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The Effect of Timing of Non-Driving Task Takeover Request Messages on Novice Drivers' Driving Trust

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ABSTRACT

The unpredictable behavior patterns of self-driving vehicles in SAE level 3 automated Vehicles can be untrustworthy to the driver. Head-up displays (HUDs) provide an opportunity to visually and effectively inform drivers about vehicle perception and interpretation of the driving environment. Research has illustrated the importance of where and when HUD information is displayed. Timing of the display of necessary information can have a significant impact on driving safety; This work focuses on the impact of HUD message appearance time on user experience and trust, measuring the impact of three HUD information presence timings (50m/70m/90m) on novice driver trust during a turning driving task. The results show that the appropriate appearance of HUD information enhances user experience and trust in the automated system. Based on the research, we provide optimized design strategies for the timing of HUD information appearance.

Keywords: Automated vehicles, Autonomous driving, Head-up displays, Information interaction, UX, Trust, Safety

INTRODUCTION

As technology advances, automated vehicles (abbreviation: AVs) are becoming more capable. This has led to an increase in the non-involvement of humans in driving tasks and uncertainty about the future actions of the vehicle. Studies have shown that when automation increases, passengers' trust in the system decreases. Collaboration between humans and robots will be more effective if the system communicates its intentions (Rödel et al., 2014, Walch et al., 2017).

As part of the in-vehicle information system, the vehicle's Head-up display (HUD) system presents various information items, such as driving and non-driving information, directly in the driver's forward field of view (FFOV). By doing so, it allows the driver to get the information they need while keeping their eyes forward, rather than taking their eyes off the road scene in front of them as they would with a conventional Heads-down display (HDD) (Doshi, 2009, Yang et al., 2018). Well-designed automotive HUDs are considered to have advantages over HDDs, including less gaze and focus shifts between the road scene and the display, and potentially faster detection of displayed information and external events (Gish et al., 1995, Liu et al., 2003, Liu et al., 2004, Oh et al., 2016, Sojourner et al., 1990).

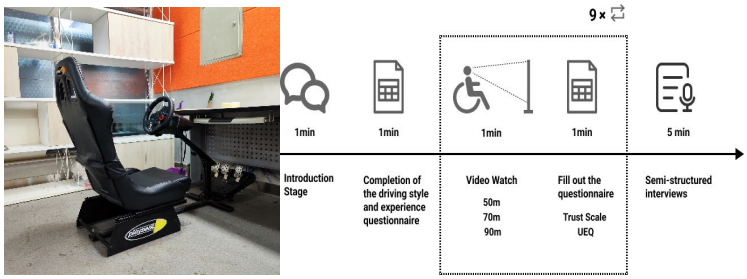

Figure 1: Experimental environment and experimental procedure.

According to the research, current automotive HUD systems can be further improved in terms of system functionality and interface/interaction design to match the driver's needs and preferences to provide a better user experience (Charissis et al., 2010, Beck et al., 2019). Also, the visibility of the system state is one of Jakob Nielsen's usability heuristics for user interface design and the system should always pass appropriate feedback within a reasonable time (Nielsen, 1994). Therefore, it is particularly important how the HUD displays the non-driving task takeover request message for user experience when it appears. In this paper, we investigate when the HUD message appears will not affect the user experience and user trust through user testing and user interviews.

In this paper, when using the term "timing of information", we are referring to when the vehicle HUD system tells the user about the vehicle's intent, i.e, when the user is aware of the vehicle's intent.

USER STUDIES

We investigated how the timing of information cues for automated vehicle intent affects user experience and trust, and how these factors correlate with other factors such as the driving experience.

Participants

We invited 26 participants (M13, F13) with a mean age of 23.5 years (SD 1.73) to the College of Design and Arts, Hunan University. Participants drove less than 5,000 km per year, meeting the criteria for a novice driver (Gerber et al., 2019). To answer how the visualization of vehicles' motion intentions.

Materials

The experimental setup was performed in a simulated cockpit (see Figure 1). We placed a screen (65-inch) in front of the cockpit and displayed the recordings of real driving on to the canvas screen (see Figure 2). To control for variable driving material without sound, the videos were not similar. The subjective scales used in the experiment - User Experience Questionnaire (UEQ), Trust Scale (TS) and Preference for Overall Driving Experience (PREF).

