Navigating the Development and Design of Automated Vehicles

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Driver assistance technologies have evolved from aiding the driver in very specific situations (e.g., electronic stability control) to automating a broader range of driving tasks (e.g., adaptive cruise control and lane-keeping systems). While recent demonstrations of automated vehicles support the possibility that even limited automation can provide safety benefits compared to fully manual driving, many challenges remain. For example, while automated vehicle (AV) designers may assume drivers will perform their allocated roles and maintain vigilance during automated driving, recent incidents have demonstrated the frailty of such assumptions. These include drivers watching videos, sleeping, and generally failing to pay attention to the driving task during automated driving. Research conducted in the wake of such incidents[1] suggests that the public's tolerance for crashes and fatalities in AVs is likely to be much less than that for manual driving.

Such incidents also serve as a reminder that AVs can change the nature of driving and the role of the driver (including safety drivers used during road testing of AVs), often in unanticipated ways. Similar outcomes were common during initial implementations of automation in the aviation and process control industries, but many questions remain. What are the attentional, decision-making, and physical requirements that AVs place on the driver, and what design features are needed to support those requirements? Recent design guidance for the human-machine interface (HMI) for automated vehicles produced by the U.S. Department of Transportation[2] provides only limited answers to these questions. How can human factors researchers help manufacturers design AV technology in a way that meets driver expectations, is easy-to-use, and generates the required levels of system safety and public trust in AVs? The following strategies can help address some of the challenges with imperfect automation, guide the AV industry towards a driver-centric approach to AV design, and produce more effective driver-vehicle interactions.

Embrace a collaborative approach to the development of the AV and the design of the HMI. Partial automation requires various types and amounts of driver involvement (especially Level 2 & 3 automation[3]). With lower levels of automation, the driver is still required to maintain awareness of the driving environment in case the automation must transfer control back to the driver. Living with imperfect automation means the driver cannot be isolated from on-going responsibilities for monitoring the roadway, making decisions, and controlling the vehicle. These responsibilities must be shared between the AV system and the driver using an interdependent, collaborative approach to driver-vehicle interactions that

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[1] AAA (2018) American Trust in Autonomous Vehicles Slips. https://newsroom.aaa.com/2018/05/aaa-american-trust-autonomous-vehicles-slips/ & https://publicaffairsresources.aaa.biz/download/10980/

[2] Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Bacon, L. P., … & Sanquist, T. (2018). Human factors design guidance for level 2 and level 3 automated driving concepts (Report No. DOT HS 812 555). Washington, DC: National Highway Traffic Safety Administration. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13494_812555_l2l3automationhfguidance.pdf

[3] Society of Automotive Engineers (2018). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. Warrendale, PA: Society of Automotive Engineers, International

promotes readiness, appropriate expectations, situation awareness, driver trust, and effective mental models of the AV's operations.

Provide engaging feedback. The key to successful AV-driver collaborations is to incorporate an HMI that facilitates flexible[4], interactive communications with the driver on all aspects of the driving task. The lack of feedback and meaningful, on-going interactions with the system is a major cause of drivers being "out-of-the-loop."[5] Feedback is also a key component of the process by which drivers develop and update their mental model of the AV's functionality. Feedback could include information about system capabilities and limitations, ongoing trip status, discrepancies between predicted and actual conditions, cues for key elements in the environment, changes in the status of the automation, countdowns to waypoints, and predictive information.

Measure and maintain effective driver engagement. Under imperfect automation, securing effective driver engagement is crucial to avoiding conflicts and crashes.[6] Engagement includes acquiring and processing the roadway information necessary for successful monitoring and safe driving. A measure of effective engagement is whether the driver is looking at specific scene elements that support the strategic and tactical objectives of the driving task. Is the driver glancing at mirrors, relevant guide signs, traffic control devices, lane markings, other vehicles, and latent hazards? In short, is the driver looking at the right things at the right times? A collaborative AV will help drivers monitor the environment and draw their attention to relevant scene elements. Although coarse "eyes on the road" measurements are currently used as proxies for driver engagement, flexible eye-tracking technologies, sensors with machine vision capabilities, and real-time vehicle-to-infrastructure communications can now be used to provide better information about driver engagement levels and even help predict the driver's readiness to take control of the vehicle.

Incorporate attention management strategies. Attention management is an on-going process by which an AV system can help the driver allocate and focus attention across competing objectives, activities, decisions, and sources of information. An attention management system could help shape driver behaviors and improve situation awareness. It would include real-time monitoring of the driver, as well as a design approach that encourages safe activities[7] and restricts unsafe ones; e.g., the strategic use of alerts, provisional access to system features, and system-initiated lockouts from distracting technology. Beyond real-time monitoring and feedback, support for appropriate management of driver attention could be provided in various ways, including the careful design of marketing messages and training materials.

Exponent has been involved in the development of advanced vehicle technologies and driver assistance systems for over a decade. Today, we are actively investigating advanced driver assistance systems (ADAS), as well as connected vehicle and automated vehicle design.[8,9] What sets Exponent apart is our ability to offer a multi-disciplinary team of Ph.D.-level engineers, scientists, and human factors experts, along with our newly minted Phoenix User Research Center (PURC)[10], attached to our automotive testing facilities at the Test and Engineering Center to quickly and seamlessly integrate with in-house teams to address a client's human factors needs throughout the design and development of advanced vehicle technologies, including AVs.

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4 Miller, C.A., and Parasuraman, R. (2007). Designing for flexible interaction between humans and automation: delegation interfaces for supervisory control. Human Factors, 49(1), 57-75.
5 Norman, D.A. (1988). The psychology of everyday things. New York: Basic Books.
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7 Llaneras, R.E., Cannon, B.R., and Green, C.A. (2017) Strategies to assist drivers in remaining attentive while under partially automated driving: verification of human-machine interface concepts. Transportation Research Record, No. 2663, 20-26.
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10 PURC - Exponent's Phoenix User Research Center. https://www.exponent.com/~/media/practices-capabilities-and-industries/human-factors/purc-brochure/exponent-purc-brochure-2018.pdf?la=en

John L. Campbell, PhD, CHFP, PMP
Human Factors
Senior Managing Scientist
Seattle
(425) 519-8719 | campbellj@exponent.com