Automated Vehicles: Driver Response to Failures and Implications of System Knowledge for Driver Training and Safe Use of Automation

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In partnership with:

CRE-MSD

ACE
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Outline

- Introduction
- Overview of advanced driver assistance systems (ADAS)
- Study 1: Effect of alerts on driver behaviour while using ADAS
- Study 2: Survey on driver knowledge of ADAS capabilities and limitations

About me

BA (‘13) – Western University,
Developmental Cognitive Neuroscience

MASc (‘17) – University of Toronto,
Industrial Engineering (Human Factors)

Current

PhD – University of Toronto,
Industrial Engineering (Human Factors)

- Research focus: training/education to improve drivers’ understanding of advanced driver assistance systems

About HFASt

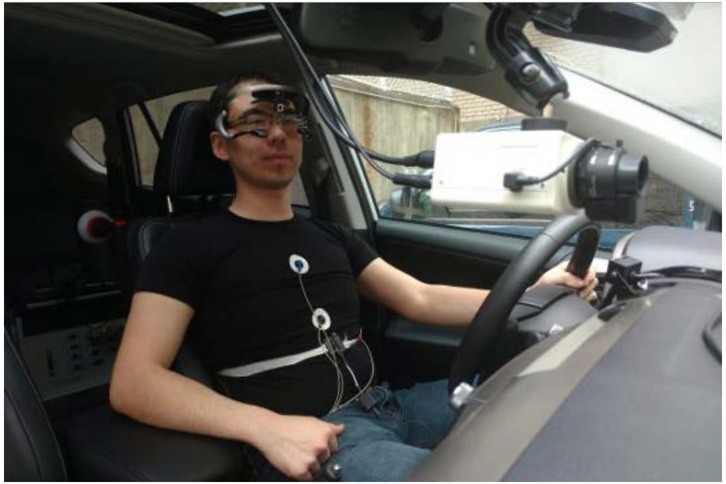
NADS MiniSim™ Driving Simulator

- Automated driving, in-vehicle technologies

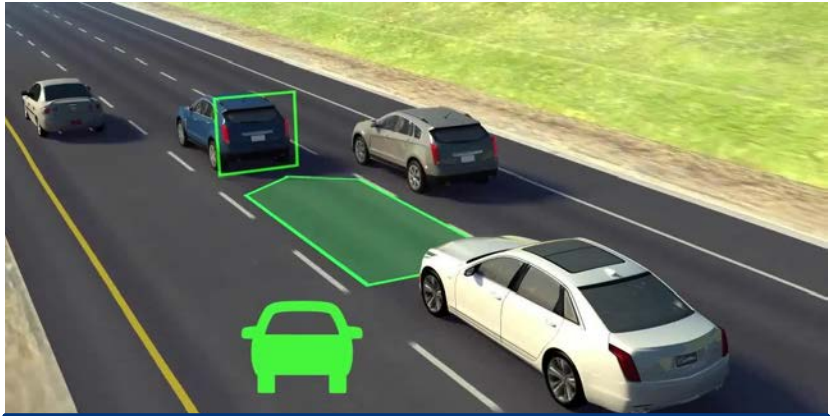
About HFASt

Instrumented vehicle

- On-road studies of driver attention



Many vehicles now come with advanced driver assistance systems (ADAS)



Adaptive Cruise Control (ACC): controls acceleration and braking

https://my.cadillac.com/how-to-support/driving-performance/driving/adaptive-cruise-control

Lane Keeping Assist (LKA): controls steering

https://my.chevrolet.com/how-to-support/driving-performance/driving/lane-keep-assist

SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/ acceleration support to the driver	These features provide steering AND brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering OR • adaptive cruise control	• lane centering AND • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Technology is far from perfect

