then be calibrated individually. The first trip will familiarize the participant with the vehicle and the simulator setting. The two remaining trips will include one driving scenario and three IVIS tasks for each driving mode, respectively. Participants will be instructed to drive according to the German Road Traffic Act and perform the tasks only when they feel comfortable doing so. After each trip, participants will complete a questionnaire pertaining to acceptance, trust, user experience, and workload in relation to their recent interaction. At the end of the experiment, participants will complete further questionnaires pertaining to their engagement in the secondary tasks, their impressions of immersion and presence, and their evaluation of the system. Overall, the experiment will take approximately 1 h to complete.

Table 1. Tasks with corresponding gestures and procedures for completion.

Driving Mode	Task	Gesture	Initial Situation	GBI Subtasks	Result
Manual/ Autonomous	Mute Radio		Radio menu displayed Song snippet played	Perform gesture	Song snippet is stopped
Manual/ Autonomous	Start Call		Start menu is displayed	Perform gesture	Instruction of navigation device is repeated at higher volume
Manual/ Autonomous	Increase Navigation Volume		Navigation map is displayed	Perform gesture	Dial tone is presented

2.5 Dependent Variables

Gaze behavior will be assessed using metrics such as the number and duration of looks to the display during each trip. The subjective rating of the interaction types will be measured using questionnaires on acceptance (Van der Laan *et al.* 1997), attractiveness (Hassenzahl *et al.* 2003), and workload (Hart and Staveland 1988), as well as the distraction engagement subscales of the Susceptibility to Driver Distraction Questionnaire (Feng *et al.* 2014). At the end of the experiment, participants will be asked to rate their affinity to new technical devices using the TA-EG (Karrer *et al.* 2009) as well as their feelings of immersion and presence when using the simulator (Lessiter *et al.* 2001).

3. IMPLICATIONS

Autonomous vehicles have the potential to increase driving safety and driver comfort, making it possible for drivers to shift their attention to other activities. However, it is important that drivers and other traffic participants are able to build suitable levels of trust in these systems, as trust is a key determinant of the willingness to use and accept such systems. On the one hand, previous studies suggest that users tend to overtrust technical systems in general, as they misunderstand application functionalities, are unaware of system constraints, or use systems for purposes for which they were not intended (Itoh 2012). On the other hand, drivers also demand an unrealistically high level of safety from autonomous vehicles before they are willing to use them (Shariff *et al.* 2021). Most drivers deem themselves to be more skilled than the average driver, which likely explains this demand (Alicke and Govorun 2005). For the driver to be able to assume control of the vehicle when necessary, it is important to sustain their attention by creating suitable levels of stimulation during autonomous driving, for example by using interaction types that offer a positive user experience. At the same time, visual driver distraction should be minimized to allow drivers to keep their eyes on the road and the traffic situation. In previous studies, we have observed that gestures not only offer this desired level of stimulation and user experience but are also rated as highly acceptable and trusted by users (Graichen *et al.* 2019b). However, in these studies, we investigated the use of GBI to perform secondary tasks on an IVIS system during manual driving. Therefore, the question arises as to whether GBI used in autonomous vehicles will yield similar results.

REFERENCES

Alicke, M.D. and Govorun, O., (2005). The Better-Than-Average Effect. In: M.D. Alicke, D.A. Dunning, and J. Krueger, eds. The Self in Social Judgment: Psychology Press, 85–106.

Chiesa, M. and Branciforti, A., (2012). Experimenting Kinect interactions in the car. In: A.L. Kun, et al., eds. AutomotiveUI 2012: 4th International Conference on Automotive User Interfaces and Vehicular Applications (Adjunct Proceedings). October 17-19, 2012, Portsmouth, New Hampshire, US.

Dahlbäck, N., Jönsson, A., and Ahrenberg, L., (1993). Wizard of Oz studies. In: W.D. Gray, ed. Proceedings of the 1st international conference on Intelligent user interfaces. New York, NY: ACM, 193–200.

