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Disclaimer

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Presentation Outline (in 3 acts)

• I
  • ADAS in MA
    • Introduction
    • Background & Motivation
    • ADAS Technologies & Relevance to MA

• II
  • Drivers’ perceptions and understanding of ADAS
    • Design & development of a survey to measure this for MA drivers
    • Outcomes and Discussion

• III
  • Improving Drivers’ Knowledge of ADAS
    • Conceptualizing and designing training content & platforms
    • Evaluation on a driving simulator
    • Outcomes and Discussion
  • Conclusions, recommendations, and future steps
ACT 1

ADAS in MA
Introduction

• Overall summary of research (and this talk)

• Problem:
  • ADAS promises safety & convenience BUT there are known pitfalls in terms of driver use of ADAS

• Because of this, we conducted this research to understand:
  • What is the prevalence of ADAS in the Commonwealth
  • What are drivers’ perceptions and knowledge regarding these technologies
  • Can ADAS knowledge be improved via education/training
Background & Motivation
Vehicle Automation

- Modern vehicles are rapidly being equipped with technologies to improve safety and convenience
  - Much of this technology helps to automate some tasks

- This has led to a general layperson and consumer expectations that these vehicles have ‘vehicle automation’
  - “self driving technologies”

- Therefore... some quick background is needed...
Background & Motivation

SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: sae.org/standards/content/J3016_202104

Copyright © 2020 SAE International. This summary table is for their copyright and distributed AS IS provided that SAE International is acknowledged as the source of the content.

SAE LEVEL 0™
You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.

SAE LEVEL 1™
You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.

SAE LEVEL 2™
When the feature requests, you must drive.

SAE LEVEL 3™
These automated driving features will not require you to take over driving.

SAE LEVEL 4™
These automated driving features will not require you to take over driving.

SAE LEVEL 5™
This feature can drive the vehicle under all conditions.

These features are automated driving features.
- 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

These features are driver support features.
- 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

These features provide steering OR brake/acceleration support to the driver.
- automatic emergency braking
- lane departure warning

These features are limited to providing warnings and momentary assistance.
- automatic emergency braking
- blind spot warning
- lane departure warning

These features provide steering AND brake/acceleration support to the driver.

Example Features
Background & Motivation

• Advanced Driver Assistance Systems (ADAS) ...
  • ... can comprise L0, L1, L2, but we are focused on L1
    • Steering, OR Brake, OR Acceleration, etc.
  • ... is rapidly gaining ubiquity
    • Most vehicle manufacturers offer these technologies, at various price points, and sometimes as standard offerings.
  • ...are available, accessible, and deployed.
    • Our driving population may directly or indirectly be interacting with these technologies regularly now.
    • Adaptive Cruise Control, Lane Keeping Assist
## Background & Motivation

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>You are driving and you are steering.</td>
</tr>
<tr>
<td>1°</td>
<td>You are driving and you are engaged even if your feet are off the pedals.</td>
</tr>
<tr>
<td>2°</td>
<td>You are driving and you are engaged even if your feet are off the pedals and you are not steering.</td>
</tr>
<tr>
<td>3°</td>
<td>You are not driving when these automated driving features are engaged – even if you are seated in &quot;the driver’s seat&quot;.</td>
</tr>
<tr>
<td>4°</td>
<td>These automated driving features will not require you to take over driving.</td>
</tr>
<tr>
<td>5°</td>
<td>These automated driving features will not require you to take over driving.</td>
</tr>
</tbody>
</table>

### Example Features
- Automatic emergency braking
- Blind spot warning
- Lane departure warning
- Lane centering
- Adaptive cruise control
- 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
Background & Motivation

• Advanced Driver Assistance Systems (ADAS)
  • ADAS promises safety & convenience
  • BUT, there are known Human Factors issues associated with vehicle technologies
  • If not addressed, promised safety benefits may not materialize..
    • Or worse.
Background & Motivation

• Human Factors issues with ADAS

1. Drivers are still supposed to be engaged
   • But driving responsibilities are reduced and hence may lead to disengagement