Twitter: @CC_Firefighters

Misuse is not uncommon

Tesla driver says she slammed into fire truck on Autopilot

MAY 15, 2018 / 3:25 AM / CBS/AP

A Tesla Model S crashed into a parked police car while Autopilot was activated

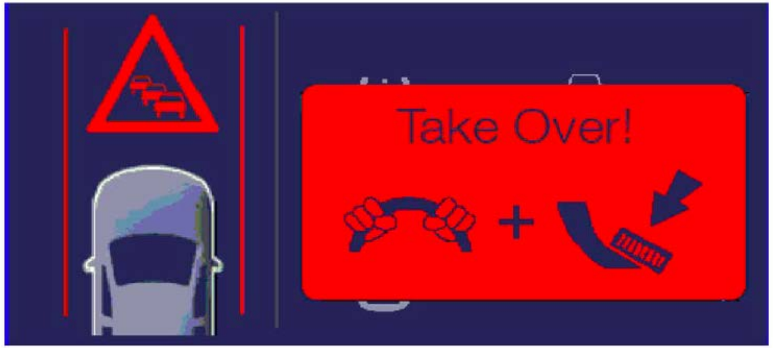
Mark Matousek May 29, 2018, 5:57 PM

Another Tesla Model 3 crashes into a truck, reportedly while on Autopilot

Dalvin Brown, **USA TODAY** Published 9:02 a.m. ET Aug. 12, 2019 | **Updated 8:41 p.m. ET Aug. 12, 2019**

Takeover Requests (TORs)

- Alert that warns drivers that they need to take over full control of the vehicle



Naujoks et al. (2017)

Eriksson & Stanton (2017)

STUDY 1

Are TORs equally effective for different failure types?

DeGuzman, C. A., Hopkins, S. A., & Donmez, B. (2020). Driver Takeover Performance and Monitoring Behavior with Driving Automation at System-Limit versus System-Malfunction Failures. *Transportation Research Record, 2674*(4), 140-151.

System-limit failures

- Automation encounters a situation that is known to be beyond its capabilities
  - e.g., stopped vehicles, faded or missing lane markings
- Driver can anticipate the failure using cues in the environment

Tesla owner almost crashes on video trying to recreate fatal Autopilot accident

Fred Lambert - Apr. 2nd 2018 5:58 am ET @FredericLambert

System-malfunction failures

- Due to sensor or algorithmic errors
- Unforeseen by system designers
- No indicators for drivers to use to prepare for a failure

Volvo recalls vehicles to fix automatic braking malfunction

The Associated Press

Published Wednesday, March 18, 2020 10:52AM EDT

Mazda recalling its most popular car for automatic braking errors

Almost 16,000 new Mazda3s in Canada are stopping themselves when they shouldn't be

by NICHOLAS MARONESE | JANUARY 12, 2020

Prior research comparing failure types

- Dogan et al. (2017) told participants the ACC would fail when travelling over 50 km/h
  - System-limit failure: automation failed at 50 km/h
  - System-malfunction failure: automation failed at 30 km/h
- Drivers looked more at the speedometer when approaching the system limit (50 km/h)
  - No effect of failure type on takeover time

Effect of TORs

- Meta-analysis showed drivers take-over sooner with a TOR (Zhang et al., 2019)
- Lack of research comparing TOR effectiveness across system-limit and system-malfunction failures

Research question

- Are TORs equally effective for system-limit and system-malfunction failures?
  - Hypothesized that TORs would be more helpful for system-malfunction failures (no other way to anticipate the failure)