Dosovitskiy, A., et al., (2017). CARLA: An Open Urban Driving Simulator. In: Proceedings of the 1st Annual Conference on Robot Learning, 1–16.

Fariman, H.J., et al., (2016). Designing a user-defined gesture vocabulary for an in-vehicle climate control system. In: H. Duh, et al., eds. Proceedings of the 28th Australian Computer-Human Interaction Conference (OzCHI 2016): 29 November - 2 December 2016, University of Tasmania. New York, NY, USA: ACM, 391–395.

Feng, J., Marulanda, S., and Donmez, B., (2014). Susceptibility to Driver Distraction Questionnaire. Transportation Research Record: Journal of the Transportation Research Board, 2434, 26–34.

Graichen, L., Graichen, M., and Krems, J.F., (2019) a. Evaluation of gesture-based in-vehicle interaction: User experience and the potential to reduce driver distraction, 1–19.

Graichen, L., Graichen, M., and Krems, J.F., (2019) b. Evaluation of Gesture-Based In-Vehicle Interaction: User Experience and the Potential to Reduce Driver Distraction. Human Factors: The Journal of the Human Factors and Ergonomics Society, 61 (5), 774–792.

Graichen, L., Graichen, M., and Krems, J.F., (2020). Effects of Gesture-Based Interaction on Driving Behavior: A Driving Simulator Study Using the Projection-Based Vehicle-in-the-Loop. Human Factors: The Journal of the Human Factors and Ergonomics Society, 18720820943284.

Hart, S.G. and Staveland, L.E., (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In: Human Mental Workload: Elsevier, 139–183.

Hassenzahl, M., Burmester, M., and Koller, F., (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In: G. Szwillus and J. Ziegler, eds. Mensch & Computer 2003: Interaktion in Bewegung. Stuttgart, Leipzig: B.G. Teubner, 187–196.

Häuslschmid, R., Menrad, B., and Butz, A., (2015). Freehand vs. micro gestures in the car: Driving performance and user experience. In: 2015 IEEE Symposium on 3D User Interfaces (3DUI): IEEE, 159–160.

Itoh, M., (2012). Toward overtrust-free advanced driver assistance systems. Cognition, Technology & Work, 14 (1), 51–60.

Karrer, K., et al., (2009). TA-EG Fragebogen zur Technikaffinität – Einstellung zu und Umgang mit elektronischen Geräten (29).

Lee, J.D., Young, K.L., and Regan, M.A., (2009). Defining driver distraction. In: M.A. Regan, J.D. Lee, and K.L. Young, eds. Driver distraction. Theory, effects, and mitigation. Boca Raton: CRC Press.

Lessiter, J., et al., (2001). A Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory. Presence: Teleoperators and Virtual Environments, 10 (3), 282–297.

Loehmann, S., et al., (2013). Culturally independent gestures for in-car interactions. In: D. Hutchison, et al., eds. Human-Computer Interaction – INTERACT 2013. Berlin, Heidelberg: Springer Berlin Heidelberg, 538–545.

National Center for Statistics and Analysis, (2022). Distracted driving 2021 (Research Note. Report No. DOT HS 813 309.

Regan, M.A., Lee, J.D., and Victor, T.W., eds., (2013). Driver distraction and inattention. Advances in research and countermeasures. Farnham, Burlington: Ashgate.

Regan, M.A., Lee, J.D., and Young, K.L., (2009) b. Driver distraction: Toward a common definition. In: First International Conference on Driver Diststraction and Inattention. 28-29 September 2009, Gothenburg, Sweden.

Regan, M.A., Lee, J.D., and Young, K.L., eds., (2009) a. Driver distraction. Theory, effects, and mitigation. Boca Raton: CRC Press.

Shariff, A., Bonnefon, J.-F., and Rahwan, I., (2021). How safe is safe enough? Psychological mechanisms underlying extreme safety demands for self-driving cars. Transportation Research Part C: Emerging Technologies, 126, 103069.

Van der Laan, J.D., Heino, A., and Waard, D. de, (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation Research Part C: Emerging Technologies, 5 (1), 1–10.