2. Drivers may misunderstand the technologies
   • Technologies are complex.
   • Capabilities may be primary focus
   • Limitations exists, but drivers may not know (or care).
   • Leads to misuse/disuse, thus negating benefits
Background & Motivation

• Human Factors issues with ADAS

  • Therefore:

    • Drivers’ understanding and expectation of these technologies is key

    • i.e., Drivers’ “Mental Models” about these technologies should be accurate and complete

    • We do not know enough about Mental Models, how they are developed, and how we can ensure their accuracy.
ADAS Technologies & Relevance to MA:

ADAS Prevalence
ADAS Prevalence

• It is important to know the prevalence of these systems on public roadways

• BUT...
ADAS Prevalence

• ADAS offerings vary widely by manufacturers

• And, ...
  • Naming conventions are not standardized
  • Descriptions of technologies are disparate
  • Sold as assistance, or convenience, or safety, or premium features
  • Focus is less on safety
  • And, aforementioned Human Factors issues with the systems
ADAS Prevalence

• It is important to know the prevalence of these systems on public roadways because...

  • From an epidemiological and public health standpoint, it is important to have surveillance of crashes/citations or other metrics associated with these technologies

  • This information may be critical for issues related to policy making, legislation, enforcement, and other related factors that have impact on public safety and mobility.
ADAS Prevalence

- Early project objective was to derive the prevalence of ADAS equipped vehicles in the Commonwealth
  - With the help of MassRMV, we had access to comprehensive vehicle registration information (1,876,439 records)
  - The registration data contained key variables including Vehicle Identification Numbers (VINs)
  - Plan was to leverage the VIN to derive the technology present in each vehicle to estimate prevalence of ADAS equipped vehicles in the commonwealth.

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Example of vehicle registration data fields. Courtesy, MassRMV
ADAS Prevalence

- Roadblock - VINs

  - In the course of the research, we learned that:
    - VINs are notoriously opaque
    - Manufacturers are reluctant (or unable) to share how (or if) in-vehicle technologies can be derived from VINs
    - Met and conferred with various expert bodies and institutes including:
      - IIHS/HLDI
      - Auto Alliance
      - Automakers
      - LexisNexis
ADAS Prevalence

• Alternate method

• We propose an alternate, somewhat more ‘brute force’, method to derive and estimate ADAS prevalence using registration data and public information about ADAS offerings

• Estimate the level of ADAS technologies in the vehicle by cross-reference vehicle registration data (Make, Model, Model Year) with ADAS technologies and manufacturer offerings data.

Comprehensive list of ADAS technologies was compiled
• Comprehensive list of vehicle manufacturers and models, along with ADAS offerings, and whether standard or optional, was compiled