We conducted a driving simulator study

NADS quarter-cab fixed base MiniSim Driving Simulator

Dikablis eye-tracker

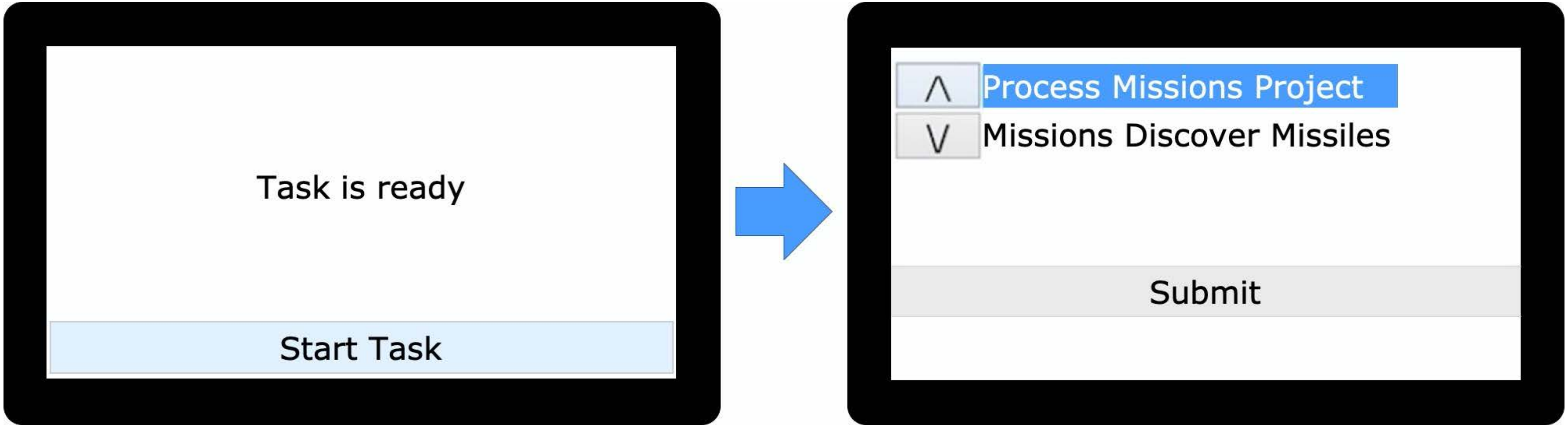
Secondary task

Participants

- 19 participants (11 male, 8 female)

- Inclusion criteria:
  - Valid full driver’s license for at least 2 years
  - Regularly drive at least several times a month
  - Age: 25-30 (*M* = 27.5, *SD* = 1.7)
  - No previous experience driving with ACC or lane keeping

Secondary task



(Donmez et al., 2007)

Driving task

- Automation: ACC + LKA
  - Training on automation and limits
  - Practice drives
- 4 experimental drives (~6 min each):
  - Two-lane rural highway, 50 mph speed limit
  - Light traffic (9-11 cars / min)
- Instructions:
  - Follow the lead vehicle (3s gap)
  - Drive safely
  - Engage automation when told by the computer
    - Use as much as possible but disengage when necessary
  - Perform secondary task as you wish

Experimental design

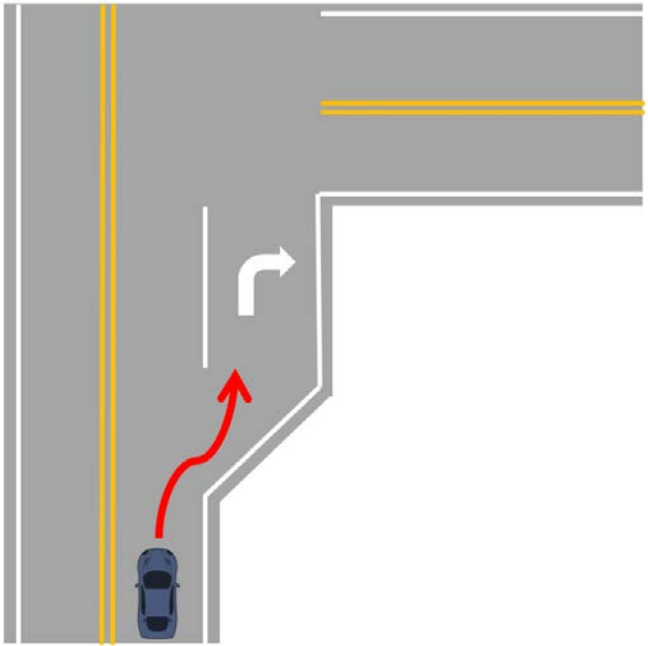
TOR Presence	Failure Type
TOR	System-limit
	System-malfunction
No TOR	System-limit
	System-malfunction

- Failures occurred with the lane keeping
  - Survey of Tesla Autopilot users found 62% of participants experienced at least one “unexpected or unusual" event
  - Most events were due to failures of lane detection

(Dikmen & Burns, 2016)

