EMERGING TECHNOLOGIES
REPORT SUMMARY | SEPT 2023

FOUNDATION FOR TRAFFIC SAFETY

Measuring and Predicting Drivers' Takeover Readiness and Supporting Takeover Transitions in Automated Driving

INTRODUCTION

As vehicle automation takes on more and more of the driving tasks, the driver's role will transform from an operator to a system supervisor. With higher levels of automation, the automated vehicle is able to monitor the environment, allowing the driver to engage in non-driving related tasks. However, if the automated vehicle reaches its system limit, the driver will be required to resume control of the vehicle in a limited amount of time. Unfortunately, when drivers are decoupled from vehicle control, they often have difficulty resuming manual control.

This report highlights two studies aimed at facilitating takeover transitions in Level 3 automation. Part 1 examines driver takeover readiness; that is, driver behavior and physiological indices and other factors that are predictive of successful takeover performance. Part 2 examines the efficacy of a gaze guidance system that helps orient drivers' attention to areas of potential risk during a control takeover.

METHOD

In Part 1, 32 participants (average age = 26 years) completed an experimental study in a driving simulator. The simulator was fixed base, with virtual worlds displayed on three monitors located in front of the participant. The vehicle was programmed to simulate the behavior of Level 3 automation, which handled the longitudinal (speed and headway) and lateral control (lane keeping) and navigation, and responded to traffic elements. When automation was engaged, participants played a Tetris game to promote more drivers' eyes-off-the-road and hands-off-the-wheel (i.e., conditions anticipated with SAE Level 3 automation). Drivers encountered several takeover situations where the automation reached its limit and they had to resume control.

Physiological data, including drivers' eye glance and pupil data, galvanic skin response, and heart rate were monitored during the study. Different machine learning modeling was used to analyze driver behavior and physiology in the moments leading up to takeover events in order to shed insights into (a) the ideal modeling approach for the current data; (b) the appropriate measurement window (time) for the different indices; (c) the most important measures to

TECHNICAL REPORT

Han, D., Liu, J., Zhou, F., Tilbury, D., Robert, L., Molnar, L., & Yang, X. J. (2023). *Measuring and Predicting Drivers' Takeover Readiness and Supporting Takeover Transitions in Automated Driving* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

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Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and educational organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this research was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

607 14TH STREET, NW, STE 701
WASHINGTON, DC 20005
202-638-5944
AAAFOUNDATION.ORG

characterize driver takeover readiness; and (d) the value of using personalized (versus general) models.

In Part 2, 12 participants (average age = 26 years) completed a similar session in the driving simulator. However, during takeover events, each participant experienced two different gaze guidance systems (either high or low salience), which helped guide their attention to critical information in the surrounding traffic environment. For both systems, the side mirror was highlighted with a red bounding box when a potential hazard (i.e., another vehicle) was about to enter the blind spot of the driver's vehicle. In the high salience condition, the red box would flash at 5 Hz for 4 seconds, whereas in the low salience condition, the red bounding box would appear for 4 seconds without flashing. Drivers also experienced a control condition with no system present.

KEY FINDINGS

Part 1 yielded several noteworthy outcomes:

- When examining driver physiological data in real-time, a random forest (RF) machine learning approach led to the best model predictions. Driver state monitoring (DSM) systems (and their underlying algorithms) should consider such approaches.
- Pre-takeover measurement windows of 9 to 14 seconds showed the best model performance, with peak performance occurring at 11 seconds for the RF model. DSM systems should strive to incorporate and/or validate their own outcomes using such time frames.
- Galvanic skin response indices were the most important measures in predicting driver performance, followed by heart rate indices. As indicators of driver takeover readiness, these measures should be considered for inclusion in DSM systems as part of a suite of measures.
- Personalized models, or models that learn and adapt to an individual driver, have great potential for increasing model accuracy and utility in real-world implementations.

Part 1 underscores the importance of examining upstream metrics or indices that occur prior to a takeover request from vehicle automation in order to identify cues that are predictive of driver readiness. Knowledge of such factors as well as information regarding the timing and modeling approaches can help to inform the development and implementation of DSM systems and their underlying algorithms.

Part 2 examined ways of supporting driver attention during takeover. The results showed that drivers using a highly salient attention guidance system were less likely to become involved in a collision with a secondary hazard during takeover transitions. These results suggest that gaze guidance (attentional) support is a viable approach to helping drivers during takeover events and worthy of further research and innovation.