Figure 2: Experiment video.

Table 1. Subjective scales used in the experiment and their internal consistency.

Scale	Factor	Items	Cronbach's α
UEQ	Attractiveness	6	.78
	Perspicuity	4	.73
	Efficiency	4	.65
	Dependability	4	.82
	Stimulation	4	.32
	Novelty	4	.57
TS	Trust	12	.73
PREF	Time Preference	1	.78

Method

The driving task involved in the video is vehicle turning. We created the video in Adobe Photoshop and Adobe After Effects. In addition, we designed a control condition i.e, the information is always displayed. We told the participants that the car was self-driving and therefore they had no option to intervene during the viewing process. After viewing each video, we measured participants' perceptions of user experience and trust. For user experience, we used the User Experience Questionnaire (Laugwitz et al., 2008) and for trust, the Trust Scale (Jian et al., 2000, Pöhler et al., 2016). Finally, the overall driving experience was rated (short: PREF, 7-point Likert scale). In addition, we asked them through interviews about what they liked or disliked about the timing of the information and whether they made any suggestions.

RESULTS

First, we checked the internal reliability of all scales (see Table 1). We found unacceptable values for the UEQ sub-scale efficiency, stimulation, novelty, so we excluded this part of the scale from further reporting and interpretation. For all other (sub) scales, the consistency ranged from acceptable to excellent. To find differences between conditions, we used univariate ANOVA. To analyze correlations between factors, such as user experience and timing preferences, we used a bivariate correlation analysis after Pearson.

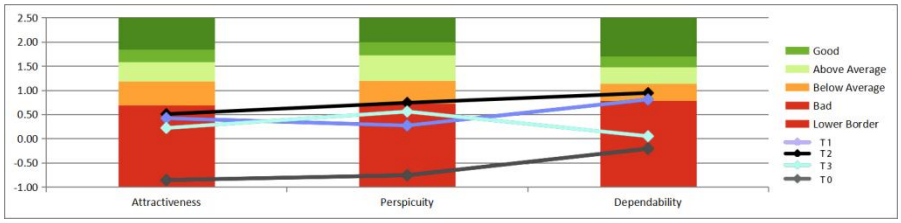

Figure 3: Mean values for UEQ factors, in all experimental conditions (lines)-The colorscale represents UEQ benchmark against other system (401 studies).

Table 2. Post-hoc comparison of experimental conditions for UEQ factors, TS, and PREF.

Scale	Factor	Significant Findings, $p < 0.05$
UEQ	Perspicuity	T2>T3>T1>T0
	Dependability	T2>T1>T3>T0
TS	Trust	T2>T1>T3>T0

User Experience

We found a significant main effect of the visualization condition on 2 factors: dependability ($F(2) = 6.08$, $p<0.05 = 0.004$, $\eta 2 = 0.15$), Perspicuity ($F(2) = 6.08$, $p<0.05= 0.004$, $\eta^2 = 0.15$), therefore it is considered that at least one of the 3 groups is significantly different from the other group.

We found that there is a significant difference between these three groups (T2>T1>T3). the timing of the HUD message presence affects the user dependability experience (see Table 2).

Automation Trust

We found a significant effect of the timing of message appearance on trust ($F(2)=3.87$, $p<0.05=0.026$, $\eta^2 =0.10$), thus concluding that at least one of the 3 groups was significantly different from the other.

We found a significant main effect of timing of information appearance on trust ($F(2)=3.76$, $p<0.05=0.029$, In other words, the timing of the appearance of all three types of information leads to higher trust (see Figure 3, Table 2), and the inappropriate timing of the information can lead to distrust of the system.

Overall Driving Experience and Preference

The timing of message presence did not affect participants' ratings of the overall driving experience.

Overall Driving Experience and Preference

To identify additional factors, we analyzed the effects of driving style and gender on the dependent variable. There was no correlation between them.

Qualitative Feedback

During the interviews, we asked users about the reasons for their message appearance timing preferences, as well as other noteworthy information.