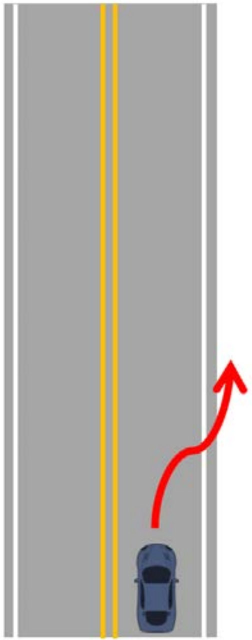
System-limit failure

- Vehicle veers into right-turn lane



System-malfunction failure

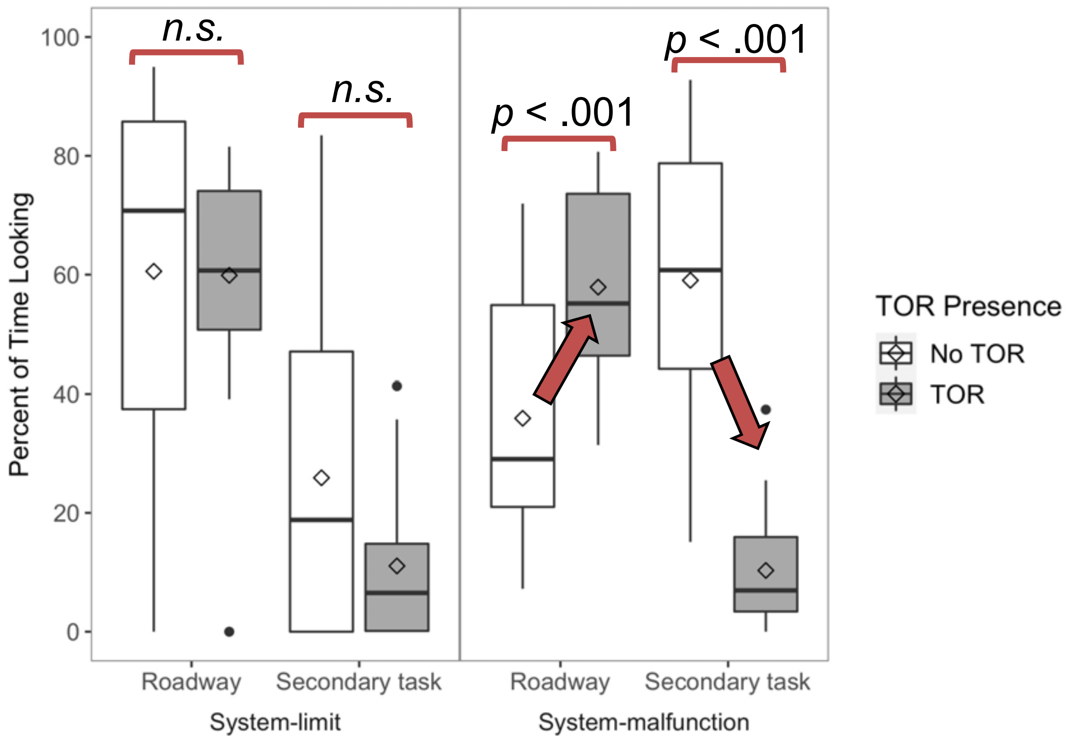
- Vehicle veers off road



DeGuzman, Hopkins, and Donmez (2020)

