Driver Monitoring System Reliability in an Advanced Driving-Assist System Highway Test

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Introduction

Advanced driver-assist systems (ADAS) in SAE Level 2 (L2) autonomous vehicles are widely employed on multi-lane divided highways. This setting entails the highest speeds of cars with these systems and thus, the greatest risk of injury and death in the event of an accident. Because L2 vehicles are considered "partially automated" and must have a driver ready to take over at any time, it is imperative that ADAS systems operating on high-speed roads employ some type of Driver Monitoring System (DMS) to verify the driver's attentiveness and ability to takeover should the need arise. There is minimal regulation of this technology and little data validating the reliability of the systems currently deployed in commercial vehicles. To this end, this study assessed variability in the performance of three Tesla Model 3s' DMSs during highway driving.

Hypotheses

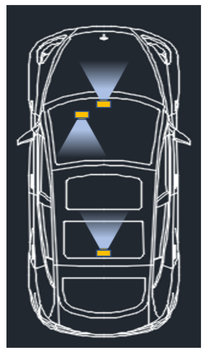
H1: During automated highway driving at 70 mph, vehicles will request driver steering input once every 25 seconds (per Tesla documentation)
H2: There will not be a statistically significant difference *between different vehicles*
H3: There will not be a statistically significant difference in performance *across observations for the same vehicle*

Methods

Sample:
Three 2018 Tesla Model 3s from the Triangle metropolitan area of North Carolina were randomly selected for study using a car sharing service over a period of two weeks during March 2020.

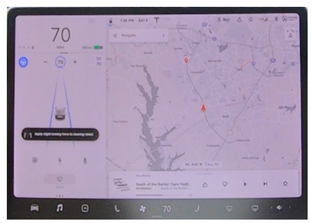
Test Conditions:
All tests were conducted during daylight, under similar environmental conditions, and between 12:00pm and 4:00pm to minimize the influence of rush hour traffic. The same person drove the vehicle for all tests. Prior to each trial, the vehicle was placed in park, with the driver exiting and using the key card to lock and deactivate the vehicle before entering the car to begin a test.

Data Collection:
Camera #1 mounted on the dashboard, facing the road
Camera #2 mounted on the dashboard, facing the driver
Camera #3 mounted on the sunroof, facing the center console.



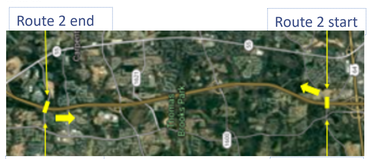
Model 3 schematic copied with permission from CAD-block.

Protocol:
(1) Enter highway
(2) Set cruise control speed to 70 mph
(3) At "route start" markers, place car in Autopilot
(4) Vehicle drives autonomously with no driver input
(5) When hands-on-wheel alert appears, immediately provide continuous wiggle to steering wheel
(3-5 degrees in each direction) until alert disappears
(6) Continue until reaching the "route end" markers



Hands on wheel alert: text reads: "Apply slight turning force to steering wheel."

Driving Routes:
-Two routes used – mirror images of each other
-5 trials per car, per route
-5.2 miles in length
-70 mph toll road

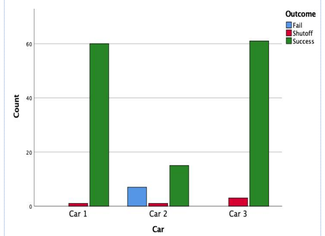


Results and Analysis

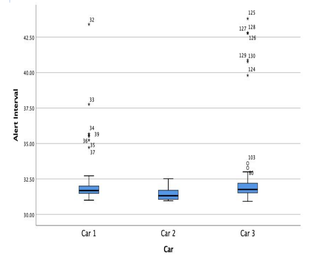
Definition: "event cycle" -> composed of 4 pieces
1: a period of automated, hands-free driving
2: the appearance of a hands-on-wheel alert
3: driver response to the alert (hands-on steering)
4: disappearance of the alert and the beginning of next cycle

Outcomes of driver monitoring alert sequence
-Success: Driver responds to alert and autopilot continues
-Shutoff: Driver responds to alert and autopilot shuts off, hands control to driver
-Failure: Driver never alerted, car makes unsafe move
***Note: entire trial immediately ends after first failure as precaution

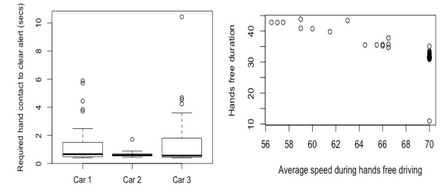
Amount of steering needed to clear alerts
- Varied widely across observations (0.5 – 10 second range)
- However, not significant between vehicles



Alert sequences:
- Only car #2 exhibited failures (overtly unsafe behavior)
- But >3% of observations across cars ended in unintended shutoff



Duration of hands-free driving between alerts:
- Most variation explained by unintended changes in speed
- Every 0.93 decrease in average speed leads to 1s increase in hands-free interval
- At 70 mph, data centered at 30 seconds per interval, not 25 seconds
- Still, greater variation at 70 mph for cars 1 and 3 than car 2
- No statistical difference individually but when 1 & 2 contrasted to 3, p =



Conclusions

- 3.6% of successful trials ended with potentially unexpected handover (shutoff)
- Everything else worked as advertised
- Accidents where people think Autopilot is on because they touched the steering wheel and it is not?
- 3.6% of millions of engagements is substantial
- Wide variation in steering needed to remove alert could potentially take drivers by surprise and distract them
- Most common failure mode differed between cars:
  - Car 2: catastrophic failure in cars ability to maneuver/perceive the roadway
  - Cars 1 and 3: components all functioned in correct state, but repeated unexpected handoffs to driver
- Car 2
  - Only car with failures but also most consistent (and safe) in alerting (reduced trials, nothing higher than 32.5s)
  - Owner reported he complained several times
  - It is possible that this was a software bug fixed on the next OTA update, but how often is this happening?
  - Tesla forum suggest this is not just unique to our experiment
- 30s is a long time to not be paying attention at 70mph…

Acknowledgements

This research was funded by the US Department of Transportation's University Transportation Center grant through the University of North Carolina's Collaborative Sciences Center for Road Safety. We were assisted by Sam True, the director of the North Carolina Center for Automotive Research, and Matthew Seong, Kausthub Ramachandran, and Vishwa Alaparthy in the collection of the data.

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