Designing displays in automated vehicles for the thrill-seeking driver: Characterizing driving profiles to create personalized driving displays

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Automation, or the performance of a task by a machine or system that might otherwise be completed by a human, surrounds us in many everyday tasks, from autocorrecting of spelling to automated vehicles (Parasuraman & Riley, 1997). Automated vehicles can range in level of automation from highly automated (SAE Level 5), requiring no input from the driver, to low automation (SAE Level 1) such as blind spot warning systems (SAE International, 2013). As automation levels increase, these systems drastically change the driving task, ultimately relegating the driver into a supervisory role in the control of the vehicle (Sheridan, 2012)

However, automation, including in vehicles, is not always perfectly reliable. In fact, in complex environments, such as on the roadways, automation can have quite variable reliability and can even fail (Dikmen & Burns, 2016). Providing the driver with a display of the automation's level of (un)certainty in its own performance has been shown to improve the experience of driving an automated vehicle, even after experiencing an automation failure, by supporting trust calibration (Noah, 2018). The research we report on, here, builds upon that automation uncertainty display research, with the end goal of improving acceptance and trust of highly automated vehicle technologies (Noah & Walker, 2018).

Having the vehicle automation system present information to the driver about what the automation is doing, the choices the system is making, and the objects detected around the vehicle aids transparency and therefore trust calibration (Hoff & Bashir, 2015; Noah & Walker, 2017). However, different drivers may want (or need) different information or the information presented in different ways. Having a variety of display approaches, or profiles, personalized to the wants and needs of various driver types is certainly possible. The question then arises how drivers characterize these different display profiles, what driving behaviors are associated with them, and what display elements would support specific profiles. The driving profiles explored in this particular study were: *Thrill-Seeking*, for the driver who finds enjoyment in driving, and wants information about speed, and vehicle performance; *Transit*, for the driver who wants to know the general route, and perhaps fuel efficiency; and *Defensive*, which provides information about what the vehicle detects in the environment, for the driver concerned with safety (Noah & Walker, 2018). These displays could even be used to gradually gain the trust of a driver who is new to highly automated vehicles. For example, the *defensive* display could be used initially to build the driver's trust, and then transition to the *transit* display. For someone who is a driving hobbyist, the *thrill-seeking* display may be what entices them to use the automation systems.

To support our research goals, we enlisted 25 undergraduate students from a large US research university to participate in focus groups that discussed the similarities and differences of each driving profile, and developed display prototypes (for the thrill-seeking profile, in this particular study). All participants were required to have corrected or normal-to-corrected vision,

corrected or normal-to-corrected hearing, and be 18 years or older or enrolled as a student. One female moderator facilitated each of the focus group sessions, while an additional researcher took written notes.

The moderator followed a discussion guide that included the following components: (1) a description of the purpose for the study and rules for the focus group; (2) an outline of the topics and corresponding discussion questions; and (3) instructions for the design activity. A fixed sequence of 13 discussion questions was used to explore three topics (knowledge of automated vehicles, identification of driving profiles, and perceptions of thrill-seeking driving behavior). Table 1 includes all topics and discussion questions used to guide the focus groups. To conclude the session, participants completed a design activity consisting of four components: initial design prototyping; narrowing down design ideas; feedback; and a final group design (Table 2). The goal of the design activity was to gain insight on what information and design elements should be included in displays for the thrill-seeking profile.

Table 1. Topics and discussion questions from the discussion guide used by the moderator.

Focus Group Topics	**Discussion Question or Activity**
Topic 1: Knowledge and Experience with Automated Vehicles/Safety Features	Please describe your experience with automated safety features.
Topic 2: Identification of Driving Styles	How would you characterize the following three driving styles: transit, defensive, and thrill-seeking?
	As a group, write a short definition for each driving style.
	How would you classify your own driving style? How does your driving style change in different scenarios?
	How would you relate your personality with your driving style(s)?
Topic 3: Perception of Thrill-Seeking Driving Behavior	(A) What are moments or situations outside of driving that make you feel thrilled?
	(B) What are moments or situations that make you feel thrilled while driving?
	(C) Describe how you believe a thrill-seeking driver would behave while driving. What overt behaviors would they show?
	(D) What information would make driving an automated vehicle more thrilling?
	(E) As a group, rank order the importance of the identified information for a thrill-seeking driver with 1 being the most important.

Table 2. Descriptions of the components of the design activity.

Design Activity	**Activity Description**
Initial Design Prototyping	Individually sketch eight display ideas based on information identified in topic 4E (Table 1)
Narrowing Down Design Ideas	Iterate designs and draw four detailed displays based on the information discussed in topic 4E (Table 1)
Feedback	Provide each other brief, positive feedback on each of the four displays designed
Final Group Design	As a group, combine display designs to create a heads-up display (HUD) for the thrill-seeking driving profile

Affinity diagramming is being used now to identify themes of thrill-seeking driving behavior and common elements among the displays from the design activity. The information

gathered from this study will guide our understanding of driving profiles and the expectations of drivers. The results will then be used to improve display designs so they match the mental models of future users. Utilizing personalized driving displays in automated vehicles can help the driver understand how the automation is performing. By improving the driver's situation awareness, they can be more prepared to transition from automated driving back to manual driving. In addition, using displays that match the driver's personal driving profile may improve trust in automation and ensure the driver has an appropriate trust calibration. Future research will investigate how the use of personalized driving displays impacts situation awareness and trust in automated vehicles.

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