They experienced each failure with a TOR and without a TOR

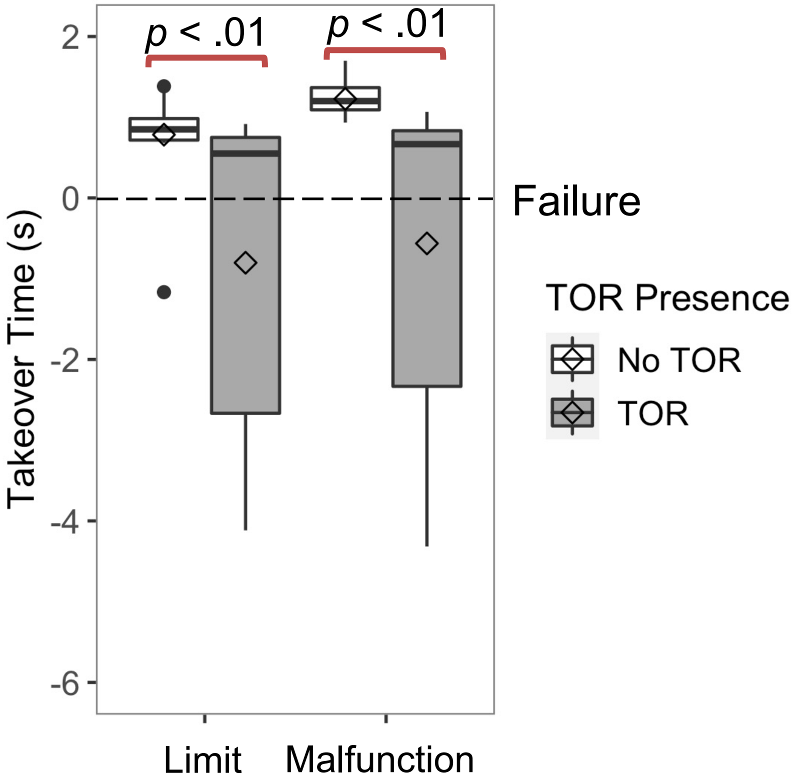
The effect of a TOR on monitoring was only significant for system-malfunction failures



DeGuzman, Hopkins, and Donmez (2020)

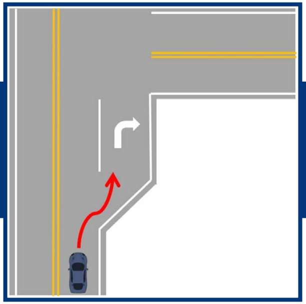
The effect of a TOR on takeover was significant for both failures

- Participants took over 0.81 s sooner in TOR drives



Summary

System-limit



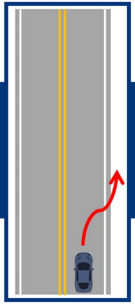
Monitoring

- **No difference** between TOR and no TOR

Takeover

- TOR = faster takeover

System-malfunction



Monitoring

- TOR = higher % of time looking at the roadway, lower % of time looking at the secondary task

Takeover

- TOR = faster takeover

Future work

- Study different types of system-limit failures
  - E.g., poor weather, stopped vehicle in ego-lane
- Increase failure criticality
- Look at long-term effects

Implications

- TOR is helpful to support drivers in taking over sooner
  - May not always be possible to provide a TOR
- Focus efforts on supporting drivers' understanding of ADAS
  - With no TOR, being able to anticipate the failure was associated with paying more attention to the roadway and taking over sooner

STUDY 2

Investigating drivers' understanding of ADAS

Prior research on driver ADAS knowledge

- Surveys show that drivers do not have a good understanding of ACC (e.g., Jenness et al., 2008; Dickie & Boyle, 2009)
  - 70% of drivers were unaware of the limitations of the ACC in their vehicle (Jenness et al., 2008)
- Survey of users of Tesla Autopilot (ACC and LKA)
  - Most users rated their knowledge as “above average”
  - But did not ask about specific capabilities or limitations to confirm whether they had a good understanding of the ADAS

  (Dikmen & Burns, 2016)

Objective

- Assess drivers' understanding of ACC and LKA
- Ask drivers how they would prefer to learn about ADAS

↓

Inform better training

Survey design

Part 1	• Demographics, driving habits • How they have learned about ADAS in the past • How they would prefer to learn about ADAS
Part 2	• ADAS knowledge → Questionnaire about capabilities and limitations of current ACC and LKA systems • Trust in ACC and LKA
Part 3*	• Reliance intention → Likelihood to engage in different secondary tasks while using (1) no ADAS, (2) ACC only, (3) LKA only, (4) both ACC and LKA

*Optional follow-up survey

Participants

- Recruited through Mechanical Turk and online postings
- Requirements:
  - Have a valid driver's license
  - Live in the United States or Canada
  - Have no experience with ACC or LKA (non-owners), or own a vehicle with ACC and/or LKA (owners)
- Non-owners (n = 224), owners (n = 88)