ADAS Technology Name | What does it do?
--- | ---
Advanced Cruise Control | Controls acceleration and/or braking to maintain a specified distance behind the car in front.
Anti-lock Braking Systems | Helps prevent wheels from locking up—possibly allowing the driver to steer safely.
Automatic Crash Notification | Detects either an air bag has deployed or that there’s been a dramatic and sudden deceleration and helps the driver.
Automatic Emergency Braking | Senses slow or stopped traffic ahead and automatically applies the brakes if the driver fails to respond.
Automatic Emergency Steering | Detects potential collision and automatically steers to avoid or lessen the severity of impact.
Automatic High Beams | Activates or-oriented headlamp beams automatically based on lighting, surroundings, and traffic.
Automatic Parallel Parking | Helps guide you into a parallel parking spot after searching and finding a viable option. Does not brake or steer.
Backup Camera | Shows a wide view behind your vehicle while in reverse, even at night.
Bicycle Detection | Alert you to a potential collision with a bicyclist ahead.
Blind Spot Warning | Detects vehicles to the rear of you, while driving and alerts driver to their presence.
Brake Assist | Detects driver slamming the brakes and applies maximum force to the brakes to help make sure the car stops.
Cruise Control | Allows you to maintain a constant vehicle speed without holding down the accelerator pedal.
Curve Speed Warning | Uses GPS to warn drivers when you’re approaching a curve or exit on the road too quickly.
Driver Drowsiness Monitoring System | Alerts you if you’re drowsy and suggest you take a break when it’s safe to do so.
Driver Monitoring System | Detects alert driver when signs of drowsiness, distraction, or fatigue are detected.
Dynamic Brake Support and Crash | Supplement the driver’s braking in an effort to avoid the crash. If the driver does not take any action to control the vehicle, it will automatically brake.
Dynamic Parking Assistant | Controls vehicle acceleration, braking, and steering. SAE standard definition of 12 Autonomous systems.
Electronic Stability Control | Helps prevent drivers from losing control of the direction of your car due to in a spin out or plow out. When
Forward Automatic Emergency Braking | Detects potential collisions while traveling forward and automatically applies brakes to avoid or lessen driver.
Forward Collision Warning | Detects impending collision while traveling forward and automatically applies brakes to avoid or lessen driver.
Fully Automated Parking Assistant | Controls acceleration, braking, steering, and shifting during parking. May be capable of parallel and/or normal safety.
High-Speed Alert | Coordinates the car’s position, via GPS, with a database of speed limit information to alert drivers if
Highway Pilot | Maintains vehicle’s lane position and following distance by automatically braking and accelerating as
Highway Departure or Assist | Helps keep you at a steady speed when driving down a hill or other decline.
Highway Assist | Helps prevent roll-back when starting up again from a stopped position on an incline.
Intersection Assistant | Warming drivers of vehicles approaching from the sides at intersections, highway exits or car parks.
Lane Centering Assist | May gently steer you back into your lane if you begin to drift out of it.
Lane Departure Warning | Monitors vehicle’s position within driving lane and alert drivers as the vehicle approaches or crosses lane.
Lane Keeping Assist | Controls steering to maintain vehicle within driving lane. May prevent vehicle from departing lane or losing control.
Night Vision | Aids driver vision at night by projecting enhanced images on instrument cluster or heads-up display.
Obstacle Detection | Uses sensors mounted in the front and or rear bumpers to determine the distance between the car and
Parking Obstruction Warning | Detects obstructions in close proximity to vehicle during parking maneuvers.
Parking Sensors | Alerts you to the position of objects around your car as you park.
Pedestrian Emergency | Provides automatic braking for vehicles when pedestrians are in front of the vehicle and the driver has not
Pedestrian Detection | Detects pedestrians in front of vehicle and alerts driver to their presence.
Push Start Button | Simplifies turning your car on and off using a key less unique to you.
Rain Sensor | Detects rainfall and activates windshield wiper.
Rear Cross Traffic Warning | Detects vehicles approaching from side and rear of vehicles while traveling in reverse and alerts driver.
Remote Parking | System parks vehicle without driver being physically present inside the vehicle. Automatically controls
Reverse Automatic Emergency Braking | Detects potential collision while traveling in reverse and automatically applies brakes to avoid or lessen
Semi-Automated Parking Assistance | Controls steering during parking. Does not accelerate, brake, and change gear position. May be capable of
Side View Mirror | Shows an expanded view of a lane beside you when you use your turn signal, or when you activate
Surround View Camera | Uses cameras located around vehicle to present view of surroundings
Temperature Warnings | Alerts you when the outside temperature is detected to be at or below freezing, which can impact the
Tire Pressure Monitoring | Warnings if your tires are under- or over-inflated, helping improve your fuel economy and even
Traffic Separation System | Helps your wheels gain traction on slippery surfaces
Traffic Jam Assist | Automatically accelerates and brakes the vehicle with the flow of traffic and keeps vehicle between lane
Trail Assistant | Assists driver during backing maneuvers with a trailer attached.
Vibrating Seat Warnings | Vibrates the driver’s seat belt cushion if a crash risk is detected. Helps hearing impaired drivers.
ADAS Prevalence