The majority of users chose T2 as the optimal message appearance time, believing that too long an interval between message appearances would cause anxiety and too short a time would result in too little time to react. Three users also indicated that the optimal message appearance time would change with long-term use. Preferences may change depending on the driving environment, e.g., traffic jams, bad weather conditions.

ADVICE ON DESIGN

We summarize the design implications of message timing that can help improve future HUD designs for automated vehicles.

D1. Design different timing for different messages.
D2. Design different message appearance timing for different driving environments.
D3. Information appearance should be configurable or adjustable depending on the user's driving skills for the automated vehicle.

CONCLUSION AND LIMITATIONS

As the actions of automated vehicles become more complex, their intent becomes more difficult to communicate. In this paper, we evaluate three different timing of message appearance to communicate vehicle intent. Users perceived that message appearing at T2 time provided the best safety and reliability. However, given the small sample size and the simplicity and homogeneity of the driving environment studied, the findings of this study may not be applicable to a broader driving environment. Further work will be conducted in more depth for different driving tasks and driving conditions.

REFERENCES

Charissis, V. and Papanastasiou, S., 2010. Human–machine collaboration through vehicle head up display interface. Cognition, Technology & Work, 12(1), pp. 41–50.

Doshi, A., Cheng, S.Y. and Trivedi, M.M., 2008. A novel active heads-up display for driver assistance. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), 39(1), pp. 85–93.

Gerber, M.A., Schroeter, R. and Vehns, J., 2019, September. A video-based automated driving simulator for automotive UI prototyping, UX and behaviour research. In Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 14–23).

Gish, K.W. and Staplin, L., 1995. Human factors aspects of using head up displays in automobiles: A review of the literature.

Jian, J.Y., Bisantz, A.M. and Drury, C.G., 2000. Foundations for an empirically determined scale of trust in automated systems. International journal of cognitive ergonomics, 4(1), pp. 53–71.

Laugwitz, B., Held, T. and Schrepp, M., 2008, November. Construction and evaluation of a user experience questionnaire. In Symposium of the Austrian HCI and usability engineering group (pp. 63–76). Springer, Berlin, Heidelberg.

Liu, Y.C., 2003. Effects of using head-up display in automobile context on attention demand and driving performance. Displays, 24(4-5), pp. 157–165.

Liu, Y.C. and Wen, M.H., 2004. Comparison of head-up display (HUD) vs. head-down display (HDD): driving performance of commercial vehicle operators in Taiwan. International Journal of Human-Computer Studies, 61(5), pp. 679–697.

Oh, H.J., Ko, S.M. and Ji, Y.G., 2016. Effects of superimposition of a head-up display on driving performance and glance behavior in the elderly. International Journal of Human-Computer Interaction, 32(2), pp. 143–154.

Park, J. and Park, W., 2019, November. A review on the interface design of automotive head-up displays for communicating safety-related information. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 63, No. 1, pp. 2016–2017). Sage CA: Los Angeles, CA: SAGE Publications.

Pöhler, G., Heine, T. and Deml, B., 2016. Itemanalyse und Faktorstruktur eines Fragebogens zur Messung von Vertrauen im Umgang mit automatischen Systemen. Zeitschrift für Arbeitswissenschaft, 70(3), pp. 151–160.

Rödel, C., Stadler, S., Meschtscherjakov, A. and Tscheligi, M., 2014, September. Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. In Proceedings of the 6th international conference on automotive user interfaces and interactive vehicular applications (pp. 1–8).

Sojourner, R.J. and Antin, J.F., 1990. The effects of a simulated head-up display speedometer on perceptual task performance. Human Factors, 32(3), pp. 329–339.

Walch, M., Mühl, K., Kraus, J., Stoll, T., Baumann, M. and Weber, M., 2017. From car-driver-handovers to cooperative interfaces: Visions for driver–vehicle interaction in automated driving. In Automotive user interfaces (pp. 273–294). Springer, Cham.

Yang, Z., Shi, J., Zhang, Y., Wang, D., Li, H., Wu, C., Zhang, Y. and Wan, J., 2019. Head-up display graphic warning system facilitates simulated driving performance. International Journal of Human–Computer Interaction, 35(9), pp. 796–803.