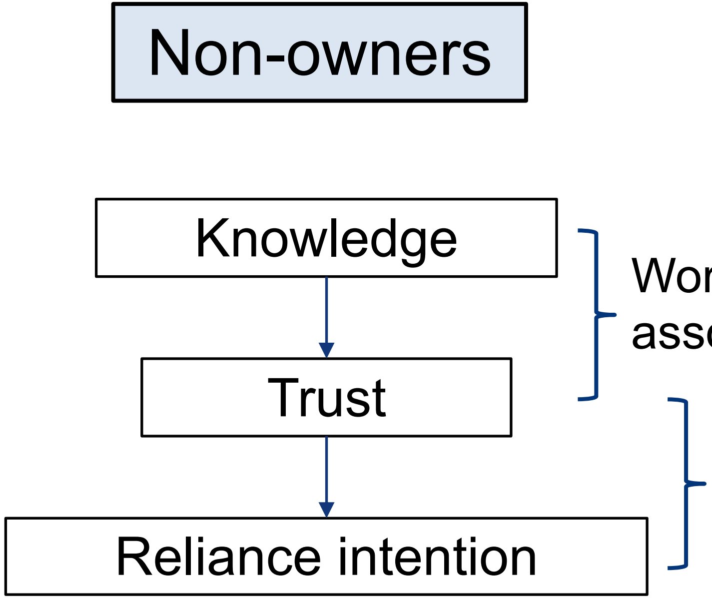
Misperceptions of ACC

ACC…	% of Owners who Agreed	% of Non-Owners who Agreed
Keeps a set distance to vehicles driving ahead in the same lane at a slower speed	77	73
Has difficulty when sensors are blocked or dirty	72	76
Has full braking power	53	45
Does not have difficulty on curvy roads	43	46
Does not have when approaching a stopped vehicle	48	54
Does not have difficulty when approaching a motorcycle	47	50

Misperceptions of LKA

LKA…	% of Owners who Agreed	% of Non-Owners who Agreed
Steers automatically	79	65
Has difficulty when sensors are blocked or dirty	75	75
Has difficulty when lane markings are faded or missing	66	66
Executes evasive steering maneuvers	38	33
Does not have difficulty when driving on city streets	70	58
Works if there is glare towards the driver	59	46

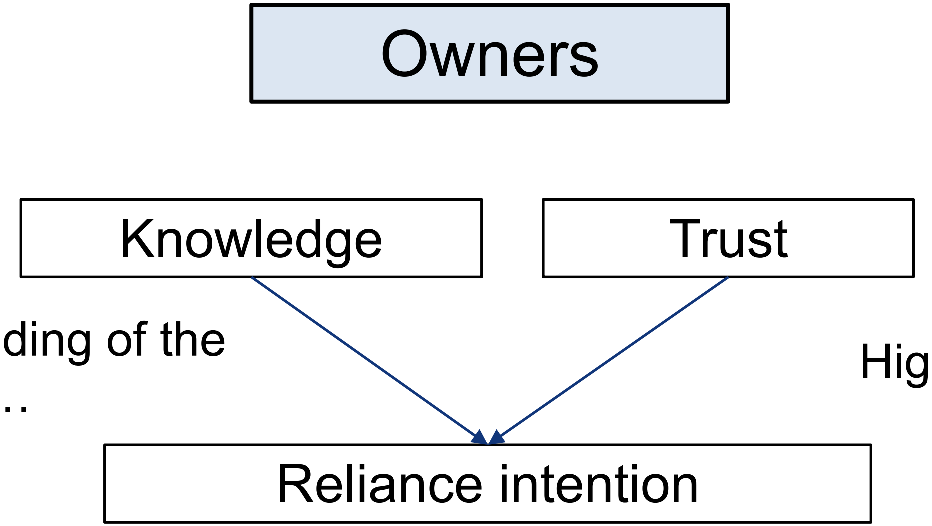
ADAS knowledge, trust, reliance



Worse understanding of ACC and LKA associated with higher trust

Higher trust in ACC and LKA associated with greater likelihood to engage in secondary tasks