• Conclusion & Discussion

• Critical outcomes:
  • 1 – Identified hurdles in identifying vehicle technologies in registered vehicles
  • 2 – Process development for alternative method for estimation
• Recommendations to mitigate roadblocks for future data:
  • Vehicle registration may be the best location for such data (if manufacturers are not transparent with VINs)
  • Recommend introducing fields in vehicle registration forms for ADAS. Owners will self-report.
• Overall, vehicle manufacturers have this responsibility for surveillance and epidemiological purposes
ACT 2

Driver Perceptions of ADAS
Drivers’ Perceptions of ADAS

• In addition to ADAS prevalence, it is important for policy makers and public safety stakeholders to understand drivers’ knowledge and perceptions of ADAS.

• Drivers’ use/misuse/disuse/abuse of these technologies will be driven by their knowledge and awareness of these systems.

• System capabilities, and arguably even more important, limitations, will form key bases for knowledge of the systems.

• This is critical for drivers who operate vehicles with this technology, AND equally important for those who drive vehicles sans the technology, but will have to interact with technology-equipped vehicles.

• This has important consequences for public policy as well, especially in regard to driver licensing and associated training/testing and for law enforcement.
Drivers’ Perceptions of ADAS

• Goal:
  • Examine drivers’ attitudes, knowledge, and perceptions, towards ADAS

• Focus:
  • ACC & LKA

• Approach:
  • Survey study
Drivers’ Perceptions of ADAS

• Survey Study:
  • Survey items (34-38 items) were developed based on previous studies (Manser et al., 2019; Tsapi et al., 2015; Boelhouwer et al., 2019; McDonald et al., 2018).
  • The survey was separated by:
    • technology - ACC and LKA and
    • experience level – experienced vs novice.
Drivers’ Perceptions of ADAS

• Survey Study:
  • Institutional review Board Approval
  • Inclusion criteria:
    • valid driver’s license with at least three months driving experience
    • residents of Massachusetts
    • Demographics: Age, sex, zip code
    • Perceptions of technology, assistance, and trust
  • Qualtrics – 10-15 minutes
  • Incentive - $5 for completing survey, and raffle for and additional $95
  • Total 153 participants, with valid data for 142 participants.
Drivers’ Perceptions of ADAS

- Survey Study – Analyses and results:

<table>
<thead>
<tr>
<th>Statistics</th>
<th>All</th>
<th>ACC Experienced</th>
<th>ACC Inexperienced</th>
<th>LKA Experienced</th>
<th>LKA Inexperienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td>142</td>
<td>44</td>
<td>98</td>
<td>30</td>
<td>112</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>Mean = 26.47 SD = 10.75</td>
<td>Mean = 27.11 SD = 11.75</td>
<td>Mean = 26.18 SD = 10.31</td>
<td>Mean = 31.16 SD = 13.18</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td>Males = 85 Females = 56 Prefer Not to Answer = 1</td>
<td>Males = 23 Females = 20 Prefer Not to Answer = 1</td>
<td>Males = 62 Females = 36</td>
<td>Males = 17 Females = 12 Prefer Not to Answer = 1</td>
</tr>
</tbody>
</table>
Drivers’ Perceptions of ADAS

• Survey Study – Analyses and results:
  • System Knowledge: Operational conditions for LKA/ACC.
    • Most experienced drivers had accurate information ADAS operational conditions
  • System Knowledge: Conditions where limitations might be triggered, requiring drivers to disengage ADAS.
    • Majority of the experienced drivers had accurate knowledge about ACC/LKA limitations
Drivers’ Perceptions of ADAS

• Survey Study – Analyses and results:
  
  • Similar outcomes for inexperienced drivers.
  
  • This could be due to a more general awareness (public perception, advertising and media, friends/family) about ADAS in the inexperienced driver population.
Drivers’ Perceptions of ADAS

• Survey Study – Analyses and results:
  
  • Trust/Willingness to Use:
    
    • Most drivers indicated a preference to trust and use ADAS systems while driving.
    
