THE IMPACT OF DRIVER'S MENTAL MODELS OF ADVANCED VEHICLE TECHNOLOGIES ON SAFETY AND PERFORMANCE

INTRODUCTION

New advanced technologies are being integrated into vehicles at an accelerating pace, offering new safety and convenience features to drivers. However, in addition to being complex systems in and of themselves, these technologies stand to change the fundamental nature of the driving task, especially as the systems take on more of the driving responsibilities. Driver knowledge and understanding of advanced driver assistance systems (ADAS)—sometimes referred to as a driver's mental model—are important considerations in the safe and appropriate use of these systems. For example, the driver needs to understand the functions of the ADAS as well as the limitations of the system and what conditions and situations the technology is (not) designed for.

Although past research has examined how mental models are developed as well as their impact on trust and acceptance of technology, research is generally lacking on how the quality of one's mental model translates to performance and safety impacts. The goal of this project, based on a cooperative research program between the AAA Foundation for Traffic Safety and the SAFER-SIM University Transportation Center, was to map the quality of drivers' mental models of adaptive cruise control (ACC), a common ADAS, to performance in a driving simulator study.

KEY FINDINGS

Participants with varying degrees of ACC experience were recruited and trained such that they had either a strong or weak mental model. Participants then completed a study where they interacted with the ACC system and encountered several safety-critical events (referred to as edge-case situations).

For three edge-case events, the ACC did not respond to the target object (i.e., work zone, offset lead vehicle, slow-moving motorcycle). For such events, there were several noteworthy outcomes:

- For the offset lead vehicle and the work zone events, participants in the strong and weak mental model groups were equally likely to disengage the ACC system. However, for the slow-moving motorcycle event, participants in the strong mental model group were more likely to deactivate ACC than participants in the weak mental model group.
- Importantly, in cases where drivers disengaged the system, participants with weak mental models were slower to deactivate ACC than participants with strong mental models across all three edge-case events and came much closer to the target object (e.g., motorcycle).
- Although there were few collisions overall, these were more frequent for participants in the weak mental model group than in the strong mental model group.
- Higher scores on the mental model assessment were associated with faster ACC deactivation time in the edge-case events.

VIEW REPORT

ABOUT

Established in 1947 by AAA, the AAA Foundation for Traffic Safety is a nonprofit, publicly funded, 501(c)(3) charitable research and educational organization. The AAA Foundation's mission is to prevent traffic deaths and injuries by conducting research into their causes and by educating the public about strategies to prevent crashes and reduce injuries when they do occur. This research is used to develop educational materials for drivers, pedestrians, bicyclists and other road users. Visit www.AAAFoundation.org for more information.

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For the event involving a slow-moving lead vehicle, in which the ACC did respond to the target vehicle by starting to slow the participant's vehicle, participants in the weak mental model group were less likely to deactivate ACC than were participants in the strong mental model group. In contrast to the events described above, there were no differences between the strong and weak groups in terms of response times to disengage the system for this event.

IMPLICATIONS

Overall, the quality of a driver's mental model clearly impacted driving safety and performance. In edge-case situations where the ACC did not respond, drivers with strong mental models were faster to deactivate ACC and maintained safer gap distances than drivers with weak mental models. Thus, whether drivers deactivated ACC or not, a strong mental model conferred performance benefits relative to a weak mental model. The performance deficits observed for drivers with weak mental models appear to reflect uncertainty surrounding how ACC will behave in edge cases.

It is clear, based on questionnaire results, that participants in the strong mental model group understood at least some of the edge cases for the ACC system and were able to extrapolate this understanding to driving situations experienced in the simulator. On the other hand, participants with weak mental models had a poor understanding of how the ACC system would behave in these situations and were therefore slower to recognize that the ACC system was not responding to the edge-case event. Consequently, drivers with weak mental models were slower to take the actions needed to maintain safety (e.g., deactivating the ACC or steering). Such delayed responses forced these participants into less safe situations, as reflected by the closer approach distances compared to those of the strong mental model group.

These results raise several important questions surrounding driver introductions to ADAS and the need for training, especially in terms of the importance of developing mental models (i.e., moving from "weak" to "strong"). Although many questions remain, it is worth noting that a modest amount of information provided in the current study concerning the function and limitations of ACC was sufficient to incur large group differences in mental model and, subsequently, performance.

METHODOLOGY

Seventy-eight licensed and experienced drivers between the ages of 25 and 65 (M=44.0, SD=10.7) completed the study. Eligible participants were prescreened for previous experience with ACC, which included ownership of a vehicle with ACC, understanding the difference between ACC and standard cruise control, and experience using ACC.

The study took place at the National Advanced Driving Simulator at the University of Iowa. The simulator contained a full Toyota Camry cab and 360-degree wraparound display. The ACC implemented in the simulator was representative of currently available systems and incorporated realistic features of the ACC user interface.

Based on responses to the initial screening questionnaire, participants were placed in either the "strong" (N = 39) or "weak" (N = 39) mental model group. Both groups received introductory and basic training material regarding ACC during the session, such as how to turn on and adjust the system; however, only participants in the strong group received detailed information on the ACC's function and limitations across various situations. An assessment of the quality of mental models in the two groups, administered before the experimental sessions, revealed clear and significant differences between the two groups (strong: 93% accuracy; weak: 66% accuracy). These results strongly corroborate the differences between the two groups in terms of their knowledge and understanding of the ACC system.

During the experimental drives, participants interacted with and engaged the ACC based on their knowledge of the system and the experimenter instructions. The driving environments were designed to mimic the range of operational design domains for ACC. Specific safety-critical or edge-case events, representing situations that possibly exceeded the capability of the ACC system, were integrated into the drive to measure potential errors stemming from incorrect or incomplete mental models. These events included: a slow-moving vehicle ahead, a slow-moving motorcycle ahead, a work zone, a fast-moving merging vehicle, a slow-moving semi-truck, and an offset lead vehicle. For most of the edge-case scenarios there were 1-2 vehicles in the adjacent lane, making it more difficult for the participant to make a quick, evasive maneuver around the obstacle.

REFERENCE

Gaspar, J., Carney, C., Shull, E., & Horrey, W. J. (2020). *The Impact of Driver's Mental Models of Advanced Vehicle Technologies on Safety and Performance* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.