ADAS knowledge, trust, reliance

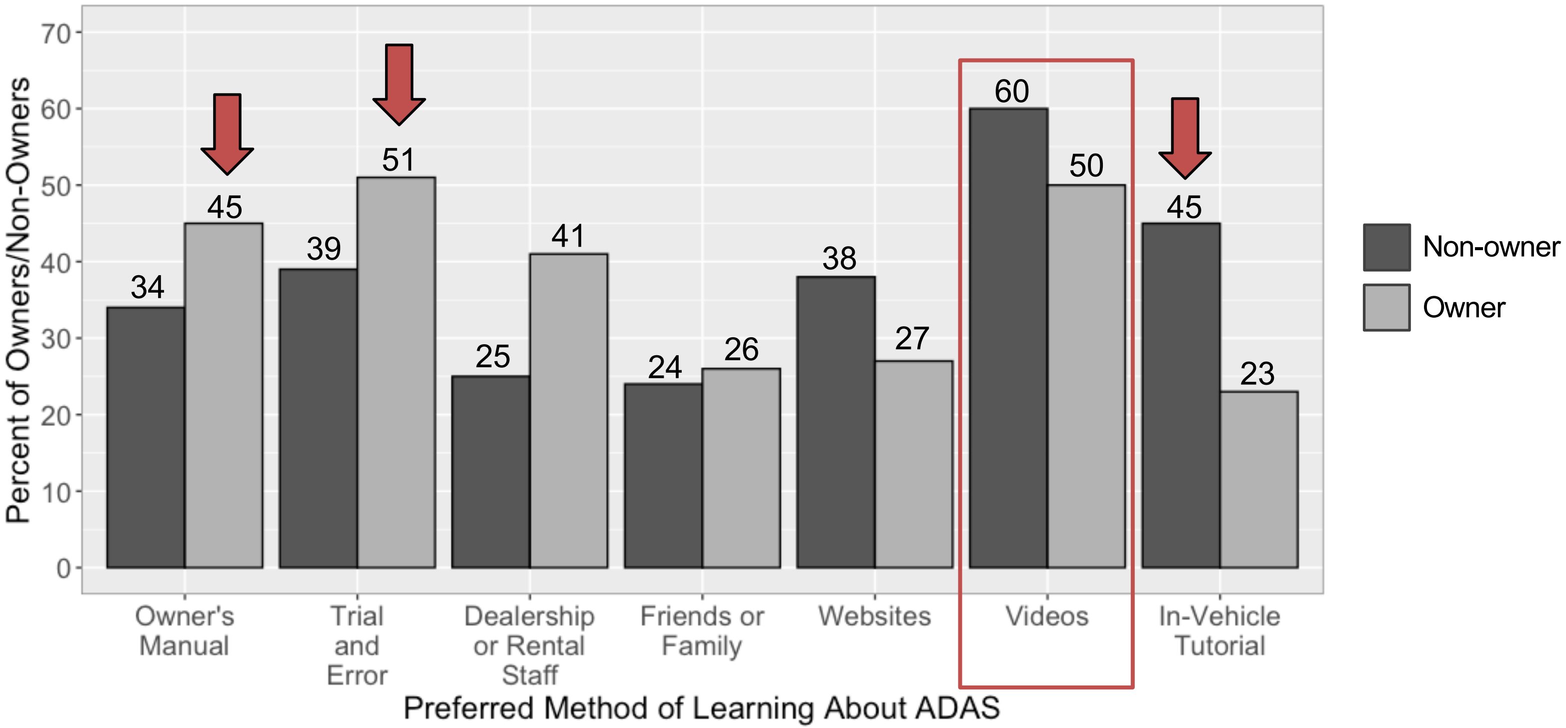


Worse understanding of the system…

Higher trust…

…associated with greater likelihood to engage in secondary tasks

Preferred methods of learning



Implications based on preliminary results

- Large percentage of non-owners and owners have misperceptions about ACC and LKA
  - Worse understanding of ADAS capabilities and limitations is associated with higher likelihood to engage in secondary tasks while driving with ADAS
  - Could lead to misuse and injury
- If we can provide drivers with better training, they may use ADAS more appropriately

Next steps

- Finish survey data collection and analysis
- Simulator study to test the effect of different training methods on drivers':
  - Understanding of ACC and LKA
  - Trust in ACC and LKA
  - Reliance on ACC and LKA
    - To what extent are they still paying attention to the roadway?
    - When do they choose to use the ADAS and disengage the ADAS?
- Focus on owner's manual and videos based on survey results

Thank you!

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