    • When asked if drivers would be comfortable with engaging in secondary tasks while driving with ADAS, most strongly disagreed.
Drivers’ Perceptions of ADAS

• Survey Study – Analyses and results:

• Training:

  • Fewer than 80% of experienced ACC drivers understood how ACC worked before they bought an ACC-equipped vehicle.

  • Only 8 of the 44 drivers were offered training or information about the ACC by someone at the dealership.
Drivers’ Perceptions of ADAS

- Survey Study – Analyses and results:
  
  - Training:
    
    - Participants still found the training satisfactory, indicating they found it informative enough to be able to use ACC.
      - However, 50% of the participants that received training still had uncertainties about the system.
      
    - ACC users preferred Learning by Trial and Error and from Friends or Family.
      - Only 29% referred to the Owner’s Manual.

    - Of the 44 participants, 34 agreed that their understanding of ACC increased after they’d driven with it for some time
Drivers’ Perceptions of ADAS

• Discussion

• Generally experienced drivers had reasonable knowledge of basic capabilities of systems
  • Also for inexperienced drivers
  • More drivers had experience with ACC than with LKA

• Training was barely offered for the systems at time of purchase.

• Drivers preferred to receive training, and in its absence learned on their own ("trial & error").
  • The owner’s manual was rarely consulted.

• Trust in the system was generally high, although drivers (correctly) reported that they would
  not feel comfortable with secondary tasks
Drivers’ Perceptions of ADAS

• Caveats and Limitations

• Our sample, although reasonably large, was skewed heavily towards younger drivers (Mean age ~28 yrs)

• The survey items covered general knowledge about the systems, and not more specific questions, which may have led to a more accurate response from all respondents given the generality of the items.
ACT 3

Improving ADAS Knowledge
Improving Drivers’ Knowledge

• “The greatest enemy of knowledge is not ignorance, it is the illusion of knowledge.”

• — Daniel J. Boorstin
Improving Drivers’ Knowledge

• ADAS users are willing to gain experience through practice (Trial & Error)

• However, ADAS features are complex
  • there can be significant negative consequences from such learning methods, especially at high speeds on public roadways.

• Understanding ADAS systems is not trivial.
  • The systems are complex, and in addition to their capabilities, it is critical that their limitations are well understood by users.
Improving Drivers’ Knowledge

• Understanding ADAS technologies rely on drivers’ developing their Mental Models of the systems accurately.

• Training designed to shape users’ Mental Models about ADAS technologies could improve ADAS use safety.

• Scientific evidence shows driver training helps accelerate specific ‘higher-order’ skills in drivers, such as attention maintenance, or hazard perception.
Improving Drivers’ Knowledge

Mental Models

• “...a rich and elaborate structure, reflecting the user’s understanding of what system contains, how it works, and why it works that way”

• “...a representation of the typical causal interconnections involving actions and environmental events that influence the functioning of the system”
Improving Drivers’ Knowledge

• Why are mental models critical to driver performance?
  • the driver must understand the capabilities and limitations
  • The driver must understand the various possible states/modes of a system
  • the driver must recognize the current mode of the system
Improving Drivers’ Knowledge

• With inaccurate or incomplete mental models:
  
• drivers may expect more performance or capabilities in a system than what has been designed

• Drivers may expect performance in situations (domains) that lie outside what the systems were designed for.
Improving Drivers’ Knowledge

- Conceptual Mental Model Training Approach

- Deconstructing complex ADAS technologies into state diagrams

- State diagrams present unique system states, and a linkage of transition between states
Improving Drivers’ Knowledge

• Conceptual Mental Model Training Approach

• Leveraging Visualization techniques to explain the system via the state diagram
Improving Drivers’ Knowledge

- Conceptual Mental Model Training Approach
  
  - Leveraging Visualization techniques to explain the system via the state diagram
Improving Drivers’ Knowledge

- Conceptual Mental Model Training Approach
- Leveraging Visualization techniques to explain the system via the state diagram
Improving Drivers’ Knowledge

- Conceptual Mental Model Training Approach

- Leveraging Visualization techniques to explain the system via the state diagram
• Visualization Training Content
Improving Drivers’ Knowledge

- Experimental Evaluation of Visualization Training
  - Randomized Control Trial
  - Driving Simulator Experiment
  - 24 participants
  - 3 groups
    - Visualization (V)
    - Owner’s Manual (M)
    - Sham training (S)
Improving Drivers’ Knowledge

- Experimental Evaluation of Visualization Training
  - Informed Consent
  - Mental Model Survey (CAMMS)
  - Training (randomly allocated)
  - Post-Survey
  - Evaluation on Driving Simulator
    - Simulated ACC drives
    - Scenarios/Events designed as corner-case scenarios & limitations
Improving Drivers’ Knowledge

• Results and Outcomes

• Mental Models Survey
  • Significant increase in knowledge due to training
  • Training type had no effect on the knowledge gain.
Improving Drivers’ Knowledge

• Results and Outcomes

• Trust
  • Significant effect training on Trust
Improving Drivers’ Knowledge

• Results and Outcomes

• Verbal responses to in-drive probes
  
  • Participants in the Text Based (M = 0.85) and Visualization group (0.77) had higher mean accuracy than the Sham group (0.708)
Improving Drivers’ Knowledge

• Results and Outcomes

• Manual responses to in-drive instructions
  
  • The Visualization group had a higher mean accuracy of manual responses ($M = 0.775$) than the Sham (0.75) or the Text-Based group ($M = 0.725$)
Improving Drivers’ Knowledge

• Discussion

• Training improves knowledge
  • Visualization and User Manual groups had higher gains than Sham training.
  • Increase in in trust after training
  • Increase in driver responses (verbal and manual) to in-drive probes
  • Visualization approach shows significant promise for increasing knowledge.
  • May be more palatable than user manuals
Conclusions and Next Steps
Conclusions and Future Steps

1. Estimating ADAS deployment is non-trivial.
   • Proposed method can help.

Next steps:

• Given value of this data, robust process may have to be established.
  • Vehicle registration forms may offer practical touchpoints for collecting this data.

• Epidemiological data (from crash/citation records) can offer novel insight into ADAS-related crashes.
  • No other states are doing this, and MA has opportunity to lead.
Conclusions and Future Steps

2. Drivers have a generally reasonable awareness of ADAS (ACC & LKA)
   • Caveat: Awareness is currently defined broadly, and defined by knowledge about general features of ADAS

3. Fewer than 80% of ACC drivers knew how ACC worked before they bought an ACC-equipped vehicle.
   • Training offered is minimal. Most prefer ‘trial and error’ learning.

Next steps:
• Explore how ADAS benefits/pitfalls awareness can be raised.
• Explore potential unintended consequence of media/advertising/normative expectations on naïve users’ perceptions/expectations of ADAS features
Conclusions and Future Steps

4. Targeted ‘higher-order skills’ training can help improve drivers’ knowledge

5. Training shows efficacy in knowledge improvement
   • Some efficacy in skills/behavior improvement
   • Some training better than none
   • Visualization holds promise for potentially quicker/briefer training content

Next steps:
• Expand training evaluation:
  • Representative population + other sub-groups (Trainers/Law Enforcement)
  • Updated content
  • Multiple deployment platforms
  • Duration of effects
  • Additional outcome measures (safety behaviors, crashes/citations?)
Thank you.

Questions/Discussion

Research Participants Needed for Driving Safety Research
(“Satellite Study”)

Are you 18 or older? Do you have a valid driver’s license? Do you have Adaptive Cruise Control (ACC) in your car?

If YES, you can come participate in our study!

What’s in it for me?

If eligible, you may receive up to $210 cash for participating.

What will I be doing?

- You will be completing 32 surveys online over the next 6 months.
- Meet IN PERSON at the Human Performance Lab, UMass or meet ONLINE over Zoom for the first and last survey sessions.

INTERESTED?

Fill up the survey here: https://bit.ly/satellite22

or use the QR code to access the survey form

If you have questions, please contact Apoorva Hungund or Jaji Pamarthi via email: DrivingResearch@umass.edu